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Micro Simulation – Models, Methods and Applications

Proceedings of a Symposium in Stockholm, Sept 19-22, 1977

IUI
THE INDUSTRIAL INSTITUTE FOR
ECONOMIC AND SOCIAL RESEARCH, STOCKHOLM

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FOREWORD

This is the complete set of papers on the Swedish micro-to-macro model presented at the conference on micro simulation models, arranged jointly by the IUI and IBM Sweden, September 19-22, 1977. To our knowledge this is the first international seminar devoted to micro based models of entire economic systems. The papers on the Swedish model have been in print for more than a year (IUI Conference Report 1978:1). They appear again in this book with some technical parts excluded.

We believe that this publication gives a fairly representative picture of the state of the art at the time of the conference. Micro simulation as an empirical method is fairly new to economics. Micro theory and macro theory with applications have always coexisted in economics but systematic integration of the two branches through explicit market modelling has been attempted only recently. It is a mathematically and technically difficult area and the approaches still differ considerably. It offers new and promising possibilities in developing theory and empirical testing in a much more parallel fashion than has been the case earlier.

We are happy to present this volume on a theme that we believe will be of rapidly growing importance in the future.

Stockholm, May 1980

Gunnar Eliasson
The Industrial Institute
for Economic and Social Research

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INTRODUCTION

INTEGRATING THEORY AND MEASUREMENT

B. Bergmann – G. Eliasson – G. Orcutt

Economic theory must always embody the particular approach that makes it most efficient for handling the chosen decision problem. The all purpose theory is probably impossible by definition and without a decision problem at the back of his (or her) mind the researcher should be at a loss about what to do. It should therefore be considered natural to find – as we do – a multitude of models or theories designed to interpret the same economic phenomena. The particular decision problem chosen determines what is important and what should be deemphasized.

There is, however, one clear restriction that limits the number of possible approaches to economic reality, namely experience and systematic observation. Aspects of a theory that do not pass the test against observation are not allowed to survive in a true scientific environment. In a complex world one should consider it natural to live with many conflicting interpretations of economic reality; but in a world of scientific progress the interpretations should change, old erroneous doctrine should be unloaded and new theory allowed to enter.

The need exists to integrate theory and measurement, in particular by developing theories that incorporate and predict relevant economic behavior and that allow for the most efficient and thorough confrontation with available experience. The basic scientific principle must be to keep ridding the set of suggested explanations of erroneous hypotheses, while simultaneously forming new hypotheses to constantly upgrade our vision of economic reality. This places the requirement on any theoretician in an applied science like economics to add specifications about how to measure his variables. There is no way for the theoretician and the empiricist to live meaningful, separate lives. They should be one and the same person.

This is where the *micro simulation* method enters as a potentially efficient device for organizing scattered versions of theorizing in a consistent manner and on a format that makes efficient confrontation with measurement necessary and feasible as not before, albeit in a somewhat new and unconventional garb.

We believe that micro simulation opens up new possibilities for estimation and analysis based on direct access to the wealth of data that exist at the micro level. The basis rules of empirical inference can be more efficiently put to use. This is why several papers and much comment in this volume are devoted to measurement and observation techniques in micro simulation models. This was originally the desire of the conference organizers, and even though we recognize that much further work is needed here – not in the least pedagogical –, we think we have made some modest contributions. In fact, the way the distinction between theory and empiricism is blurred is perhaps one of the most useful aspects of economics that are illustrated in this conference volume. Some of the papers and models presented should be regarded as theoretical contributions by conventional standards. All models presented here are, however, based on a much more solid and relevant empirical footing than what is common in theoretical papers in economics. By this we reemphasize again one theme of the conference, namely that a criterion of good theory in economics can only be how well grounded in relevant, empirical facts it is.

The main purpose of the conference, however, was to organize a meeting around the *technique* of large scale (economy wide) micro based modelling. At the time of organizing the conference three more or less complete model systems were in existence – the *Urban Institute – Yale model* project headed by Guy Orcutt, the *U.S. Transactions model* headed by Barbara Bergmann, and the *IUI-IBM Swedish model* project headed by Gunnar Eliasson. These models are all presented in this volume.[1] They illustrate the multitude of approaches that can be taken to economy-wide modelling and how emphasis on different kinds of problems gives rise to different methodologies.

Most questions asked of economists are addressed to typical macro economic phenomena. Macro economic modelling using Keynesian concepts was a first efficient answer that allowed economists to cut through the analytically impossible maze of partial theory existing at the time. The Keynesian revolution was the first true systems approach in economics. It provided the rationale for several grand steps forward in combining theory with measurement (=models) encompassing entire economic systems.

1) Demand driven, national income based *business cycle macro models* have turned out to be quite successful over the last two decades.

[1] At the conference several special reports were given on *other* micro simulation projects in progress. Brief presentations of some of these projects are given in a separate section at the end of this conference volume.

2) Demand driven *input-output, macro sector models* of the Leontief-Keynesian type represent a second major step forward in applied economic theory and several successful models of that type have become operational during the last ten years.

There are at least three serious draw backs associated with these models,

a) a major "element" in economic thinking simply is not allowed to figure explicitly, namely the *market process,*
b) macro modelling deprives us of the efficient use of existing, high quality micro information,
c) it makes it formally and technically difficult to model true dynamic macro economic behavior that is essentially a micro market-macro income determination process over time.

The new methodological development in economic systems modelling, 3) *micro simulation,* solves these three problems simultaneously and also relieves us of the unsound practice of deliberate misspecification to achieve solutions and answers. This is, of course, at the expense of something, most notably easy intelligibility of results. This is, however, largely a beginner's dilemma. Understanding comes with experience. New, sometimes surprising results, and complex problems should not necessarily be easily and immediately comprehended. The black box dilemma of the micro simulation model should always be viewed against the back drop of the full fledged multi-sector macro models currently in use in many institutions, where transparency is no typical virtue.

The micro simulation model in fact offers itself as a great didactic instrument if one understands how to use it properly. Assumptions not only can be stated correctly but also more intelligibly, whereas macro theory forces us to a high level of abstraction in this respect. Dynamic processes can be described one at a time in quite easy language and we never have to resort to traditional but awkward constructs like forcing the economic world to be in perpetual equilibrium – an absurd construct to say the least. The problem is understanding the whole economic machinery at work simultaneously, but it is not altogether clear that a human brain (and eye) should be capable of seeing through such a system at a glance. On the other hand one can learn and become familiar with the properties of a theory (a model) and learn to put it to efficient use to enhance one's understanding of empirical phenomena. This is something that has long been recognized in natural sciences.

The many uses of the term micro simulation often confuse more than they reveal. Before we proceed it is appropriate to state what we think the term means.

Micro simulation represents a numerical method of dealing with more complex versions of conventional theoretical structures. It represents a method of coordinating large volumes of numerical information.

It takes testing and estimation down to basic behavioral assumptions at the micro level and relieves the researcher of an unsound overreliance on goodness of fit criteria at the macro level.

It represents, by freeing one of the confines of the "analytical paradigm" of economics, a new and extremely rich language of theoretical expression. This is no longer new in many other sciences.

It offers a new "cognitive" way of handling more realistic, and hence more complex, thought about the ways society works, much in the same way that various branches of mathematics have done a lot of good to many applied sciences. One example is the possibility of integrating market price theory with income determination theory in an empirically relevant fashion.

In fact, the listing above simply describes a method of integrating theory and measurement, and any theory pretending to be relevant should have that aspect well developed.

The description given also emphasizes that micro simulation is a theoretical and empirical method combined, as it should be. The set of papers presented in this conference volume illustrates this well. The papers represent various theories on how a national economy works, shaped in a micro simulation framework. The common denominators are two, namely, that they all deal with behavior (decision) units at the micro (firm, household, etc.) levels and that they all aggregate up to large parts or all of the national economy.

THE THREE MODELS

The Urban Institute – Yale (Orcutt) model is primarily concerned with behavior in the household sector, which is enclosed in an outline of a production system with few feedbacks. The U.S. Transactions (Bergmann) model places more emphasis on the production system, which is a semi-macro construct with each cell in the input-output matrix representing one firm. The firm behaves on the basis of expectations drawn from past experience and is guided by a mark-up pricing system. The household sector has a full micro presentation in a reduced scale U.S. economy consisting of 800 households of different wealth, income, marital, occupational, etc. status. The overriding emphasis, however, is on the financial side where all volume transactions are traced financially from week to week.

The IUI-IBM (Eliasson) model on the other hand places *most* emphasis on the production and supply side, where a large number of individual firms (most of them being representations of real Swedish firms) appear as decision makers in an *explicit* market process. An explicit feedback at the micro market level from profits via investment and capacity growth to the supply decision in effect means that market price theory has been merged with income determination theory.

The *U.S. Transactions model* works by having each of the actors represented in the model follow a weekly schedule of economic decisions and consequent activities, in the course of which interactions with the other actors occur. The major decisions for households (job search, home and auto acquisition, other expenditure, debt and portfolio management) for the non-financial firms (production, employment and hours setting, price and wage setting, acquisition of capital goods, debt and portfolio management) and of the non-financial firms (interest rate setting, loan rationing, port-folio management) are all based on the position of the variables at the moment the decision is contemplated. The weekly period is short enough so that no simultaneity need be allowed for, which greatly simplifies the task of running the model and modifying it to reflect policy changes whose impacts are being evaluated. The structure allows for policies to be represented in a great deal of naturalistic detail, with such elements as "triggers" and other nonlinearities easily incorporated.

The *Urban Institute – Yale model* described in this volume is a member of the Urban institute DYNASIM class of microanalytic models. It is implemented in a new microanalytic simulation system called MASS.

The DYNASIM models have been and are being developed for use in the analyses of United States public welfare and social security policies and so are strongly focused on individual and family behavior, income, and income maintenance. They represent a useful step toward development of models which successfully relate outcomes to policies concerned with unemployment, inflation and inequality as well as income maintenance and poverty.

The core of the model presented consists of program modules which determine the probabilities that various events will occur to an individual or family, and which assign quantitative values to person and family characteristics. In addition to the micromodel a simple macromodel of the economy is also included. The key steps involved in using the model for policy analysis are:

1. An initial population is specified. Currently, samples of ten to twenty thousand drawn from the 1960 or 1970 decennial census are used.
2. For each person and family unit in the population the probability of occurrence of an event that would change an individual or family characteristic of concern (e.g., marriage, death, entrance to the labor force, unemployment) is computed.
3. Assignment of changes in status to some of the individuals in the population are made to provide a fully specified set of attributes for each individual and family which will generate the simulated population sample for the next year.
4. For some events, a quantitative amount is assigned, such as hours in the labor force, wage rate, or amount of social security benefits. In the case of transfer payment income, the quantities are calculated by applying administrative rules.
5. In conducting policy analyses, changes in government programs are introduced. Their impact is then predicted taking into account predicted induced effects as well as direct effects.

The *Swedish model* is complete, in the sense of covering the entire economic system and being equipped with all the necessary feedbacks on a quarterly basis. For the time being, everything outside the manufacturing sector is a conventional Leontief-Keynesian macro model. Micro to macro contact is established through (explicity modelled) labor, product and money market processes. Interaction runs across markets as well as over time through price-quantity adjustments. As in the U.S. Transactions model, expectations figure importantly in the decision machinery. Wage income by individuals working in the production system are added and transformed into taxes, savings and various consumption items in the household sector, represented by a nonlinear expenditure system with saving and durable goods stock demand being determined simultaneously with other spending categories.

The money and financial system is explicit but much more crude. An important link is the quarterly feedback through market price-quantity determination via profit formation and investment decisions in individual firms to capacity growth. Growth may be said to be endogenous under an exogenous upper technology constraint. In this sense the IUI-IBM Swedish model combines market price theory with income generation theory in a dynamic fashion not often found in current theorizing. It makes the model very market-oriented and capable of investigating the allocative efficiency-market stability trade off pattern of an economic system which was one of the ambitions of the model venture to begin with.

The micro simulation approach thus allows us to break the analytical confines of equilibrium theory and develop a true numerical disequilibrium framework of analysis. The explicit feedback loops at the micro level between market pricing, profit generation, investment, capacity growth and the supply decisions of each firm gives the total model system a spectrum of "new" properties that so far have received strong support in empirical testing of the model. Several papers on this are included in this conference volume. It has been demonstrated throughout the hundreds of experiments performed so far that micro market disturbances that cannot easily and rapidly be learned and adjusted for by decision makers invariably tip the economy on to a lower, long-term growth path.

The disequilibrium approach is carried further in the Nichols micro simulation model that is exclusively concerned with the labor market. In fact, a positive, frictional unemployment rate that is efficient in the sense of maximizing output probably needs the disequilibrium characteristics of the microsimulation approach to be established.

The more complete full economy model of Yndgaard, on the other hand, is designed in the Arrow-Debreu tradition, in the sense that the system, when disturbed from an equilibrium position if stable, is forced to return it to the same fix point by some time path.

Nichols' results are particularly interesting to compare with the IUI-IBM model. He begins with a random distribution of variously talented workers on jobs requiring various talents. He then allows the model market to reallocate the workers on new jobs. Over some ranges he finds that misallocated labor is such a severe handicap that GNP actually increases from a reallocation even if unemployment also increases. There seems to exist a particular rate of turnover in the labor market that is efficient in a macro economic sense. An interesting collary would be to see if the reallocation mechanism itself is so fast that it disturbs the market signalling function and hence hampers growth in the longer run through profit and investment feedback, as in the Swedish model.

In all three full economy models rigid distributed lag specifications from econometric models are replaced by a sequential decision machinery and frequent feedback loops through the entire economic system. Some would argue that this way of reducing the number and importance of fixed coefficients in the model system and making the hierachical ordering of decisions more important is the true and relevant way of representing an economy. From a qualitative time ordering of decisions and a period specification that conforms approximately with decision times, a quantified time pattern of responses can be derived. As illustrated in the price transmission study on the Swedish model (see p. 281 ff) distributed lags will appear as expected. They will, however, often not be invariant to the impulse being transmitted and more perilious, even if invariant, the traditional inertia interpretation of the distributed lag will be erroneous.

By this we want to emphasize again that there is no meaningful dividing line between theory and empiricism. All econometric models used for, say, forecasting are a mix of assumption and measurement. So are all the models presented in this volume. There is no basic difference between Yndgaard's and Nichols' truly *"principles"* model on the one hand and the Orcutt model, based on very extensive measurements on the other. They all tell us something about an economy in a particular decision context. They differ with respect to the extent and character of quantitative measurement entered.

As stated by both Orcutt and Klevmarken in their methodological papers the micro simulation method allows efficient partial testing and estimation of the model and the piecewise integration of more empirical information into a relevant theoretical system. In principle this makes the micro simulation approach potentially very useful for comparing different economic systems. The micro simulation modelling technique is still too new for this to have been done at an empirical level. However Albrecht has loaded the Swedish model with "synthetic data" adding up to a closed

U.S.-like economy allowing him to study the effects of inflationary expectations on two differently structured economies.

College Park, Stockholm and New Haven in February 1980

Barbara Bergmann	*Gunnar Eliasson*	*Guy Orcutt*
University of Maryland	IUI	Yale University

THE U.S. TRANSACTIONS MODEL

A SHORT DESCRIPTION OF A MICROSIMULATED MACROECONOMIC MODEL: THE TRANSACTIONS MODEL OF THE U.S. ECONOMY

Barbara R. Bergmann

The Transactions Model consists entirely of explicit descriptions of decision making and the consequent simulated actions of individual decision makers. The model's "action" on the macroeconomic level is built up exclusively from the record of the "action" on the microeconomic results into the macroeconomic results numerically by computer.

The Transactions Model has the following characteristics:

1. The model has been designed primarily to elucidate phenomena and policy options in macroeconomics. Production, employment and unemployment, inflation, productivity, investment in capital goods, money markets, portfolio management are among the subjects of interest.

2. Not only decisions, but also interactions among individual decision makers in the economy are explicitly represented. The interaction of individual decision makers takes the form of transactions between individual buyers and sellers in which goods, services or claims are exchanged against money. Thus, the monetary and "real" sides are integrated in the model's simulated economy precisely as they are in the actual economy.

3. Each time a transaction occurs, the effect of that transaction on all simulated macroeconomic variables -- nominal GNP accounts, flow-of-funds accounts, price indexes, etc. -- is recorded. Values of endogenous macrovariables are changed in no other way. All of the usual macroeconomic variables are thus simulated by the model on a basis consistent with the portrayed action on the microeconomic level.

4. All of the decision makers represented in the model -- firms producing different kinds of goods and services, financial firms, governments, the monetary authority, and workers who are also consumers and asset holders -- are subject to constraints on their behavior deriving from technological requirements, and the finiteness of real and financial stockpiles which are honored at all times.

Constraints imposed by governmental policies (such as unemployment insurance requirements, interest rate maxima and the like) are also observed. Each individual decision maker's "experience" and situation in the simulated economy are kept track of by means of numerous microeconomic variables whose values enter into the decision making process and effect the constraints on behavior. Where the application of policy instruments to individuals depends on that individual's history (such as the dependence of unemployment insurance eligibility on employment history), this can be portrayed in a simple manner.

5. The model is cast in a form designed to be useful for purposes of discussions of economic policy in the United States. In all of its magnitudes, it is a "scale model" of the United States economy. Parameters have been set so that the simulated macroeconomic time series output of the model tracks the macroeconomic time series generated by the United States economy for the seventies. Policy instruments -- taxes, subsidies, open market operations, interest rate and price regulations, unemployment insurance, opportunities for training -- appear in the model as impinging on the actions of individual decision makers, and affect the outcomes they individually experience.

The Transactions Model is written down in the form of a computer program and associated files of data on the U.S. economy. The program controls the creation of the initial microeconomic and macroeconomic conditions, it schedules and regulates the behavior of the decision makers, and it produces as output time series of simulated macroeconomic results. Decision makers in the model "know" what to do in each contingency, because the computer program schedules their decision making and provides them with decision making procedures whose nature will be discussed below. The data files serve three purposes:

(1) they provide information on the basis of which the initial microeconomic conditions are set up;

(2) they contain macroeconomic time series data on events which are taken to be exogenous to the model, but which influence the course of events in the simulated economy;

(3) they provide a basis for comparing the simulated macroeconomic time series produced by a run of the

model with actual time series macrodata and thus for computing errors of simulation.

All of the data currently used by the model are from published sources, and are either macroeconomic magnitudes or distributions. Unfortunately, deseasonalized data have had to be used.

The first step in a run of the model is the assignment to each individual decison maker of characteristics and attributes which will remain fixed in the course of the run. For a firm, an example of a fixed attribute is the type of product produced; for a worker-consumer, the most important fixed attribute is broad occupational group. Next, we assign the initial values of attributes associated with decision makers which will vary as the action proceeds. A firm's variables include the average of its past sales, current price of its output amount of inventory held, number of employees by type, quantity and input-output characteristics of "capital goods" by vintage, and a complete accounting of assets and liabilities by type, including money. A worker-consumer's variables include financial assets and liabilities by type, car ownership, home ownership, employment status, average past expenditures. The initial conditions on the microeconomic level are set so as to conform to U.S. macroeconomic data for the calendar quarter in which the run is to start. U.S. data on distribution of assets and on persons by occupation have also been used.

After the creation of the initial conditions, a scheduling program takes over, which arranges for economic events to occur in a fixed sequence. The economic events include decision making and actions based on the decisions which have been taken. Most of the events involve two actors in an interaction whose results must be in accord with the wishes of both. An example of a set of events depicted in the model is the consumption decisions of a consumer, followed by interactions between that consumer and a firm during which the consumer makes purchases from the firm and money flows from the consumer's cash account to the firm's. Another example of a set of events is a decision by a firm to increase its liquidity, followed by an interaction between the firm and a bank, in which a loan might be granted and money created and credited to the firm's cash account.

A full set of all of the actions within the repertoire of the decision makers occurring in a prescribed sequence is called a "round." All of the usual kinds of activities which bear on the macroeconomic performance of the economy in the short and medium run are represented in a round: production and hiring, wage and price setting, government procurement, the creation and sale of financial claims by business firms, the government and worker-consumers, the payment to worker-consumers for their services as factors of production, the making of transfer payments and sales of consumer and investment goods, as well as intermediate goods.

A quarter of a year of calendar time in the United States economy is represented in the Transactions Model by twelve complete rounds of events. As the rounds proceed, macroeconomic magnitudes affected by the events which occur are changed appropriately. National income accounts are continually built up in this way, and at the end of each cycle of twelve rounds the program arranges for the printing out of simulated quarterly national accounts, brought up to the scale of the United States economy by an unchanging multiplicative factor.

Decision-Making in the Transactions Model

The delineation of decision making in the present version of our model derives in an eclectic manner from the economic and business literature. Consumers (after the payment of taxes and installment debt) follow a Stone-Geary linear expenditure system. The parameters which control consumers' consumption behavior are set by finding those values which best track the U.S. macrodata. Although all consumers are assumed to have the same tastes, they spend differing amounts because of their differing assets, differing incomes and differing past expenditures. In their portfolio management, consumers compare rates of return to the various available assets, as economic theory says they should, and they vary the mix of assets they hold according to relative rates of return. The size of the porfolio each consumer has to manage depends, of course, on the sum of his previous savings decisions.

Business firms set prices at the beginning of each round on a cost-plus basis, and sell to all customers at that price. They set output for each round so as to allow inventory to approach a desired ratio to recent sales. They set desired employment by a lagged adjustment to production, making weekly hours adjustments to achieve manhour targets for the current round. Business firms' portfolio management and borrowing activities depend on their cash inflow from sales, cash outflow for purchases and dividend payments, and on investment plans. Like consumers, they are pictured as being sensitive to relative rates of return. In making decisions about investment in capital goods, firms forecast future sales and compare the costs of operation of their older equipment with the purchase price and operation cost of newly available equipment.

Expectations of the future are shown as entering into those decisions from which considerable damage is possible if the future is very different from the present, such as decisions to invest (or not to invest) in long-lived financial and real assets which may prove costly, according to how economic conditions materialize after the decision is made. In such cases, forecasts of future conditions become an ingredient in decision making. The actors in the present version of the model are represented as using very simple forecasting techniques. Firms considering capital outlays make forecasts of demand for their output at current prices using the rate of growth they have experienced in the recent past, if it has been positive. The expected future rate of inflation which enters into portfolio management in terms of willingness to keep assets in cash and willingness to borrow, is forecast as a moving average of past rates or the current rate, whichever is higher.

At this pont, it is worth emphasizing that any piece of decision making machinery currently in the model can easily be entirely replaced by another piece of machinery which makes the decision in question in a qualitatively different way. The ease of doing this is derived from the recursive structure of the model, which eliminates simultaneous solution processes.

Simultaneity in the Actual Economy and the Simulated Economy

Analyses of the macroeconomy have traditionally represented the economy by a system of simultaneous equations. Originally, simultaneous equation formulations were developed for use in describing static systems, where the only movement contemplated was a shift of unspecified rapidity from one more-or-less long-lasting equilibrium to another. The time periods involved were generally left vague.

When empirical macromodels based on time series data began to be estimated, the simultaneous equations formulation was carried over, but with the time dimension of the analysis more explicitly specified. The basic period of the analysis generally was taken to be identical with the shortest period for which all the data were available (the "data period"), and the system was solved anew for each data period. This use of the simultaneous equations formulation can be thought of as an adaptation to the fact that available data on economic activity are averaged out or aggregated over time periods which are so long that the actors must be seen as reacting more than once within a data period to actions of others which occur within the same period. Within a calendar quarter, for example, there is time for a fall in production to cause a reduction in consumption which will in turn react back on production. The simultaneous solution of a set of behavioral equations which specify such reactions purports to represent the stable situation after all of these actions and reactions have taken place, and behavior has settled down into a pattern in which all actions are mutually consistent in the sense that they can remain at constant levels. If we were to try to think concretely (perhaps some might say, to the point of mistaken concreteness) of what kind of an actual economic system might be exactly represented by an empirical quarterly simultaneous equations model, it would have to be an economy where the law requires that a "tâtonnement" takes place before ordinary business hours on the first day of each quarter and further requires that activity proceed at the steady pace thus determined for all the rest of the days of the quarter.

In the Transactions Model, the fact that within a data period there can be multiple interactions among the actors is dealt with in a different way, which we believe to provide somewhat greater realism. We have done away with the identity of the data period and the basic period of analysis. and have disaggregated the data period into shorter periods, taking as the basic period of analysis a time interval so short that it is plausible to represent each actor as revising each type of decision only once each basic period. We have chosen to represent each calendar quarter as being made up of 12 such basic periods; the basic period thus corresponds approximately to a week of real time. Within each basic period, a complete "round" of economic events is scheduled.

The construction of an entirely recursive model (with respect to the basic operation periods rather than the data periods) does more than advance somewhat the cause of realism. It also saves us from the surely tedious and perhaps infeasible chore of simultaneously solving all the behavioral equations. Put another way, the elimination of simultaneity (in the sense of multiple intra-period reactions) frees us to postulate realistic behavioral rules for the actors (if we know any) without having to worry that the mathematics of the solution process will be too difficult. While this latter consideration may seem to some readers to be mere self-indulgence on the part of the authors, there is little evidence that actors in the actual economy consider the effect of their choice of behavioral rules on the solvability of the system when they formulate such rules for themselves.

The one form of simultaneity which _is_ actually observed in economic life is, of course, the coincidence in time of economic events -- many acts of production, consumption and exchange all go on at the same time and some go on continuously. In depicting the actions of individual actors on the computer one is constrained to represent all actions by computations which are bound to occur sequentially. Regarded retrospectively, it does not matter whether two economic events are represented as occurring simultaneously or in immediate sequence _if_ the occurrence of one event does not affect the likelihood, feasibility or characteristics of the other. The adoption of a short basic period reduces the implausibility of removing all coincidence in time, and reduces the implausibility of representing activities which are continuous in the real world by action concentrated at particular instants.

In the operation of the Transactions Model, the ability of an actor to carry out a decision is usually not affected by whether he is first or last in line to implement his decision, since in the real world and the simulated world which mimics it, there is usually ample excess capacity. In the rare case of temporary shortages, however, the ability of individuals to carry out decisions would be affected by whether they are early or late within a round to try to engage in a transaction. In such a case, the model prescribes procedures for the rationing of goods in short supply, so that latecomers are not closed out in favor of complete fulfillment of orders by earlier customers. This occurs most importantly in the allocation of labor among firms when the unemployment rate is very low.

Workers-Consumers-Asset Holders

The Transactions Model represents the United States economy by a much smaller-scaled simulated economy. The labor force in the model consists of 800 persons, divided into four occupational groups. The scale of the simulated economy is the ratio of the simulated labor force to the actual labor force in the base period.

Members of the labor force of the simulated economy are assigned to one of four broad occupational groups whose relative sizes are derived from U.S. Labor Department data: (1) Professional, Technical, Managerial and Administrative Workers, (2) Clerical and Sales Workers, (3) Crafts Workers and Operatives, and (4) Service Workers and Laborers. In the present version, an individual cannot change his occupational group. When new individuals enter the labor force they are assigned to an occupational group and have no assets. Persons not in the U.S. labor force who are in families which include labor force members are not directly represented in the Model; consumer expenditures are made and assets held by labor force members on their behalf. However, families with no labor force members are represented and receive transfer payments, which they use exclusively for purchasing consumption goods.

Figure 1 gives the items of information available for each individual in the model. Some characteristics of individuals which importantly influence their economic functioning are not represented in the model as it now stands. The most important are a person's age and educational attainment. Two of the major decisions made by consumers concern saving and portfolio management, illustrated in Figures 2 and 3 respectively.

Figure 1. Information Continually Updated and Available Concerning Each Fictional Person during a Run of the Transactions Model

Unchanging Personal Characteristics

ISEX	Sex
ISPOUS	Identity of spouse (=0 if unmarried, = -1 if married, but spouse not in labor force, = "address' of spouse if latter is in labor force)
ICASTE	Occupation (1-4)
IDIS	Skill level within occupation
ISTIG	= 1 if at a disadvantage in being hired when unemployed; = 0 otherwise
OWNCAR	= 1 if person has possibility of car ownership, 0 otherwise

Labor Force Status

LF	= 1 if in labor force, = 0 otherwise
IEMPST	= identity of employer if person is employed, = 0 otherwise
IUDAT	Date of last accession or separation
IELIGW	Unemployment insurance eligibility, in weeks
UI	= 1 if currently receiving unemployment insurance, = 0 otherwise

Financial Status*

HCASH	Money held in checking account
SAVACC	Value of savings account deposits
HBONDS	Maturity value of bonds held
AMORT	Weekly payment due on consumer loans
ISTART	Starting date of current consumer loan arrangements
AMORTG	Weekly payment due on home mortgage
INMORT	Starting date of mortgage

Other*

IDGAGE	Date of last new car purchase
EXP	Moving average of consumer expenditures (geometric weights)

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* In the case of two labor force participants who are married to each other, the variables representing their financial status are consolidated into one account.

Figure 2. Decision Making on Spending and Saving

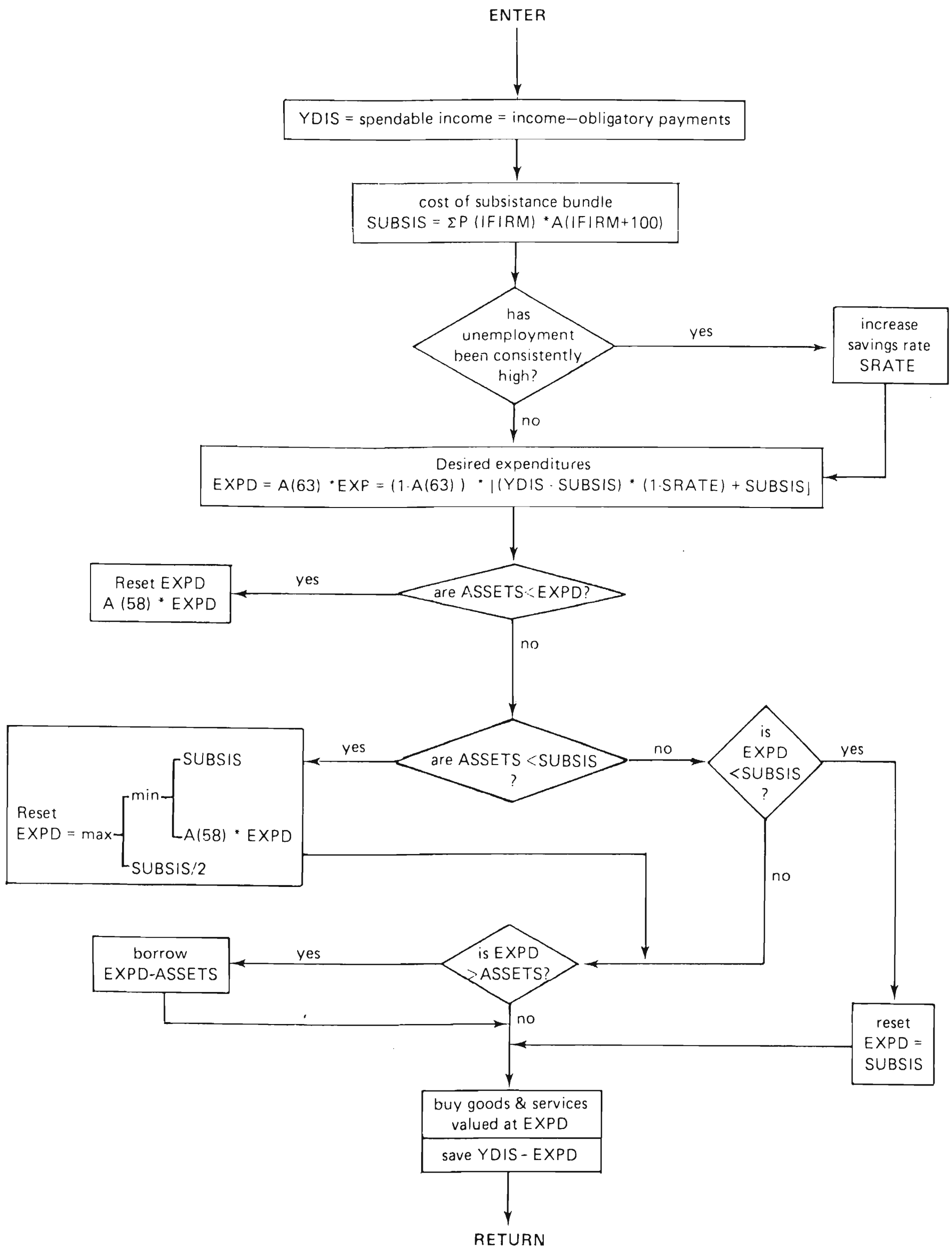
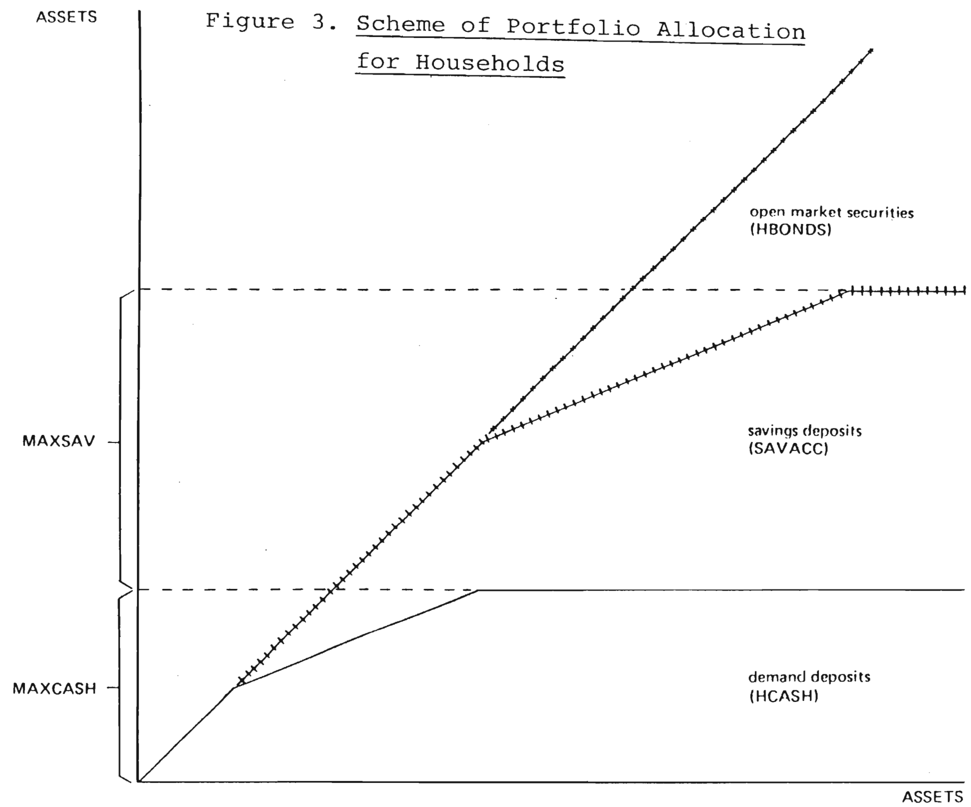


Figure 3. Scheme of Portfolio Allocation for Households



MAXCASH is a function of weekly outlays and interest rates on savings accounts.

MAXSAVE is a function of weekly outlays and interest rates on savings accounts and open market securities.

The Firms

Private production in the simulated economy has been divided into twelve industries[1] and one firm assigned to each industry. Figure 4 gives a list of the items of information concerning each firm which is represented in the model. A physical unit of output of each industry is defined as the amount of that product which could have been bought in the base period with one dollar. Units of capital goods called "machines" are also defined on a physical basis. A machine is specialized to the industry in which it is used, and for each using industry is defined as an appropriately weighted combination of physical quantities of the outputs of eight of the twelve industries costing one dollar in the base period. The physical quantities of the goods which make up a machine used by a particular industry are assumed not to change through time, although the cost does, as prices of the output of the eight industries change. Each machine is assumed to be "born" with a particular labor requirement and a particular rated output associated with it. As the machine ages these characteristics do not change until the machine goes out of service, which occurs at the end of a fixed period.

A firm's capital goods are differentiated by quarterly acquisition date; the more recently produced physical units of capital goods are assumed to have better output-labor ratios than the older units, with a higher rated output per machine and a lower amount of labor required for a machine to produce its rated output. The rates of change of the output capabilities and labor input requirements for physical units of newly produced capital goods are among the basic parameters of the model, since they are an important component of productivity change.

1
The industries are: Agriculture, Forestry & Fisheries; Mining; Contract Construction; Automobile Manufacturing; Other Durable Manufacturing; Non-Durable Manufacturing; Transportation; Communication; Electric; Gas and Sanitary Services; Wholesale and Retail Trade; Other Services; Real Estate; Banks & Savings Institutions; and Other Finance & Insurance.

Purchases by one firm of the outputs of others for non-capital inputs to current production (so-called flow inputs) are governed by the 1967 Input-Output Table, and are taken to be unchanging over the time period of the simulation, and unaffected by capital goods purchases.

The firms' short-run average cost curves are influenced by two familiar factors: the presence of substantial fixed costs and rising marginal costs. Larger outputs cause the firm to bring into production successively older vintages of capital goods with smaller output/labor ratios. A firm's simulated cost curves shifts whenever the prices of labor and flow inputs change; they also shift when investment results in the acquisition of new capital goods, which are always more labor-saving than the average of the old capital stock.

Figure 5a illustrates the firm's decision procedure with respect to price setting. Figure 5b illustrates investment decision making.

Figure 4. Information Continually Updated and Available Concerning Each Fictional Firm During a Run of the Transactions Model

Materials Requirements

AIO(KFIRM,IFIRM)	Physical units of the product of firm KFIRM required as input for the production of one unit of the product of firm IFIRM.
AIOCAP(KFIRM,IFIRM)	Units of output of KFIRM required to put in place a new "machine" for the use of IFIRM.

Capital Stock

OPUT(IFIRM,JVIN)	Maximum output producible on all of the machines of vintage JVIN in a week if workers are on a standard workweek.
OPUTS(IFIRM,JVIN)	Maximum output producible in all of the structures of wintage JVIN in a week if workers are on a standard workweek.
CAPCY(IFIRM)	Maximum currently available capacity for output in a standard workweek.
ONEW(IFIRM)	Output producible with one unit of new machine.
ONEWS(IFIRM)	Output producible with one unit of new structures.
STARTC(IFIRM)	Backlog of firm's orders to the construction industry.
STARTM(IFIRM)	Backlog of firm's orders for machines.
VIN(IFIRM)	Marginal vintage of machines currently used.
VINS(IFIRM)	Marginal structure vintage.

4771
4772

Figure 4. (continued)

Labor Requirements and Usage

EMPFIX(IFIRM)	Number of employees on the "fixed" staff.
RLAB(IFIRM,JVIN)	Number of employees required to cooperate with all machines of vintage JVIN.
RLABS(IFIRM,JVIN)	Number of employees required to cooperate with all structures of vintage JVIN.
FLABOR(LCASTE,IFIRM), RLABOR(LCASTE,IFIRM)	Proportion of employees of the fixed and variable staffs respectively who are required to be of occupation LCASTE.
HRS(IFIRM)	Ratio of weekly hours to standard workweek.
WAGEF(LCASTE,IFIRM)	Weekly wage paid by IFIRM to average worker in occupation LCASTE, adjusted for weekly hours.
PRTAX(IFIRM)	Current period's payroll tax liability.
DESEMP(IFIRM)	Desired employment of "variable" employees.
EMP(IFIRM)	Total current employment.
XLNEW(IFIRM)	Labor required to cooperate with one unit of new machines.
XLNEWS(IFIRM)	Labor required to cooperate with one unit of new structures.

Figure 4. (continued)

<u>Sales, Production and Inventories</u>

SALE(IFIRM)	Current weekly sale, in physical units.
AVSALE(IFIRM)	Moving average (with geometric weights) of weekly sales.
EXPORT(IFIRM)	Firm's share of total U.S. constant dollar exports.
GOVBUY(IFIRM)	Firm's share of constant dollar sales to the Federal Government.
GOVBYL(IFIRM)	Firm's share of constant dollar sales to state and local governments.
ORDERS(KFIRM,IFIRM)	IFIRM's order backlog of KFIRM's product.
DPROD(IFIRM)	Current desired weekly production.
XPROD(IFIRM)	Actual weekly production.
XINV(JFIRM,IFIRM)	Quantity of output of product of JFIRM held as inventory by IFIRM.
PINV(JFIRM,IFIRM)	Inventory of JFIRM's product held at end of last period by IFIRM.
INVEN(IFIRM)	= 1 if IFIRM's product is held as inventory; 0 otherwise.
SHPROD(IFIRM)	Additional quantity firm desired to produce, but could not because of capacity, labor or input shortage.
SHORT(IFIRM)	Quantity of product demanded but not sold because of inventory deficiency.
CAPSHT(IFIRM)	Output which was not produced because of capacity shortage.

Figure 4. (continued)

Other Cost, Price and Profit Information

CAPCO(IFIRM)	Depreciation allowance, weekly.
TAXIND(IFIRM)	Rate of indirect taxes on value of firm's output.
CORP(IFIRM)	Proportion of firm's computed profit subject to corporate income tax.
XINTER(IFIRM)	Interest payments weekly on firm's debt.
ACOST(IFIRM)	Average cost of units of output currently produced.
XMCOST(IFIRM)	Marignal cost at current level of output.
P(IFIRM)	Current price of firm's output.
PLAST(IFIRM)	Price of firm's output in last period.
PI(IFIRM)	Acquisition price of the average unit of IFIRM's current inventory.
PO(IFIRM)	Average price of unfilled orders for IFIRM's product.
PROFIT(IFIRM)	Profits on current week's output.
PMARG(IFIRM)	Customary profit margin over average cost.

Financial Assets

CASH(IFIRM)	Size of firm's demand deposits.
BBONDS(IFIRM)	Maturity value of open market securities held.

Financial Liabilities

BLOANS(IFIRM,IMAT)	Bank loans maturing in period IMAT.
BONDS(IFIRM,IMAT)	Maturity value of bonds outstanding maturing in period IMAT.
BONSEL(IFIRM)	Desired weekly sale of the firm's bonds.

Figure 5a. Flow Chart Illustrating the Sequence of Decision Making Concerning Prices

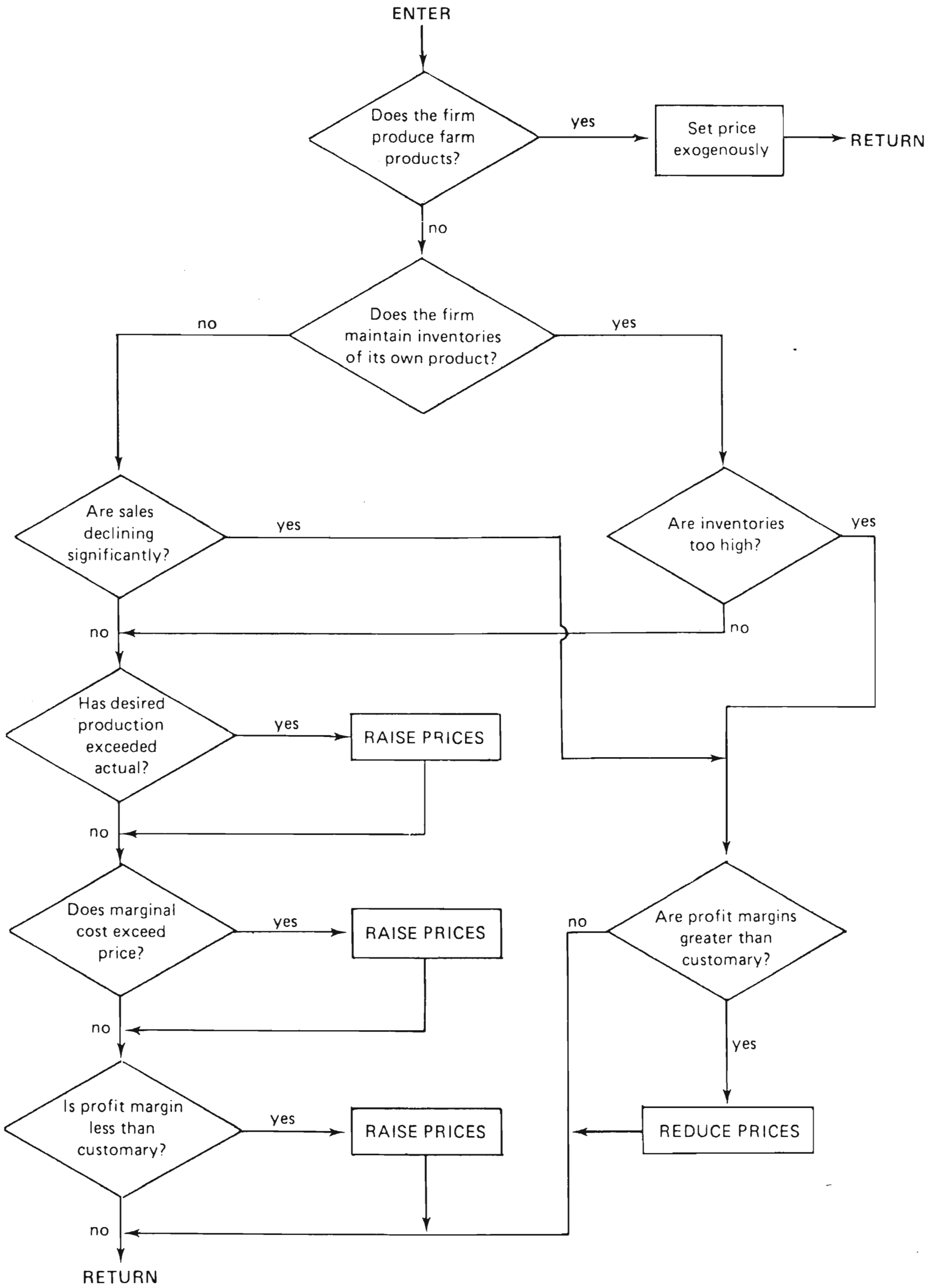
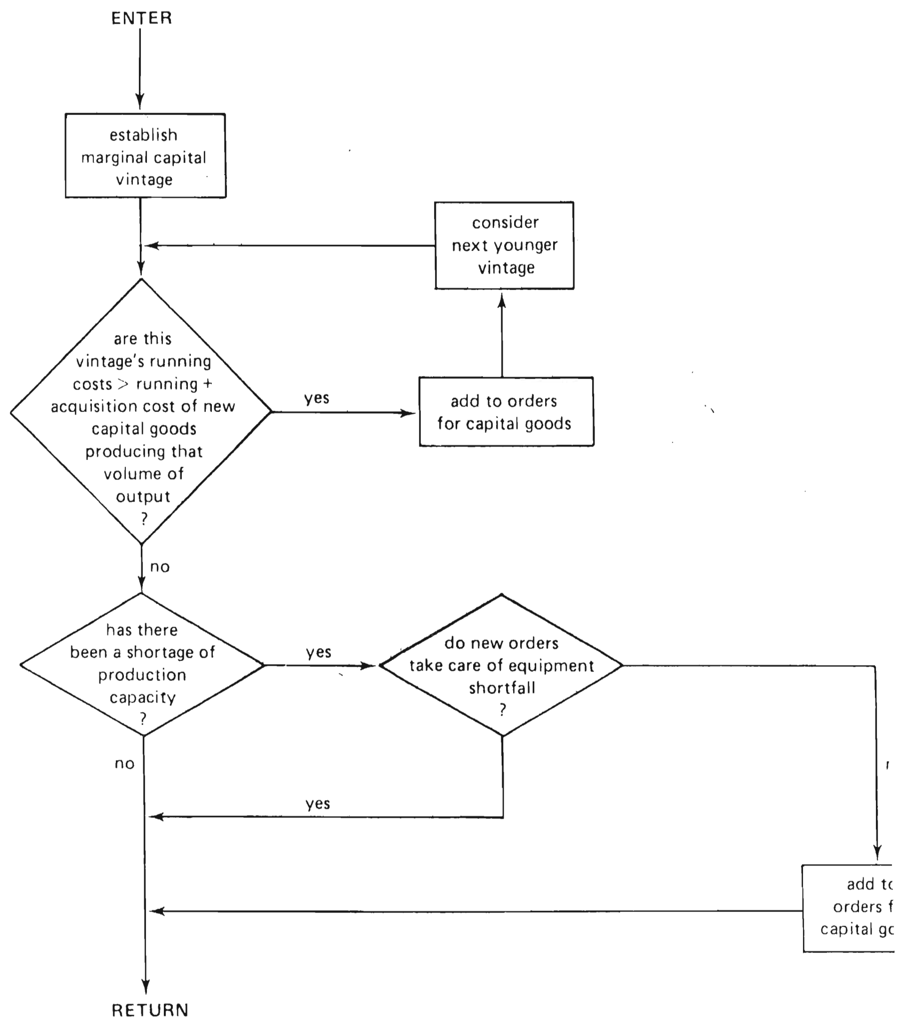


Figure 5b. Flow Chart Illustrating the Sequence of Decision Making with Respect to Investment



The Scheduling of Microeconomic Activity

Twelve times each calendar quarter a round of microeconomic events occurs -- all of the actors go through their entire repertoire of decision making and activity in a regularly scheduled order. A summary of the sequence of scheduled events in a round is listed in Figure 6, together with the name of the computer subroutine which controls each event. A particular event will influence other events which occur later in the same round; for example, wage setting decisions will influence consumer expenditures, which occur subsequently, which in turn will influence the demand for financial assets still later.

Business inventories (maintained in physical units separately for each product), which are built up by production and drawn down by purchases of all types play a central role in the simulated economy. The decision made by each firm concerning how much of its product it would like to produce is based on its inventory position and on sales in the recent past. A business firm knows the physical quantity it has sold in the previous round because it can compare the size of its inventory position along with their costs and profit margin when making decisions about changing the prices they charge for their products. These price changes also have a central role in the model, since they affect quantities purchased, wages and, in subsequent rounds, profits.

Portfolio Adjustments by Firms, Worker-Consumers, the Financial Firms and the Government

All of the various economic units attend to the servicing of their debt obligations and make decisions about their portfolio of assets each round. They accomplish the desired transactions in financial assets and liabilities to the extent that they are feasible. Households keep track of the maturation schedule of their existing debts, and roll them over or make repayments of interest and the maturing principal of existing debts on schedule. Households also adjust their stocks of debt liabilities and distribute their assets among cash, savings accounts, open market securities and equities in homes.

As decisions by firms are made on the purchases of current inputs and capital equipment, decisions on bond and mortgage issues are made and bank loans under lines-of-credit are planned to meet cash deficiencies. The non-financial firms also make their decisions with respect to the distribution of their financial assets among cash, consumer debt and open-market securities. The two government sectors and the rest-of-the-world issue the amount of short-term and long-term debts they desire and allocate their financial assets among cash and open-market securities.

Next the commercial bank calculates its excess or deficient reserves and makes its decisions to increase or decrease its holdings of open-market securities. It will have made loans at business and consumer loan rates announced at the end of the last round and its loan inventory may have undergone (within limits) involuntary changes which reflect excess loan demand at current rates.

The Federal Reserve now makes its open-market purchases or sales of foreign exchange and domestic securities to bring actual bank reserves to the desired level, in accordance with open market policy, which is set every fourth round.

At this point in the round all portfolios have been adjusted insofar as is feasible to the quantities desired, given the yields which prevail on each asset during the round, with the exception of the bank and the financial intermediary. The latter makes the market in open market securities, and will have purchased or sold all that were offered or demanded at yields announced at the beginning of the round. On the basis of the sign and magnitude of the excess demands for bank loans, at the end of the round the bank will adjust the savings account rate, business loan rate, and consumer loan rate. The financial intermediary, on the basis of excess demand or supply for open market securities, will adjust rates for treasury bills, treasure bonds, state and local bonds, private bonds, and home mortgages.

Figure 6. Summary of Sequence of Events in a Round of the Transactions Model

Event	Sub-routine name
tentative production decisions by firms	PROD
hiring and weekly hours decision by firms	PROD
search by firms & governments for workers, and by workers for jobs; quits, layoffs and hirings	EMPLOY
wage rate setting by firms for each occupation	WAGES
production occurs, affecting firms' inventories	COST
cost accounting by firms, computation of taxes owed	COST
price setting by each firm for its product	PRICE
inter-industry purchases by firms of flow inputs	INPUT
payment of payroll, sales and profits taxes by firms to governments	INPUT
investment decisions & capital goods purchases by firms from those firms producing capital goods	INVEST
decisions concerning housing stock by real estate firm	HOMES
events which give rise to inputed items in GNP but no flow of funds	IMPUTE
payment of wages by firms & governments	CONSUM
government transfer payments to unemployed and other beneficiaries	CONSUM
receipt by workers of property income from financial intermediary	CONSUM

Figure 6. (continued)

Event	Sub-routine name
Payment of income & social security taxes by workers to government	CONSUM
workers make payments on mortgages & bank loans	CONSUM
consumption decisions & purchases of goods & services other than housing	CONSUM
portfolio management decisions & activities by consumers	CONSUM
government purchases of goods & services from firms	GOVERN
purchases by rest of the world from firms	GOVERN
finance & liquidity decisions by nonfinancial firms; actions through bank & financial intermediary	FINANC
government debt management decisions & actions	FINANC
monetary authority decisions & actions on open market	FEDRES
banks set loan policy & discount with monetary authority	BANK
setting of current consumer loan rate, business loan rate, mortgage & savings accounts interest rates by banks	INTER
current bill & bond rate set by financial intermediary	INTER
government & firms pay interest on existing obligations at original rate to financial intermediary	INTER
payment of interest to firms on their holdings of bonds and bills by financial intermediary	INTER

Next the financial intermediary and bank announce the commitments they are willing to make to purchase home mortgages in the future, which will affect the decisions of the construction industry to begin construction of homes.

Finally, the government and Federal Reserve financial policies for the next round are announced. The federal government decides its level of mortgage purchases for the coming round by such agencies as the Government National Mortgage Association, which will affect new commitments for the following round by the private financial institutions. The Federal Reserve sets the discount rate, the maximum savings account rate, and the required reserve ratios for demand and savings deposits.

"Markets" in the Transactions Model

Market participation by the actors in the Transactions Model are summarized in Figure 7, where each horizontal line represents participation of each type of actor as buyer and/or seller in each of the markets for a good or financial claim. Prices in each of these markets are set once in a round, and all transactions for an entire round proceed at that price. Inventories serve as buffer stocks, allowing for differences in supply and demand in the short run.

For goods and services produced by nonfinancial firms, prices are normally set by producers on a cost-plus basis, and firms then sell all they can at that price. An exogenous shift upward in average costs is followed by a price adjustment which leads in turn to a reduction in quantity demanded, depending on the price elasticity for the product, and what changes in other prices have been occurring. Changes in costs in the simulated economy also affect the demand for goods and services through their effects on incomes.

Wage changes are made by firms, and vary directly with quit rates, profit rates, and cost of living change and inversely with unemployment rates. The demand for labor in the present version of this model is only in the medium run affected by wages.

In the very shortest run, the demand for labor is based on the labor necessary to produce desired output using the existing stock of capital equipment, with desired output being based on sales and inventory levels. However, higher labor costs affect prices, which affect total demand and the distribution of demand among products. In the longer run, higher wages encourage the purchase of larger quantities of the new, more labor-saving capital equipment which, when it is put in place, has the effect of reducing the amount of labor required to meet a given production target.

The markets for financial claims are run along lines perhaps more congenial to neoclassical theory. For each type of claim the financial intermediary "makes" the market by buying and selling to all comers at a price set by itself. If it finds itself accumulating inventory of an item beyond what it desires on its own account, it reduces the price in the next round and increases it in the opposite case.

Transactions and the Flow of Funds

Every sale of goods and services engaged in by individuals in the simulated economy involves the passing of merchandise from one decision maker to another and the passing of demand deposits in the opposite direction.[1] Each transaction is accomplished by a subroutine named TRANS, which is called into action whenever any decision maker wants to buy anything from any other decision maker. TRANS is the principal means by which the interactions of decision makers are depicted, and it is also the principal means by which "action" on the micro level is made to contribute to the GNP and the flow-of-funds accounting.

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1 Currency is not used by the actors in the present version of the model.

Figure 7. Market Participation in TRANSACTIONS, by Sector. S and D indicate participation on the supply and demand side, respectively. For financial claims, those on the demand side may sell already existing claims in their posession, but only those on the supply side may create new ones.

SECTOR	Input Markets		Final Demand Markets				Financial Markets: Long Term Claims					Financial Markets: Short Term Claims					
	Labor Services	Inter-Firm Purchases	Consumer Goods	Fixed Capital	Net Exports	Govt Purchases	Corporate Bonds	Fed Govt Bonds	State & Local Bonds	Mortgages	Equities	Treasury Bills	Bank Loans	Money	Time & Svgs Deposits	Discounts & Advances	Bank Reserves
Households																	
Labor-force households	S		D			S	D	D	D	S	D	D	D	D	D		
Other households			D														
Non-Financial Businesses																	
Agriculture, Forestry & Fisheries	D	DS	S	D	DS	S	DS	D	D		S	D	D	D			
Mining	D	DS	S	D	DS	S	DS	D	D		S	D	D	D			
Contract Construction	D	DS	S	DS	DS	S	DS	D	D		S	D	D	D			
Automobile Manufacturing	D	DS	S	DS	DS	S	DS	D	D		S	D	D	D			
Other Durable Manufacturing	D	DS	S	DS	DS	S	DS	D	D		S	D	D	D			
Non-Durable Manufacturing	D	DS	S	DS	DS	S	DS	D	D		S	D	D	D			
Transportation, Communication, Electric, Gas and Sanitary Services	D	DS	S	DS	DS	S	DS	D	D		S	D	D	D			
Wholesale and Retail Trade	D	DS	S	DS	DS	S	DS	D	D		S	D	D	D			
Other Services	D	DS	S	D	DS	S	DS	D	D		S	D	D	D			
Real Estate	D	DS	S	D	DS	S	DS	D	D	S	S	D	D	D			

Figure 7. (continued)

	Input Markets		Final Demand Markets				Financial Markets: Long Term Claims					Financial Markets: Short Term Claims				
	Labor Services	Inter-Firm Purchases	Consumer Goods	Fixed Capital	Not Exports	Govt Purchases	Corporate Bonds	Fed Govt Bonds	State & Local Bonds	Mortgages	Equities	Treasury Bills	Bank Loans	Money	Time & Svgs Deposits	Discounts & Advances	Bank Reserves
Financial Businesses																	
Banks & Savings Institutions	D	DS	S	D	DS	S	DS	D	D	D	S	D	S	S	S	D	D
Other Finance & Insurance	D	DS	S	D	DS	S	DS	D	D	D	S	D	D	D			
Governments																	
Federal Govt (Incl.Govt Enterprises)	D	DS	S		DS	DS	D	S		D		S		D			
State & Local (Incl.Govt Enterprises)	D	DS	S		DS	DS	D	D	S			D		D			
Rest-of-World		DS	S	S	DS	S	DS	D	D		DS	D	DS	D			
Federal Reserve								D				D				S	S

TRANS is used whenever money changes hands -- for the purchase of commodities, labor, financial assets, as well as for the payment of taxes, and the making of government transfer payments. It is the consistent use of this "naturalistic" mechanism that makes possible the automatic integration of real and nominal GNP accounts and the flow-of-funds accounts. TRANS also insures that all stocks (of money, financial claims, or of goods) are built up or drawn down in accordance with the flows which the micro-units decide shall occur.

Figure 8 contains a summary list of all events in the model which trigger cash flows by source and destination of the flow. It includes flows on both current and capital account. Since every actor in the model has a cash account and each cash flow (with the exception of those in which the monetary authority is an actor) is accomplished by the building up of one cash account at the expense of another, the distribution of cash stocks at any moment in time is kept track of, and may be printed out at will.

We have chosen to maintain the fiction that all of the open-market financial assets of households and businesses are held for safekeeping in the firm "other financial institutions", which collects the income due to owners of these assets and disburses it to the owners. This firm also buys and sells these assets for customers' accounts, and makes the market in them.

Assigning Parameter Value in the Transactions Model

Builders of large-scale microsimulated models which purport to represent the past and future operations of actual economic processes are presently in need of two kinds of development:

1) We need to develop more knowledge of and experience with computation procedures which will conduct an efficient search for parameter values that will optimize whatever objective function(s) we choose, and which are within our expense and time constraints.

2) We need the development of methods for associating a chosen objective function with the stochastic characteristics of the estimates we make.

The following are some of the methodological issues relating to the choice of a parameter search routine.

1) One might choose to fit the parameters of each piece of a system separately, using for each piece a separate loss function which has as arguments the simulation errors of that piece alone. Alternatively one might try to fit all of the parameters using a single loss function in which all of the system's errors enter as arguments. The former would be analogous to the single equation, ordinary least squares methodology used with conventional models: the latter would be analogous to a simultaneous equations approach.

2) One might fit parameters using runs of the model in which errors of simulation in a particular period were or were not allowed to influence the "action" in subsequent periods. The former is usually termed a "dynamic" approach.

3) There is a wide variety of loss functions one might adopt.

4) There is a wide variety of techniques for deciding which parameter vectors to try: conjugate gradient methods, random search, pattern search, etc.[1]

The parameter values currently being used in the Transactions Model were selected by a two-stage process. Corresponing to each of the important subroutines an "exogenous" version was developed, which forced the actors to behave so as to generate simulated results identical to the time series data relating to the activities described. For example, in the endogenous version of subroutine INVEST, business firms are represented as taking account of interest rates, wage rates, business activity and the like in deciding how much capital equipment to purchase In the exogenous version, firms are constrained to order in a particular time period the amount of fixed capital the National Income Accounts series on fixed investment indicates they actually ordered.

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[1]See Goldfeld and Quandt, Nonlinear Methods in Econometrics, North-Holland, 1972, Ch. 1.

Figure 8. Cash Flow between Sectors Occurring in the Transactions Model

(1) From/to	(2) Non-Financial Business	(3) Households	(4) Government
Non-Financial Businesses	Investment Goods IO Purchases	Cons Goods & Svcs Cons Debt Interest Cons Debt Amort	Govt Goods & Svcs
Households	Wages New Cons Loans		Wage Payments Transfer Payments
Governments(Fed) (Incl Fed Govt) Enterprises)	IO Purchases Sales Taxes Profit Taxes Soc Ins Taxes	Cons Goods & Svcs Income Taxes Soc Ins Taxes	IO Purchases S & L Soc Ins Taxes
Government (S & L) (Incl. S & L Govt Enterprises)	IO Purchases Sales Taxes Profit Taxes	Cons Goods & Svcs Income Taxes Soc Ins Taxes	IO Purchases Fed Grants-in-aid
Other Financial Intermediaries	IO Purchases Dividend (Ind Prgs)* Bond Interest* Bond Amort* Govt Sec Purch*	Cons Goods & Svcs Interest Cons Debt Amort Cons Debt Home Purchases* Home Repairs* Home Interest* Home Taxes* Bond Purchases* Govt Sec Purch* Home Mtg Amort*	Govt Goods & Svcs Govt Sec Interest* Govt Sec Amort* Home Mtg Purch* Govt Sec Purch* (S&L Purch Fed Govt)*
Banks & Savings Institutions	IO Purchases Bank Loan Interest Bank Loan Amort	Cons Goods & Svcs Interest Cons Debt Amort Cons Debt Savings Deposits	Govt Goods & Svcs
Monetary Authority			
Rest-of-World	IO Purchases	Cons Goods & Svcs	IO Purchases Govt Transfers Govt Purchases

Note: (Cash payments which accrue to "Other Financial Intermediaries" in their capacity as agent for the account of others, or are made by them in that capacity are marked with *.

(5) Other Financial Intermediaries	(6) Banks and Savings Institutions	(7) Monetary Authority	(8) Rest-of-World
Investment Goods 10 Purchases Home Purchases* Home Repairs* Interest (Govt Sec)* Amort (Govt Sec)* Business Bond Issues*	Investment Goods 10 Purchases Bank Loans		Exports
Wage Payments Consumer Loans Home Mort Issues* Dividend (Incl Prgs)* Interest (Govt Sec)* Amort (Govt Sec)* Interest (Bus Sec)* Amort (Bus Sec)*	Wage Payments New Cons Loans		
10 Purchases Sales Taxes Profit Taxes Soc Ins Taxes	10 Purchases Sales Taxes Profit Taxes Soc Ins Taxes		Exports
10 Purchases Sales Taxes Profit Taxes Home Taxes* Interest Home Mtg* Amort Home Mtg* Interest Govt Sec* Amort Govt Sec*	10 Purchases Sales Taxes Profit Taxes		Exports
10 Purchases	10 Purchases Dividend (Ind Prep)* Bank Loans Home Mtg Purch* Govt Sec Purch Bus Bond Purch	Govt Sec Purchases	Exports Govt Sec Purchases Bus Sec Purchases
10 Purchases Interest (Bank Loans) Amort (Bank Loans) Home Mtg Interest* Home Mtg Amort* Govt Sec Interest* Govt Sec Amort* Bus Bond Interest* Bus Bond Amort*	10 Purchases	Discounts	Exports Interest (Bank Loans) Amort (Bank Loans)
Interest (Govt Sec)* Amort (Govt Sec)*	Interest on Discounts Amort on Discounts		
10 Purchases Interest (Govt Sec)* Amort (Govt Sec)* Interest (Bus Sec)* Amort (Bus Sec)* Net Imports	10 Purchases Bank Loans	For each Purchase	

In searching for parameter values for a particular subroutine, the "endogenous" version of that subroutine was first run in conjunction with the "exogenous" version of all the other subroutines. After tentative values had thus been given to all the parameters, additional runs were made to adjust the parameter values to produce an improved performance for the system when it was run with the endogenous versions of all of the subroutines.

All runs were dynamic, in the sense above, and were based on the twelve quarters of National Income Accounts and Flow of Funds data and the 36 months of unemployment and interest rate data in the period 1973-75. The loss functions used were sums of squares of percentage errors of simulation. The method of bringing in new vectors of values was "judgmental" rather than automated.

We are currently working on an automated method of choosing new vectors by computer. The major difficulty in doing this derives from the fact that a single run of the fully endogenous version of the model covering three years takes 20 minutes of real time under optimal conditions on a time-shared Univac 1108 and most of the standard programs for parameter search would require hundreds or thousands of runs. We are working to adapt a number of such programs so as to cut the number of runs required by a large factor.

BANKS AND FINANCIAL INTERMEDIARIES IN THE MICROSIMULATED TRANSACTIONS MODEL OF THE U.S. ECONOMY

Robert L. Bennett

This paper is a description in some detail of the markets for financial assets and the forces affecting interest rates in the Transactions Model.[1)]

There are five basic interest rates in the model:

(1) the three-month bank loan rate
(2) the three-month treasury bill rate
(3) the fifteen year federal government bond rate (which also governs the municipal and private bond rates)
(4) the twenty-five year home mortgage rate, and
(5) the savings deposit rate.

These rates are adjusted each round in response to excess demands in the market for the specific financial asset. Excess demand for a financial asset may result in the model from the issuer of the security changing the outstanding stock or from owners of the outstanding stock changing their holdings. Transactions by all of the actors in the model take place at yields which are announced at the beginning of the round by the actor which "makes a market" in the particular security. For bank loans and savings deposits this is the bank, industry IBANK; for treasury bills, bonds and home mortgages this is the other financial institution, industry IOFI. The bank and financial intermediary accomodate all transactions desired by other actors to the extent that the securities are available (and in some cases sell unavailable securities short).

The decisions which most significantly affect interest rates are made by the individual actors in the process of adjusting their outstanding liabilities and their portfolios of financial assets each round. This paper discusses in turn the portfolio decisions of households, nonfinancial business, governments, the bank, the other financial institution and the monetary authority.[2] The order of presentation is almost without exception the order in which the decisions are made during the course of a round.

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1 Unfortunately it has as yet not been possible to complete dynamic runs of the model for 1973-75 period which we are currently using to set parameters.

2 The financial activities of governments and the Rest-of-World sector are exogenous in our model and are not described in detail here.

FINANCIAL ACTIVITIES OF HOUSEHOLDS

Home Mortgage Issues

Our households are the sole issuers of home mortgages; these are issued on the occasion of a consumer's first home purchase, or on the occasion of a step up from one house to a larger one. The major determinants of the quantity of new issues of mortgages are the quantity of new homes available for sale in the round, the price of a unit of new housing, the current mortgage interest rate, the policy of financial institutions with respect to down payment requirements, and government policy with respect to down payment requirements.[1]

Consumer Debt Issues

Households also issue both installment and non-installment consumer debt. Currently in the model the rate charged on these loans is exogenously determined, so only a cursory description of this "market" appears here. Installment loans are made when automobiles are purchased or when the consumer attempts a transaction for which he has insufficient cash. Non-installment consumer loans, representing charge accounts primarily, are made under lines of credit related to the consumer's income and current credit conditions. The household maintains these non-installment debts at the desired multiple of weekly expenditures, subject to a cushioned adjustment to substantial changes in expenditures. For computational convenience these loans are made by the bank to the household and later apportioned to other firms in exogenously determined shares.

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[1] An extended discussion of the decision on the part of households to purchase homes and the conditions under which homes are ordered and constructed is found in Bennett and Bergmann, A Microsimulated Transactions Model of the U.S. Economy, Chs. 3 and 4. (Forthcoming.)

Adjusting the Portfolio of Assets

We have assumed that consumers wish to end the round with their assets allocated among cash, savings accounts and open market securities according to a simple scheme, illustrated in Figure 1. Consumers with very low assets keep them entirely in cash. After a certain accumulation has been reached, additional assets will be allocated half to the cash account and half to the savings account until the cash account is of size MAXCASH. As accumulation proceeds, a point will be reached at which half of additional assets are allocated to open market securities. After the savings account has reached size MAXSAVE, all additions to assets are put into open market securities.

We have set the ceiling on desired cash as a proportion of all cash outlays made in the current round by the consumer.

$$(1)\quad \mathrm{MAXCASH} = A(68) * \mathrm{OUTLAY} * \left(1 + \frac{\mathrm{RCAS-RSAC-AVRCAS+AVRSAC}}{\mathrm{AVRSAC}}\right)^{A(153)}$$

where OUTLAY is taxes, debt service, and commodities purchases; RSAC is the current yield on savings accounts; RCAS is the current yield, if any, on cash; AVRSAC is a moving average if RSAC and AVRCAS is a moving average of RCAS.[1]

The ceiling on desired savings accounts will depend on the previous round's ceiling on OUTLAY and on the degree of advantage which open market securities have over savings accounts. This advantage will depend partly on the rates of return on savings accounts (RSAVAC) and on open market securities (R) and partly on risk and transactions costs.

The consumer evaluates

$$(2)\qquad \mathrm{ADV} = A(56) * R - A(66) - \mathrm{RSAVAC}$$

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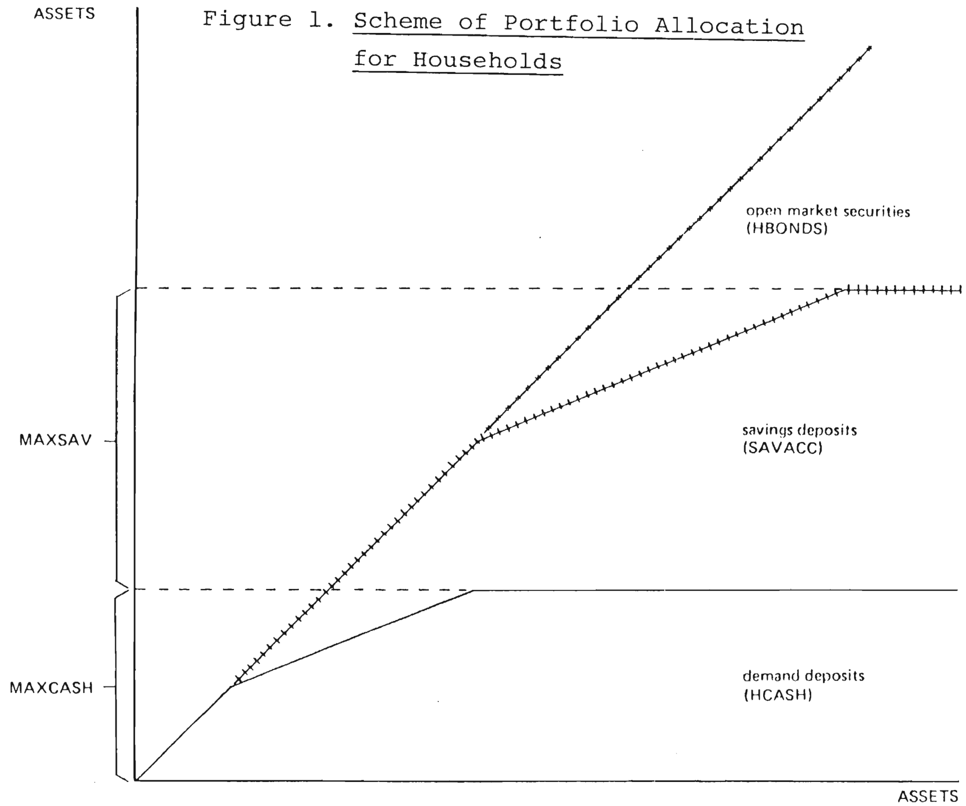
1 Moving averages are computed with geometric weights and are consistently designated with AV in this paper.

Figure 1. Scheme of Portfolio Allocation for Households



MAXCASH is a function of weekly outlays and interest rates on savings accounts.

MAXSAVE is a function of weekly outlays and interest rates on savings accounts and open market securities.

which gives the interest rate advantage of open market securities over savings accounts. The quantity 1-A(56) may be thought of as an annual risk premium for securities over savings accounts, and A(66) represents the transaction cost of entering the securities market expressed as a fraction of the price of the security. This amounts to the assumption that the transaction cost is amortized fully in the first year of ownership.

We then compute

$$(3) \qquad \text{SIGN} = \frac{\text{ADV}}{|\text{ADV}|}$$

which takes the value +1 or -1 and set

$$(4) \qquad \text{MAXSAV}_1 = \text{MAXSAV}_0 - \text{SIGN}*\text{A}(55)*\text{OUTLAY}$$

Consumers start to accumulate savings accounts when their cash is at one half of MAXCASH, and they start to accumulate open market securities when their savings accounts are one half of MAXSAV.

In the course of adjusting the composition of his portfolio, the consumer may realize some capital gains or losses, which will affect his tax liability. If bond holdings are reduced, the amount realized will depend on PBOND, the current ratio of the market to the maturity value of the average security owned by households, calculated as

$$(5) \qquad \text{PBOND} = \text{RETAVG}*\text{DISFAC} + \text{DISMAT}$$

where RETAVG is the coupon rate of the average security in the household's portfolio calculated on the assumption that the distribution among maturities and specific types of securities is uniform across households. DISFAC and DISMAT are discount factors for interest and principal, respectively, based on current securities yields, R,

$$(6) \qquad \text{DISFAC} = \frac{1 - \dfrac{1}{(1+R)^{\text{AVMAT}+1}}}{1 - \dfrac{1}{1+R}} - 1$$

(7) $$\text{DISMAT} = \frac{1}{(1+R)^{\text{AVMAT}+1}}$$

where AVMAT is the number of months to maturity for the average security in the household's portfolio.

In the decisions of individual households, open market securities are not differentiated. However, after the total stock of household securities holdings, HBONDT, is determined, we allocate it between treasury bills and bonds on the basis of the spread between the bill and bond rates, relative to the usual spread. Thus:

(8) $$\text{HBILLS} = A(201) * \text{HBONDT} * \left(1 - \frac{\text{RBIL-RBON-AVRBIL+AVRBON}}{\text{AVRBON}}\right)^{A(202)}$$

and

(9) $$\text{HBONDS} = \text{HBONDT-HBILLS}.$$

FINANCIAL ACTIVITIES OF NONFINANCIAL FIRMS

The activity of the firm during a round, and the activities of its customers, debtors, and creditors and of the government result in a change in the quantity and composition of the assets and liabilities of the firm from what they were at the start of the round:

1) Money has flowed in through sales of its product and through the receipt of interest payments on the bonds it owns: money has flowed out because of purchases of the output of other firms, because of wage, tax, and dividend payments, and because of the firm's payments of interest on its bank loans and bonded indebtedness.

2) The firm's inventory position will have changed, and it has probably enlarged its holdings of the fixed capital it uses in production.

3) New bank loans may have been taken out if the firm found itself wishing to make a transaction but without the ready cash on hand to pay.

The last action of the firm during the round is to pay off those of its obligations which are due, collect payment on obligations of others which it owns, and to adjust the composition and quantities of its assets and liabilities so as to bring itself into a "comfortable" liquidity position for the start of the next round.

The first item of business is the flotation of new long-term bond issues. The firm will wish to issue new bonds with a maturity of 15 years in an amount which is proportional to the fixed capital purchases it has made in the round. However, the firm will reduce the ratio of new bond issues to new fixed capital when there is an unusually high bond rate relative to its own history and conversely, The former takes into consideration the relative costs of the two forms of debt, while the latter represents expectations with respect to the future bond rate. The firm will float bonds in an amount

$$(10)\quad BONSEL = RFACTOR * \sum_{JFIRM} CAPBUY(JFIRM,IFIRM) * P(JFIRM)$$

where

$$(11)\quad RFACTOR = A(28) * \left(1 - \frac{RBON-RBLO-AVRBON+AVRBLO}{AVRBON}\right) A(181) * \left(1 - \frac{RBON-AVRBON}{AVRBON}\right) A(182)$$

and RBON, RBLO, AVRBON, AVRBLO are the current bond and business loan rate and their respective moving averages.

Next the firm pays off those of its long term bonds and its bank loans which have come due, BONDS(IFIRM, 1) and BLOANS(IFIRM, 1) respectively, and receives cash for a proportion of its holdings of other's obligations BBONDS(IFIRM) and BILLS(IFIRM), equal ot the share of all such obligations coming due in the current round.

The firm next makes a simultaneous decision on its desired stock of cash, DESCAS, treasury bills, DESBIL, and bonds issued by governments and other firms, DESBON, and its desired outstanding stock of indebtedness to the bank, DESBLO. With its decisions already made regarding other assets (such as real assets and consumer loan) and liabilities (such as bond issues) in the round, the firm can only change a particular one of these assets by changing another in the opposite direction or by changing its bank debt in the same direction.

The firm makes a tentative decision on each of the assets without considering the possibility of substitution among them; then it adjusts for desired substitutions. The initial demand for the assets is as function of a moving average of the firm's sales, AVSALE(IFIRM)*P(IFIRM) and of the cost of borrowing. Thus:

(12) $$DESCAS_o = A(221) * AVSALE(IFIRM) * P(IFIRM) * \left(1 - \frac{RBLO-RCAS-AVRBLO+AVRCAS}{AVRBLO}\right) A(226)$$

(13) $$DESBIL_o = A(222) * AVSALE(IFIRM) x P(IFIRM) * \left(1 - \frac{RBLO-RBIL-AVRBLO+AVRBIL}{AVRBLO}\right) A(227)$$

(14) $$DESBON_o = A(223) * AVSALE(IFIRM) * P(IFIRM) * \left(1 - \frac{RBLO-RBON-AVRBLO+AVRBON}{AVRBLO}\right) A(228)$$

Then desired substitutions among assets are computed; the necessary computations are substitutions of bills by cash (BILCAS), bonds by cash (BONCAS) and bonds by bills (BONDBIL). These substitutions are a function of the current spread between the yields on the assets, relative to the customary spread.

(15) $$BILCAS = DESCAS_o * \left[\left(1+ \frac{RCAS-BRBIL-AVRCAS+AVRBIL}{AVRBIL}\right) A(231)_{-1}\right]$$

(16) $$BONCAS = DESCAS_o * \left[\left(1+ \frac{RCAS-RBON-AVRCAS+AVRBON}{AVRBON}\right) A(232)_{-1}\right]$$

(17) $$BONBIL = DESBIL_o * \left[\left(1+ \frac{RBIL-RBON-AVRBIL+AVRBON}{AVRBON}\right) A(233)_{-1}\right]$$

The desired stocks of assets then become

(18) $$DESCAS = DESCAS_o + BILCAS + BONCAS$$

(19) $$DESBIL = DESBIL_o - BILCAS + BONBIL$$

(20) $$DESBON = DESBON_o - BONCAS - BONBIL$$

The firm is now in a position to compute the desired change in its bank loans DLOAN as the sum of the desired changes in its assets, subject to the maximum of its current line of credit

A(21)*AVSALE(IFIRM)*RATION, [1]

and subject to the restriction that only loans made during the current round BLOANS(IFIRM,12) can be paid off before they are due.

$$(21)\ \text{DLOAN} = \min \begin{cases} \text{A(21)*AVSALE(IFIRM)*RATION-ACTBLO} \\ \max \begin{cases} \text{BLOANS(IFIRM,12)} \\ \text{DESCAS-ACTCAS+DESBIL-ACTBIL} \\ \quad \text{+DESBON-ACTBON} \end{cases} \end{cases}$$

Finally the firm makes the necessary adjustments by calls to Subroutine Trans, with the effects of the constraints felt first in the cash account and then in the loans.

THE OPERATIONS OF THE BANK

Deposits and Required Reserves

The firm IBANK in the Transactions Model represents the activities of all commercial banks and all entities designated as savings institutions in the Flow of Funds accounts. All of the actors in the model, with the exception of the monetary authority but including the bank itself and the financial intermediary, keep money in the form of demand deposits at the bank. No currency is represented in the current version of the model.

Money in the form of demand deposits is created in the model whenever the bank makes a payment to an economic agent other than the monetary authority. This occurs when the bank grants a bank loan, purchases securities in the open market, or pays wages, rents or dividends in the course of running its business. Money is destroyed whenever an economic agent other than the monetary authority makes a payment to the bank.

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1 RATION is an availability factor which rises and falls with excess bank reserves. (See the discussion of the bank, below.)

Savings accounts at the bank are created or destroyed in the amounts desired by households, as explained above.

Against its deposit liabilities the bank is required to hold reserves, RESREQ, in the form of a deposit at the Federal Reserve,

(22) RESREQ = POL(21)*TCASH + POL(22)*TOTSAC,

where POL(21) and POL(22) are policy variables set by the Federal Reserve, TCASH is all demand deposits except those owned by the bank itself and TOTSAC is the sum of all of the households' savings deposits.

LOAN ACTIVITIES OF THE BANK

In the course of a round of activity of a run of the Transactions Model, the bank will be approached by households, firms and by the financial intermediary for new loans. For each customer, the bank has a rule of thumb which it uses to decide on an appropriate line of credit. The rule will depend on both the customer's and the bank's financial situation. For business firms, bank loans repayable in one lump sum 12 rounds (one quarter) later are made upon application of the firm as long as the stock of the firm's bank loans does not exceed

(23) SLOANS = A(21)*AVSALE(IFIRM)*P(IFIRM)*RATION,

where AVSALE(IFIRM) and P(IFIRM) are a moving average of sales in physical units of the firm's product, and the firm's current price for its output, respectively. RATION is a variable set by the bank in response to its reserve situation and its desire to affect the proportion of bank loans in its portfolio of assets (see below).

Consumers have a line of credit for non-installment bank loans to a total stock of

(24) A(62)*EXP*RATION,

where EXP is a moving average of a certain portion of consumer expenditures. Such a loan is amortized only when the consumer wishes to reduce his or her indebtedness. Consumers also have access to installment loans and mortgage credit from the bank on certain set occasions.

The bank's customers are programmed to make installment payments and to extinguish their loans on schedule. However, if they are unable to do so, they are not required to depart from their usual rules of behavior and the bank will refinance them.

The bank influences the amount of bank loans which are demanded by the other actors through its setting of the interest rates for the business loans it grants, RBLO.

It also constrains the supply of new loans by enlarging or contracting the size of the line of credit it considers appropriate for each actor in the model. These matters are dealt with in detail below, but the general idea is that lines of credit are contracted when the bank finds itself short of reserves and loan rates are raised when the value of loans in its portfolio is greater than allowed for its own rules of thumb, and conversely.

The Bank's Commitment to Purchase of Home Mortgages

A portion of the home mortgages in the model is purchased by the bank for its portfolio. The real estate industry will not order new housing starts without a commitment that the necessary mortgage money will be forthcoming 30 rounds into the future, when it is assumed that houses started in the current round will be ready for occupancy. These commitments will come from the bank and the financial intermediary.

The bank determines its commitment by computing its desired holdings of home mortgages 30 periods ahead. This is the sum of desired holding by commercial banks, DMORTB, and by savings institutions, DMORTS. Both demands are fractions of the current level of savings accounts for which the institutions are liable:

(25) DMORTS = (A(72)+POL(30))*TOTSAC*SAVRAT

(26) DMORTB = A(73)*TOTSAC*(1-SAVRAT)

where SAVRAT is the fraction of total savings accounts which are liabilities of savings institutions, set exogenously from the Flow of Funds accounts, and POL(30) is a policy variable representing advances by the Federal Home Loan Bank Board to savings and loan associations.

The bank's excess demand for home mortgages, XDMORB, is

(27) XDMORB = DMORTS+DMORTS-(BMORTB+CMORTB)*(1-AMORZ)

where BMORTB is the bank's current holdings of home mortgages, CMORTB its commitments to buy mortgages, and AMORZ is the proportion of the maturity value of currently held or committed home mortgages which will be amortized over the next 30 rounds.

The value of mortgages the bank acquires in the current round will depend on housing starts made 30 rounds previously, and may be less than the bank's commitment if demand for new dwelling units was not sufficient to induce holders to start as many dwelling units as could have been financed by the financial community's commitment of mortgage money at that time.

REACTION TO RESERVE REQUIREMENTS

The bank holds reserves, RESERV, soley in the form of a deposit at the Fed. Reserves are created whenever the Fed makes a payment -- which occurs in the model only through open-market operations and discounting. Reserves are destroyed whenever a payment is made to the Fed -- which occurs only through open market operations and repayment of discounts. Thus, except for discounting, the bank cannot through its own actions change the quantity of reserves which it owns. This conforms relatively closely with the conditions of the banking <u>system</u> in the United States, but not with the options open to an individual bank (which can engage in transactions which will transfer reserves from or to other banks).

At the end of each round after all of its customers for bank loans have been dealt with, the bank in the model reviews its reserve situation. The activity of the bank in granting new loans, the interest payments it has received, the repayments which its customers have made of the principal of loans which have become due, and the activity of households in increasing or decreasing their savings deposits will all affect the amount of reserves required. Actual reserves will have been affected by open market operations which have taken place since the bank's last review of the reserve situation in the previous round.

The constraints on the supply of new loans in the form of maximum lines of credit for each customer are loose enough to permit a rise in bank loans during the round sufficient to cause required reserves to rise above actual reserves. The rationale we have used here is that bank loans are the bank's most lucrative investment, and it is willing to meet a surge in demand for them in part by discounting and in part by disposing of other assets.

In the case where the bank's end-of-the-round review discloses a reserve deficiency, it must decide on a course of action which will move it towards meeting the deficiency.

The bank with deficient reserves will employ four measures in combination:

1. increasing its discounts at the monetary authority,

2. selling open market securities from its portfolio to the financial intermediary for cash,

3. planning to restrict the supply of bank loans in the next round,

4. setting the interest rate for bank loans higher.

In theory, the bank must do enough to get required reserves to be less than or equal to actual reserves by a combination of steps 1 and 2. In the real world, the banking system has some latitude and can move toward the mandated position rather than achieving it continually.

We have reflected this situation in the model by allowing the bank to employ steps 1 and 2 above to move towards meeting reserve requirements but allowing it to stop short of achieving equality of actual and desired reserves. The bank must decide what fraction of reserve deficiency will be met by discounting at the Fed. In the model, we have made the fraction depend on the Fed's discount policy and inversely on the spread between the interest rate the Fed charges for discounts, RDIS, and the current Treasury Bill rate RBIL relative to the customary spread AVRDIS-AVRBIL. New discounts are made in rounds in which reserves are deficient in the amount BORROW.

$$(28)\ \text{BORROW} = \text{POL}(28)*(\text{RESERVE}-\text{RESREQ})*\left(1 - \frac{\text{RDIS}-\text{RBIL}-\text{AVRDIS}+\text{AVRBIL}}{\text{AVRDIS}}\right)^{A(93)}$$

in which POL(28) is a policy variable representing the ease or difficulty of obtaining discounts from the Fed. The reserve deficiency remaining after the discounting will partially be taken care of by sales of open market securities by the bank to the financial intermediary for cash in the amount of the remaining reserve deficiency, which will extinguish demand deposits and reduce required reserves.

This sale will result in the financial intermediary for cash in the amount of the remaining reserve deficiency, which will extinguish demand deposits and reduce required reserves.

This sale will result in the financial intermediary's having to end the round with a larger inventory of securities and this will tend to raise the interest rate it will set for them. The bank's portfolio, as a result of this transactions will have a reduced ratio of securities to loans. Since the bank has a rule of thumb which sets desired proportions of loans and securities in its portfolio, and adjusts the business loan rate in an attempt to move towards these proportions, a reserve deficiency will result in a higher business loan rate than otherwise would have prevailed (see below).

(29) ASSETS = RESREQ+ACTBIL+ACTBON+ACTMOR+ACTBLO

Next the bank calculates its tentatively desired holdings of each of these five assets, i.e., those desired before allowing for any substitution among them:

$$(30)\quad DESRES_o = RESREQ$$

$$(31)\quad DESBIL_o = (1.-RESREQ/ASSETS-A(263)-A(264)-A(265)) * ASSETS$$

$$(32)\quad DESBON_o = A(263) * ASSETS$$

$$(33)\quad DESMOR_o = A(264) * ASSETS$$

$$(34)\quad DESBLO_o = A(265) * ASSETS$$

where RESREQ is reserves required by the monetary authority plus any desired excess reserves, before considering the possibility of substitution among the above assets.

Desired substitution between loans and each of the other assets is now computed. It depends on the current spread between the yield on loans and the yield on the other asset relative to the customary spread between those yields. Thus the desired substitution of loans by reserves, BLORES, loans by treasury bills, BLOBIL, loans by bonds. BLOBON, and loans by home mortgages, BLOMOR are calculated.

$$(35)\quad BLORES = DESRES_o * \left[\left(1+ \frac{RRES-RBLO-AVRRES+AVRBLO}{AVRBLO}\right)^{A(274)} - \right.$$

$$(36)\quad BLOBIL = DESBIL_o * \left[\left(1+ \frac{RBIL-RBLO-AVRBIL+AVRBLO}{AVRBLO}\right)^{A(277)} - \right.$$

$$(37)\quad BLOSON = DESBON_o * \left[\left(1+ \frac{RBON-RBLO-AVRBON+AVRBLO}{ABRBLO}\right)^{A(279)} - \right.$$

$$(38)\quad BLOMOR = DESMOR_o * \left[\left(1+ \frac{RMOR-RBLO-AVRMOR+AVRBLO}{AVRBLO}\right)^{A(280)} - \right.$$

The bank now determines its final desired stock of loans by adjusting the initial estimate for substitutions.

In addition to discounting and selling securities when it finds itself with deficient reserves, the bank also reduces TARION, which reduces the consumer and business loan requests that it will accommodate in the next round. RATION is permitted to vary between .9 and 1.05 and by no more than .005 per round. This change in RATION can be interpreted as a change in the non-price conditions under which consumer and business loans are made; it will put a tighter constraint on the quantity of such loans in the bank's portfolio, and, concomitantly, on the supply of money in future rounds.

We have traced through in detail the response of bank to a reserve deficiency. If the end-of-the-round review of the reserve situation reveals a reserve excess, the bank will follow a course which is the reverse of the one outlined above: it will increase RATION, reduce discounts (using equation (28)) and make purchases of open market securities equal to the reserve excess with resulting lower interest rates for bank loans and open market securities.

THE BANK'S PORTFOLIO ADJUSTMENTS, AND THE ADJUSTMENT OF BANK LOAN INTEREST RATES

The model's bank has a portfolio of financial assets consisting of

1. A reserve account at the monetary authority, whose size is controlled by open market operations of the latter and discounting activity of the bank.

2. Mortgages, whose commitments are determined as explained above.

3. Consumer installment credit. The bank will hold an exogenously determined share of total consumer installment credit outstanding, with the financial intermediary and some of the non-financial firms holding the rest.

4. Bank loan instruments, whose genesis is described above.

5. Bonds, consisting of Treasury bonds, bonds of the local governments, and bonds of all the other firms, in exogenously determined shares.

6. Treasury bills.

The bank's liabilities consist of

1. Demand, and savings deposits

2. Debt and equity instruments issued by the bank such as bonds, stocks and large certificates of deposit, all consolidated under a vector BONDS(IBANK,IMAT), where the instruments have maturities IMAT of up to 180 months into the future. In the present version of the model, the stock of the bank's own debt instruments is exogenous.

The description given so far of the banks' behavior in the present version of the model adds up to saying that the bank's major instruments for influencing the size and composition of its assets are the variables which it manipulates to control the volume of bank loans.

As explained above, the ease or stringency of the bank's credit rationing will depend on its reserve position. Changing the degree of credit rationing can be seen as a device to control both the size of the bank's asset portfolio and its composition. In addition, the bank manipulates the bank loan rate each round if the composition of its assets is out of line with its desires.

In setting the business loan rate for the next round, the bank takes as given the sum of its holdings of reserves (ACTRES), treasury bills (ACTBIL), bonds (ACTBON), home mortgages (ACTMOR) and business loans (ACTBLO). The bank also has consumer loans as earning assets which, in the current version of the model, do not enter directly into decisions with respect to the business loan rate.[1]

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[1] The symbols in this section end in RES for reserves, DIS for discounts, BIL for treasury bills, BON for bonds, MOR for home mortgages and BLO for business loans. The beginning of the symbols is ACT for actual, DES for desired, R for current interest rate and AVR for geometrically weighted moving average of past interest rates.

8344
8346

(39) DESLON = $DESLON_o$-BLORES-BLOBIL-BLOBON-BLOMOR;

and computes its excess holdings of loans as ACTBLO-DESBLO. The business loan rate is raised by A(13) if ACTBLO-DESBLO is positive, and is lowered by that amount if it is negative.

Each round the bank sets the current interest rate on consumer loans, RCONS. This is done exogenously in the current version.

Setting the Interest Rate on Savings Accounts

The bank's decisions with respect to the rate paid on savings accounts comprise a decision by the commercial bank part of the model's bank sector setting the rate, RSAVAB, on its savings accounts and a decision by the savings institutions part to set RSAVAS. The rate which is considered by households, in their portfolio decisions RSAVAC, is a weighted average of the two rates. Thus,

(40) RSAVAC = RSAVAS*SAVRAT+RSAVAB*(1-SAVRAT)

in which SAVRAT is the proportion of total savings accounts owed by savings institutions, set exogenously as indicated in the Flow of Funds accounts. RSAVAS is set at a fixed spread, A(97) below RETS, the weighted average current yield on securities held by savings institutions, subject to a maximum rate which is a percentage, A(16), of the maximum rate permitted by the Federal Reserve, POL(23):

$$(41)\ \text{RSAVAS} = \min \begin{cases} \text{A(16)*POL(23)} \\ \text{RETS-A(97)} \end{cases}$$

RSAVAB is set similarly as:

$$(42)\ \text{RSAVAB} = \min \begin{cases} \text{A(16)*POL(23)} \\ \text{RETB-A(118)} \end{cases}$$

in which RETB is the weighted average current yield on securities held by commercial bank and A(118) is the customary margin of interest received on securities over that paid on savings accounts.

THE OPERATIONS OF THE FINANCIAL INTERMEDIARY

The financial intermediary, firm IOFI in the model, is composed primarily of the insurance industry and securities brokers and dealers. In the National Accounts it corresponds to the portion of the Finance, Insurance and Real Estate industry that remains after excluding the Banking industry and the Real Estate industry.

The financial intermediary's primary function in the model is to make a market in all open market securities by announcing a yield to maturity for each type of security at the beginning of each round and purchasing all securities offered and selling all securities demanded at these yields. It also acts in behalf of all non-governmental asset holders, holding for them all of their financial claims (except deposits and bank loan instruments) collecting the flows of interest and dividend payments which accrue on them and disbursing the approporiate share to each individual asset holder represented in the model.

Portfolio

The financial intermediary holds a portfolio of assets on its own account, partly as a buffer stock in connection with its market-making activities, partly on account of its insurance function and partly as an investment.

When the orders to sell a particular debt instrument which come to the financial intermediary from the other actors in the model do not match the orders to buy, the amount of that instrument held in the portfolio of the financial intermediary expands or contracts accordingly. An undesired expansion of the amount (measured in terms of maturity value) of a particular type of financial instrument in its portfolio will cause the financial intermediary to raise the interest rate it announces in the next round for that type of instrument, while an undesired contraction will cause it to lower the interest rate.

The open market instruments in which the financial intermediary makes a market are:

1. Mortgages: HMORTG(IMAT), (IMAT)=MON, MON+299

2. Longer term federal government bonds: BONDS(IGOVF,IMAT), IMAT = 13, 180

3. Treasury bills: BLOANS(IGOVF,IMAT) and BONDS (IGOVF,IMAT), IMAT = 1, 12

4. Municipal bonds: BONDS(IGOVO,IMAT), IMAT = 1, 180

5. Private business bonds: BONDS(IFIRM,IMAT), IFIRM = 1, 12; IMAT = 1, 180

Mortgages originate in loans made by the financial intermediary to home-buying households and are held only by the bank (BMORTB), the federal government (BMORTG) and by the financial intermediary (BMORTIN). All of the other assets in the list above are potentially held by all of the actors represented in the model. The financial intermediary buys a particular type of open market security from its issuer but when it sells non-mortage assets to investors (or buys them back) it does so by selling or buying either treasury bills or "shares" in all of the other non-mortgage assets ("bonds") which are in existence (all of which are held in the "street name" of the financial intermediary in any case). When it comes time to make interest, dividend or capital gains payments to individual investors, we exogenously determine by reference to the Flow of Funds data the composition of each sector's "bonds".

The financial intermediary is assumed to desire a total portfolio of cash, bills, bonds and mortgages, DESASS, that is a linear function of (1) a geometrically weighted average, AVSALE(IOFI), of its weekly sales, evaluated at current prices, P(IOFI) and (2) the cost of borrowing, RBLO, relative to the usual cost, AVRBLO.

Thus, before considering the possibility of substitution among assets the demanded stocks are

(43) $DESASS = DESCAS_o + DESBIL_o + DESBON_o + DESMOR_o$

$$(44)\quad DESCAS_o = A(241)*AVSALE(IOFI)*P(IOFI)*\left(1-\frac{RBLO-RCAS-AVRBLO+AVRCAS}{AVRBLO}\right)^{A(246)}$$

and similarly for $DESBIL_o$, $DESBON_o$ AND $DESMOR_o$ with their returns substituted for the return on cash in (44).

Next the desired substitutions between pairs of these assets are calculated. The necessary calculations are substitutions of bills by cash, BILCAS, bonds by cash, BONCAS, HMOCAS, BONBIL, HMOBIL, and HMOBON. For example,

$$(45)\quad BILCAS = DESCAS_o*\left(1+\frac{RCAS-RBIL-AVRCAS+AVRBIL}{AVRBIL}\right)^{A(251)}-1$$

and similarly for the others, substituting the appropriate tentative desired stocks and interest rates.

The stocks of these assets desired by the financial institution for its own account are then computed as:

$$(46)\quad DESCAS = DESCAS_o+BILCAS+BONCAS+HMOCAS$$

$$(47)\quad DESBIL = DESBIL_o-BILCAS+BONBIL+HMOBIL$$

$$(48)\quad DESBON = DESBON_o-BONCAS-BONBIL-HMOBON$$

$$(49)\quad DESMOR = DESMOR_o-HMOCAS-HMOBIL-HMOBON$$

The financial institution finally adjusts the interest rates for which it is responsible as follows:

$$(50)\quad RBIL = RBIL_o \pm A(22) \text{ as } ACTBIL\ DESBIL$$

$$(51)\quad RBON = RBON_o \pm A(23) \text{ as } ACTBON\ DESBON$$

$$(52)\quad RMOR = RMOR_o \pm A(24) \text{ as } ACTMOR\ DESMOR$$

The current private business bond rate is now set at A(17)*RBON, where A(17) is an average risk premium for private business bonds over federal government bonds. The municipal bond rate, RMUNI(180) is set exogenously.

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THE OPERATIONS OF THE MONETARY AUTHORITY

Monetary and credit policy are determined in the model by the monetary authority. The policy instruments at its disposal are the following (listed in the order in which they are discussed below, rather than in the order of their importance):

(1) Required reserve ratios for savings accounts at commercial banks, POL(22) and at savings institutions, POL(30);

(2) Maximum savings account interest rate, POL(23);

(3) Down payment requirement on home purchases, POL(18);

(4) Required reserve ratio for demand desposits, POL(21);

(5) Discount rate, RDIS;

(6) Discount policy, POL(28);

(7) Open market operations.

Required Reserve Ratios for Savings Accounts

In the United States some savings accounts are liabilities of commercial banks and some of saving institutions, primarily savings and loan associations. The Federal Reserve sets the required reserve percentages for member banks while the Federal Home Loan Bank Board sets it for federal savings and loan associations. In the model all savings accounts are the liability of the single bank, and the monetary authority sets both reserve rates.

In actual practice the reserves for savings accounts held at commercial banks are required to be held in the form of a deposit at the Federal Reserve, while the reserves required of savings institutions are not.

In running the model to replicate the policies that were in fact in effect in historical periods, all savings accounts require reserves held at the monetary authority and the required ration, POL(22) is set as the 30 day deposit rate set historically by the Federal Reserve, reduced by the percentage that savings institution accounts were of commercial bank savings accounts.

(POL) is set by the monetary authority and controls the fraction of savings institution deposits invested in home mortgages, thus performing the function of Federal Home Loan Bank Board advances to savings and loan associations.

The major direct impact of raising POL(22) or POL(30) would be to leave a smaller quantity of reserves available to satisfy requirements for demand deposits, thus inducing the bank to curtail lending and investing in securities. This could have the effect of raising interest rates on loans and securities.

Maximum Savings Account Interest Rate

Currently in the United States the Federal Reserve and the Federal Home Loan Bank Board set maximum interest rates on various categories of savings accounts, including the rates permitted for savings institutions. Usually the rate permitted for savings institutions is somewhat higher than for commercial banks. In the model the monetary authority sets one maximum rate, POL(23), for all savings accounts, and this is set to approximate the average maximum permitted historically. This is a relatively powerful policy variable in periods of high interest rates in affecting the level of investment in residence. When yields on open market securities continue to rise while the rate on savings accounts is at a maximum, the model's actors shift more and more funds out of savings accounts and into open market securities. This reduces the ability of the savings institutions to commit funds for home mortgages, thus reducing housing starts.

Down Payment Requirement on Home Purchases

In the model, POL(18) is a policy variable which controls the fraction of the cost of a home which can be financed with a given quantity of funds available to the financial system. At the same time it may prevent a prospective purchaser with a given stock of assets for the down payment from acquiring a home.

Required Reserve Ratio for Demand Deposits

In the model, the monetary authority sets a uniform required reserve ratio, POL(21), for demand deposits. The setup in the model differs from the one in the U.S. economy in a number of respects:

(1) In the model, there is no currency; all money is treated as a deposit liablity of the bank, whereas in fact some money is a currency liability of the Federal Reserve and the Treasury;

(2) In the model all required reserves must be held as a deposit at the monetary authority, whereas vault cash is counted in the real world;

(3) In the model no distinction is made among banks in their reserve requirements, since we have only one bank, whereas the Federal Reserve actually has smaller percentage requirements for smaller banks.

In correcting for these simplicities of the model, the "historic" values of POL(21) are set each quarter by taking actual bank reserves reported by the Flow of Funds accounts, TF(IQQ,31) adjusted by a parameter A(95) fitted to take care of estimated excess reserves desired by the banking system, less the quantity of reserves required for actual savings accounts. POL(22)* TF(IQQ,9,2). This is divided by the actual stock of money (M1) reported in the Flow of Funds accounts, with minor adjustments for other Federal Reserve liabilities.

The Discount Rate and Discount Policy

In attempting to simulate the historical past, the discount rate which prevailed in the real world was used in the model. However, for simulations of alternative policies it is more reasonable to have the discount rate determined as nearly as possible in response to the behavior of variables on which the Federal Reserve actually sets it.

Thus, in the model the monetary authority monthly sets the rate charged on loans of reserves to the bank, RDIS, as a lagged adjustment to a moving average of the treasury bill rate, ARVBIL, subject to a maximum POL(29):

(53) $RDIS = RDIS_o - A(120)$, if $RDIS_o > AVRBIL+POL(27)$

(54) $RDIS_o = \min \begin{cases} RDIS_o + A(120), \text{ if } RDIS_o < AVRBIL \\ POL(29) \end{cases}$

(55) $RDIS = RDIS_o$, otherwise.

The extent of discounting in the model is influenced not only by the relation between the treasury bill rate and the discount rate, but also by discount policy with respect to the ease or difficulty of obtaining funds from the Federal Reserve. In the model this policy is represented by POL(28) which governs the maximum fraction of the bank's reserve deficiency which can be covered by discounting.

A higher discount rate and/or a lower POL(28) will reduce the quantity of reserves borrowed to meet at reserve deficiency. This, in turn, will reduce the bank's loans and investments, which will lead to a rise in interest rates on bank loans and open market securities.

Open Market Operations

The heart of the short run operation of monetary policy in the model, as in the real world, is open market operations. These are conducted in each round by the monetary authority after all sectors have completed their transactions on goods and services markets and after all sectors except the bank have fully adjusted their portfolios for the round. The Federal Reserve computes the reserves which it desires for the bank to have DRESER and engages in open market operations. BUY, to bring actual reserves, RESERV, to the desired quantity.

The Federal Reserve can formulate its desired reserves in three different manners in the model, depending on the purpose for which the model is being used. The simplest formulation is for the Federal Reserve to set DRESER at the level which prevailed in the real world:

(56) DRESER = TF(IQQ,3,1)*SSCALE

in which SSCALE is the scale factor for stocks in the model. This formulation of DRESER, representing a fully exogenous monetary authority, is appropriate for fitting parameters of the model and to some extent for computing "ceteris paribus" multipliers.

An alternative decision on DRESER is also useful primarily in calibrating the model. This formulation initially equates DRESER with the quantity of reserves required by the bank in the model, RESREQ. DRESER is increased if the simulated values of the narrowly defined money supply, M1, and the broadly defined money supply, M2, are lower than the actual values or if the simulated value of the treasury bill rate is lower than the actual value.

A third, more fully endogenous, method of setting the level of desired reserves is for the Federal Reserve to establish each fourth round (monthly) the desired annual rate of growth of reserves, POL(25). This is determined as its previous rate adjusted for the change in prices and unemployment during the previous four rounds. Specifically,

(57) $$\text{DRESER} = \text{POL}(24)^{1/48} * \text{DRESER}_o, \text{ where}$$

(58) $$\text{POL}(24) = \text{POL}(24)_o * 1 - \left(\frac{\text{PINDEX-PINDEL}}{\text{PINDEL}}\right) \text{POL}(25) * \left(1 + \frac{\text{URATE-URATEL}}{\text{URATEL}}\right) \text{POL}(26)$$

where PINDEX, and PINCEL are the GNP deflators of the current and fourth previous rounds, respectively, and URATE and URATEL are the civilian unemployment rates for the current and fourth previous rounds, respectively.

MODELING ALTERNATIVE MONETARY POLICIES

The financial aspects of the Transactions Model which are described above give a rich assortment of realistic avenues through which actions of the monetary authority affect the economy. We would, of course, be receptive to suggestions for including response paths which have been excluded, improving those which are modeled inadequately, and eliminating those which are erroneous or otiose.

The process of modeling alternative policies is relatively inexpensive with the Transactions Model, both in terms of computer time and the programmers time. To simulate one year of calendar time requires approximately ten minutes of computer time on our UNIVAC 1108 at the University of Maryland. Many financial policies are represented by one variable (for instance the discount or required reserve rate) which can be changed quite simply. It is also relatively easy to add some new instruments by revising the program appropriately.

An expecially advantageous feature of the Transactions Model is the rich detail of the data which can be made available in measuring responses to policy. At any point in any round we can take a reading on any of the micro or macro variables. This is especially useful in identifying the avenues of responses and in measuring the lags in responses, which are so important for monetary policy.

Table 1. Symbols Used in this Paper

I. Financial Assets

CAS = Cash
RES = Bank Reserves
BIL = Treasury Bills
BON = Treasury, Other Government and Private Bonds
HMO = Home Mortgages
BLO = Business Loans
CLO = Consumer Loans
SAC = Savings Accounts and Time Deposits other than large denomination CD's.

II. Interest Rates

RCAS = Yield, if any, on cash
RRES = Yield, if any, on bank reserves
RBIL = Treasury Bill Rate
RBON = U.S. Government Bond Rate
RMOR = Home Mortgage Rate
RBLO = Business Bank Loan Rate
RCLO - Consumer Loan Rate
RSAC = Rate paid on Savings Accounts and Time Deposits
RDIS = Discount Rate.

III. Sectors (used as subscripts)

IREAL= Real Estate Rental Firm
IOFI = Non-Bank Finance and Insurance
IBANK = Banking, including Savings Institutions
IGOVF = Federal Government
IGOVO = Other Governments
IROW = Rest of World
IFED = Federal Reserve.

Appendix

PERFORMANCE OF THE TRANSACTIONS MODEL: 1973–1975

Barbara R. Bergmann and Robert L. Bennett

The parameters of the Model are set so as to minimize the square root of the sum of squared percentage errors (hereafter the standard percentage error or SPE) during the 1973-75 period. This period witnessed very large fluctuations in most of the macroeconomic variables that are of interest, and turning points for some of them, and tracking the relevant variables during such a period is more stringent a test than during a period in which there were either small or monotonic changes. The procedure for setting the parameters was to run the Model for the entire period after setting up the initial conditions, and to make no mid-course corrections. Thus, the Model's errors in a particular quarter incorporate the cumulative effects of simulation errors in previous quarters. Most of the data which we used for tracking were available only quarterly: to track flow variables we cumulated the simulated data over the quarters and for stock variables we used the end-of-period figures. Several variables were available monthly, and for some of these - particularly interest rates - we tracked the monthly series.

The National Accounts

Table 1 shows the simulated and actual values for the gross national product and its major components. The mean values of the simulated and actual GNP series for government expenditures in Table 1 includes net exports. Both government expenditures and net exports are set exogenously in the real values and the errors noted in Table 1 result largely from errors in the price series. For personal consumption expenditures the mean value of the simulated series is a little low, while the SPE is a respectable 1.6 %.

Fixed investment is simulated quite closely to the actual series, with the mean values almost identical and a SPE of 2 %. The two components of fixed investment - investment in plant and equipment and investment in residences - had somewhat greater variance. Residential investment's simulated mean was 5 % below the actual mean and the SPE was 8.4 %.

TABLE 1. GROSS NATIONAL PRODUCT (BILLION OF DOLLARS AT ANNUAL RATE)

	GNP		PCE		CH INVY		FIX INVT		GOV EXP		GNP DFF	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	1280	1265	800	787	12	12	202	199	267	267	104	103
73 2	1312	1288	814	801	22	15	206	203	271	269	106	105
73 3	1332	1317	824	818	20	15	206	205	282	279	109	107
73 4	1344	1355	834	833	10	29	205	202	295	290	111	109
74 1	1375	1373	852	853	8	13	205	204	309	303	113	112
74 2	1396	1399	876	879	11	13	204	206	306	302	116	115
74 3	1427	1432	895	907	18	7	202	206	313	311	118	118
74 4	1428	1449	894	911	12	10	199	202	324	327	120	122
75 1	1460	1446	931	933	-6	-22	197	195	338	341	123	125
75 2	1531	1482	969	960	5	-30	195	194	361	358	125	126
75 3	1560	1549	975	987	17	-2	196	199	372	365	127	128
75 4	1550	1588	972	1012	9	-4	194	206	376	375	129	130
MEAN	1416	1412	886	890	11	5	201	202	318	316	117	117
SE (PCT)	.0151		.0156		2.9741		.0207		.0118		.0120	

TABLE 2. NATIONAL INCOME (BILLION OF DOLLARS AT ANNUAL RATE)

	NAT INC		COMP EMP		RENT		PROP INC		CORP PRO		NET INT	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	1058	1027	769	771	24	22	107	86	114	101	44	47
73 2	1069	1048	786	790	24	21	103	91	109	98	47	47
73 3	1091	1070	810	807	22	21	102	95	104	98	54	49
73 4	1101	1099	829	828	19	22	98	98	99	99	55	51
74 1	1104	1110	854	846	18	21	87	91	90	96	56	55
74 2	1114	1122	875	867	17	21	81	85	84	88	57	62
74 3	1118	1145	893	890	17	21	78	86	71	82	60	66
74 4	1128	1152	904	902	16	21	78	86	67	74	62	69
75 1	1176	1145	920	904	18	22	96	81	78	69	65	69
75 2	1250	1178	941	913	20	22	113	87	107	87	67	70
75 3	1265	1229	956	935	21	22	105	95	114	105	69	70
75 4	1255	1260	966	963	19	23	96	97	103	105	71	72
MEAN	1144	1132	875	868	20	22	95	90	95	92	59	61
SE (PCT)	.0260		.0129		.1508		.1410		.1093		.0656	

TABLE 3. PERSONAL INCOME AND OUTLAY (BILLIONS OF DOLLARS AT ANNUAL RATE)

	PERS INC		PERS TAX		DIS PER INC		PCE		PERS INT		PER SAVE	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	1028	1012	146	145	882	867	800	787	21	19	61	60
73 2	1054	1038	151	147	904	891	814	801	21	20	68	70
73 3	1080	1064	155	153	925	912	824	818	21	21	81	73
73 4	1097	1095	157	158	940	938	834	833	21	21	86	83
74 1	1108	1110	158	161	950	948	852	853	20	21	78	74
74 2	1133	1137	161	167	973	969	876	879	20	22	77	69
74 3	1156	1173	164	174	992	998	895	907	20	23	77	69
74 4	1174	1194	165	178	1009	1016	894	911	20	23	95	82
75 1	1223	1203	170	179	1053	1024	931	933	20	22	102	68
75 2	1278	1230	145	142	1133	1088	969	960	20	22	144	106
75 3	1284	1265	184	174	1100	1091	975	987	20	23	104	81
75 4	1286	1300	183	180	1103	1120	972	1012	20	23	111	85
MEAN	1158	1152	162	163	997	988	886	890	20	22	90	77
SE (PCT)	.0167		.0385		.0174		.0156		.0952		.2277	

Investment in plant and Equipment, on the other hand, had an error of the mean of only 1.5 % and a SPE of 2.6 %.

Most of the variance in GNP is explained by errors in tracking changes in inventories. The pattern of changes in inventory is reasonably accurate - the turning points are tracked rather well. But the magnitudes of the swings are somewhat erratic - indicating an area for improvement of the Model in the future.

On the income side of the national accounts (Table 2), the Model does very well in tracking compensation of employees and reasonably well in tracking net interest, but in tracking the other property income series there is considerable room for improvement. Some of the errors in the property income accounts may result from the Model's failure to depict the business practice of shifting income among periods for tax purposes in the way in which this is done in reality.

This weakness carries over from the business income series to the personal income series shown in Table 3. The errors in the pattern of personal income and personal taxes probably result in large part from the faulty pattern of property income and again may be exacerbated by the failure of the Model's individuals to shift incomes among time periods. Even with this problem of timing income receipts and, hence, tax payments, the series shown in Table 3 for the household sector are evidence of reasonably good tracking - particularly prior to 1975. The series on personal saving has a distressingly large SPE of 23 %, and one can see that the bulk of this error occurs in 1975. Obviously this is an area in which improvement needs to be made.

Prices

The last two columns of Table 1 show the Model's performance with respect to the GNP deflator - an identical mean and a standard percentage error of 1.2 %. In simulating price behavior it seemed best to try to track individual industry prices rather than the GNP deflator, even at the sacrifice of larger SPE for the latter. Summary statistics for the Model's performance in tracking industry prices are presented in Table 4. Farm and automobile prices are set exogenously in our Model, but in counterfactual runs we adjust the exogenous values to reflect divergences between the simulated and actual GNP deflator. A major problem was posed by

TABLE 4

Prices by Industry in the Period 1973-75 (1967 = 100)

Industry	Simulated Mean	Actual Mean	Standard Percentage Error
Agriculture, Forestry and Fisheries (exogenous)	-	-	-
Mining (exogenous after 1973.III)	190	190	.015
Construction	206	203	.026
Automobile	-	-	-
Other Durable Manufacturing	136	137	.024
Non-durable Manufacturing	126	127	.024
Transportation and Utilities	133	133	.019
Wholesale and Retail Trade	148	146	.022
Services, n.e.c.	154	153	.008
Real Estate	135	137	.019
Banking	135	137	.037
Other Finance	136	137	.022

the substantial change in oil prices beginning toward the end of 1973. The brunt of the impact was on our "mining industry" and we have set that industry's price exogenously after 1973. For the other industries simulated means are within 2 % of the actual and standard percentage errors are under 3 %, except for the banking industry's 3.7 %.

Unemployment Rates

Table 5 shows the Model's performance with respect to unemployment rates for the civilian labor and each of our four occupations. These rates are, of course, computed as the difference between simulated employment and simulated labor force, and a small error in either produces a relatively large error in their difference. However, the civilian unemployment rate's simulated and actual means are almost identical and the standard percentage error is 7.6 %. As one would expect, there is somewhat less accuracy in tracking the unemployment rates of the different occupations, but the SPE is large (17 %) only for the craft workers. This large error for craft workers is due to the larger fraction of that occupation which is subject to dismissal or hiring as production is varied - a fraction which varies from .9 for craft workers to zero for professional, managerial and technical workers, with sales and clerical workers at .2 and laborers at .4.

Interest Rates

The Model's performance with respect to major interest rates is shown in Table 6. One can see at a glance that tracking is much better for the long-term (bond and mortgage) rates than for the short-term (treasury bill and bank loan) rates. Each of these interest rates is changed each round in proportion to the excess stock of the respective asset held by the institution which sets the rate - the bank in the case of the bank loan rate and the financial intermediary for the others. (Some idea of the variations in these excess stocks can be seen in Tables 11 and 12, below.) A major reason for the large errors in the short-term rates may be our smoothing the exogenous series on bank reserves on which our Federal Reserve's policy is based. The basic data on member bank reserves is monthly and we have converted this into a synthetic series which spreads the between-month changes evenly over rounds - with the end of month stocks coinciding with those of the basic data. This procedure is probably superior to using the unrefined data, but

TABLE 5

UNEMPLOYMENT RATES (PERCENT)

	CIVILIAN		PROFESS		CLERICAL		CRAFT		LABORER		HOURS	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	4.9	4.9	2.5	2.5	4.6	4.6	5.4	5.5	6.6	6.5	1.0	1.0
73 2	4.9	4.9	2.5	2.6	4.6	4.6	5.4	5.4	6.6	6.4	1.0	1.0
73 3	4.8	4.8	2.5	2.4	4.8	4.6	5.2	5.5	6.3	6.3	1.0	1.0
73 4	5.2	4.8	2.5	2.5	4.7	4.4	6.2	5.5	6.7	6.4	1.0	1.0
74 1	5.7	5.0	2.5	2.5	5.1	4.7	7.5	5.9	6.9	6.5	1.0	1.0
74 2	5.8	5.1	2.5	2.5	5.0	4.6	7.8	5.9	7.3	6.8	1.0	1.0
74 3	5.7	5.6	2.7	2.7	5.9	5.1	5.6	6.7	8.3	7.3	1.0	1.0
74 4	6.3	6.7	3.0	3.2	6.2	5.7	6.8	8.8	8.7	8.1	1.0	1.0
75 1	7.5	8.1	3.4	3.8	6.6	6.7	9.7	11.2	9.2	9.6	1.0	1.0
75 2	7.9	8.7	3.4	3.9	7.0	7.1	10.4	12.5	9.6	10.1	1.0	1.0
75 3	7.9	8.6	3.5	3.9	7.0	6.9	10.2	12.0	10.1	10.2	1.0	1.0
75 4	8.2	8.5	3.5	4.0	7.2	7.1	10.3	11.2	10.7	10.5	1.0	1.0
MEAN	6.2	6.3	2.9	3.0	5.7	5.5	7.6	8.0	8.1	7.9	1.0	1.0
SE (PCT)	.0760		.0719		.0638		.1672		.0572		.0270	

TABLE 6

INTEREST RATES (PERCENT)

	GOV BOND		MORTGAGE		TREAS BILL		BUS LOAN	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	6.0	6.2	8.8	8.7	5.6	6.1	8.5	8.8
73 2	6.2	6.3	9.2	9.0	6.5	7.2	9.5	10.5
73 3	6.4	6.4	9.7	10.4	7.5	8.5	11.6	13.8
73 4	6.7	6.4	10.4	10.0	8.5	7.4	13.5	13.6
74 1	6.9	6.8	11.5	9.9	9.2	8.0	14.8	12.4
74 2	7.1	7.0	11.9	10.8	8.6	8.1	14.5	16.2
74 3	7.0	7.3	11.6	11.8	7.8	8.4	12.9	16.8
74 4	6.9	6.8	10.9	10.8	7.9	7.2	11.9	14.7
75 1	6.9	6.7	11.0	9.9	7.4	5.5	10.5	11.1
75 2	6.7	6.9	10.8	10.3	6.4	5.2	9.2	9.9
75 3	6.5	7.3	10.7	11.1	6.3	6.4	8.7	11.0
75 4	6.4	7.2	10.7	10.6	6.0	5.5	8.5	10.2
MEAN	6.6	6.8	10.6	10.3	7.3	6.9	11.2	12.4
SE (PCT)	.0497		.0728		.1491		.1451	

is ineffective in capturing the weekly variations in actual bank reserves and, hence, the large short-run fluctuations in the treasury bill and bank loan rates.

The only really large and persistent discrepancy between simulated and actual interest rates occurs for the treasury bill rate during the first part of 1973 - the simulated values are substantially below the actual series even though they coincide at the start of the run. A search for the cause of this discrepancy has as yet been unsuccessfull, except to point to some problem in the initial conditions.

Stocks of Assets and Liabilities

Selected balance sheet information for the household sector is presented in Table 7. This sector's cash, savings accounts and mortgage debt are tracked closely, but bonds, bills and loans are quite wide of the mark. The bond and bill holdings of consumers are in a sense residual accounts which feel the effect of most of the errors in the Model's savings function and the functions which allocate those savings among assets and liabilities. In brief, the households allocate their current receipts after all spending for debt repayments and commodities acquisition among cash, savings accounts, treasury bills and bonds. The demands for cash and savings accounts are fractions of usual spending adjusted for interest rates. Any surplus of a household's funds over desired cash and savings accounts is automatically invested in bonds and bills in proportions affected by relative interest rates. The large and systematic errors in the loan account are evidence of the necessity of more work on this part of the Model, based on the incorporation of data on the initial distribution among households of various types of assets. The error in consumer debt is rather a serious matter since it affects consumer expenditures in an important way, and hence employment. This is another area in which structural improvements in the Model are called for.

Table 8, selected accounts from the consolidated balance sheet of the ten nonfinancial firms, indicates that the Model performs quite well in tracking their major financial assets and liabilities. Bond liabilities, which depend largely on investment and interest rates, show simulated and actual means quite close and the SPE is a respectable .9 %. The error in nonfinancial firm holdings of consumer debt is determined by errors in consumer debt issues that were discussed above. Bank loans, which are governed by interest rates and firms' demand for

TABLE 7

HOUSEHOLD BALANCE SHEET
(END OF PERIOD FIGURES IN BILLIONS OF DOLLARS)

	CASH		SAVACC		BONDS		HILLS		LOANS		MORTG	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	158	150	603	591	209	229	14	13	236	224	340	338
73 2	159	156	612	610	215	236	19	14	233	234	350	350
73 3	160	156	627	623	224	245	23	17	230	238	363	363
73 4	162	170	639	636	232	248	28	18	226	247	374	372
74 1	164	162	651	657	244	248	32	24	225	242	377	378
74 2	167	168	664	673	261	252	30	24	226	248	379	389
74 3	170	166	678	680	278	265	27	26	228	251	385	397
74 4	172	179	693	695	286	267	29	24	223	256	395	403
75 1	175	165	712	725	300	272	27	20	225	250	405	409
75 2	182	181	742	748	314	274	23	18	230	255	415	418
75 3	184	180	759	765	332	284	24	21	230	257	424	429
75 4	184	187	771	787	356	293	24	19	227	266	434	439
MEAN	170	168	679	682	271	259	25	20	228	247	387	390
SE (PCT)	.0327		.0116		.1091		.2992		.0918		.0143	

TABLE 8

NONFINANCIAL FIRMS BALANCE SHEET
(ENDS OF PERIOD FIGURES IN BILLIONS OF DOLLARS)

	CASH		CON CRED		BILLS		BONDS A		LOANS		BONDS L	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	51	54	36	34	2	3	171	175	149	158	512	510
73 2	52	54	35	35	2	3	178	182	155	168	526	519
73 3	51	54	34	35	2	2	182	185	157	174	539	534
73 4	51	55	35	39	2	2	187	189	162	180	554	549
74 1	52	54	34	37	2	-1	197	204	168	187	568	568
74 2	54	53	35	38	2	-1	205	213	176	201	582	582
74 3	56	53	35	39	2	-1	214	215	183	205	596	601
74 4	56	56	36	41	2	2	218	223	184	210	610	618
75 1	58	55	36	41	2	3	226	228	186	201	623	632
75 2	62	54	37	41	2	5	239	233	200	199	636	635
75 3	63	55	37	41	2	3	246	233	206	196	649	643
75 4	62	58	38	44	2	3	251	243	208	197	661	658
MEAN	56	55	36	39	2	2	209	210	178	190	588	587
SE (PCT)	.0756		.0938		1.5252		.0280		.0878		.0087	

financial assets, track less well than bonds, but the difference in the means is only 6.3 % and the SPE is 8.8 %. For nonfinancial firms the bank loans and bond asset accounts share all of the errors in the flow of funds associated with nonfinancial businesses - dividend payouts too small, bond issue too large, profits too large, and cash or bond demand too small, etc. This is because a firm with excess cash uses it to bring current borrowing to zero, after which the remainder is invested in bonds. Thus, the SPE's of bank loans and bond holdings are evidence that the cumulated errors associated with nonfinancial firms are moderate.

Tables 9 and 10 give actual and simulated balance sheets of the federal and other governments, respectively. Most of the government accounts are exogenous in the Model. However, government expenditures have been set exogenously in the real values, so errors in prices and government wages result in simulated values of some government series different than those of the real world. Similarly the errors of various tax payments result in errors in government receipts. In the case of the federal government all of these errors affect the quantity of its bond and treasury bill issues. The errors in those series are seen to be moderate, and to indicate that the Model's federal government receipts are somewhat small and/or its expenditures are somewhat large compared with the real world. All of the errors of the state and local government's transactions cumulate in its bond issues, and they are seen to be somewhat low - indicating that its receipts are too high and/or its expenditures too low.

Selected series from the bank's balans sheet are shown in Table 11. The bank's stocks of financial assets and liabilities can be divided conveniently into the following three types depending on the source of errors in the simulated series: (1) series which depend for their errors largely on the errors in one equation for some sector other than the bank, (2) series whose errors depend largely on the errors in one equation for the bank, and (3) series whose errors compound those of several other series. Each of these types will be discussed in turn.

There are three bank series whose errors are largely those of one equation for another sector: (1) reserves, (2) consumer credit, and (3) savings accounts. Bank reserves are set at their exogenous level, subject to the constraint that excess or deficient reserves may be no more than 5 % of required reserves. This constraint explains the relatively small error in this series. The error in the bank's

TABLE 9

FEDERAL GOVERNMENT BALANCE SHEET
(END OF PERIOD FIGURES IN BILLIONS OF DOLLARS)

	CASH		BONDS A		MORTG		BILLS L		BONDS L	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	15	15	101	101	29	29	145	146	263	264
73 2	15	15	102	102	30	30	139	139	271	271
73 3	10	10	111	111	32	32	141	141	276	276
73 4	13	13	116	116	34	34	152	153	277	277
74 1	11	11	120	120	36	36	160	160	276	275
74 2	12	12	120	120	39	39	157	155	286	281
74 3	11	11	132	132	42	42	160	155	303	294
74 4	8	8	140	140	45	45	170	164	312	302
75 1	8	8	138	138	48	48	175	171	320	313
75 2	9	9	130	130	51	51	183	179	330	323
75 3	11	11	135	135	55	55	181	179	353	350
75 4	11	11	140	140	59	59	179	179	379	380
MEAN	11	11	124	124	42	42	162	160	304	300
SE (PCT)	.0000		.0000		.0000		.0178		.0169	

TABLE 10

LOCAL GOVERNMENT BALANCE SHEET
(END OF PERIOD FIGURES IN BILLIONS OF DOLLARS)

	CASH		BILLS		BONDS A		BONDS L					
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT				
73 1	14	13	18	18	107	107	168	173	124	131	41	41
73 2	15	14	16	16	110	110	166	176	127	126	40	40
73 3	13	13	17	17	113	113	166	180	130	129	40	40
73 4	15	15	17	17	117	117	170	184	133	131	40	40
74 1	13	13	19	19	119	119	173	188	137	135	42	42
74 2	15	15	15	15	125	125	177	194	140	139	43	43
74 3	13	13	16	16	128	128	178	198	143	143	44	44
74 4	15	15	15	15	134	134	187	202	146	146	46	46
75 1	13	13	18	18	134	134	191	205	149	150	50	50
75 2	15	15	17	17	136	136	195	210	152	153	53	53
75 3	13	13	17	17	138	138	197	214	154	156	57	57
75 4	15	15	17	17	145	145	207	217	157	158	58	58
MEAN	14	14	17	17	125	125	181	195	141	141	46	46
SE (PCT)	.0303		.0000		.0000		.0730		.0177		.0000	

consumer loans is due entirely to the error in the tracking of consumer loans by households discussed earlier. (The aggregate consumer loan issues are divided among the various sectors of the Model in exogenously determined proportions.) Since the bank supplies all savings accounts demanded by households at the rate of return determined by the bank, the error in this series, which is quite small, depends on that demand equation which, in turn depends on the equation setting the rate of return. The simulated mean for savings accounts is .4 % smaller than the actual mean and the SPE is only 1.2 %.

Three of the bank's series depend largely on one of the bank's equations: (1) bond assets, (2) mortgage assets, and (3) other liabilities. The mortgage series is simulated very well - the simulated mean is quite close to the actual mean and the SPE is only 1.2 %. The bank's bond liabilities are not simulated very well - the simulated mean is 8.3 % below the actual and the SPE is 10.4 %. This large error is due primarily to our including a diverse group of short-term bank obligations like bankers' acceptances and large negotiable certificates of deposit in this series. We then simulate the bank's other liabilities issues as depending on its investment and relative interest rates in the same manner as for other firms' bond issues. This procedure obviously can and should be improved. The bank's bond asset track rather well with the mean 1.4 % too low and and an SPE of 3.4 %.

Three of the bank's series cumulate errors from several sources: (1) bank loans, (2) treasury bill holdings, and (3) demand deposit liabilities. Bank loans are in a sense a residual account for the businesses. The firms' transactions during a round leave them with cash and other financial asset positions which are adjusted to the desired level through borrowing, or repaying bank loans. Thus, while the error of the mean and SPE for this series are large compared to most others, they are not surprisingly large. The bank's holdings of treasury bills are in a sense a residual account for the bank. All of its transactions during a round affect the relation of the bank's reserve holdings to those required. When all of the bank's transactions are completed for the round, it invests any excess reserves in treasury bills or sells treasury bills to meet reserve deficiencies. Thus, it is not surprising to see the very large SPE in this account. Finally, the demand deposit liabilities of the bank are affected by every transaction in which the bank engages. Money is created whenever the bank makes a payment to someone other than the Federal Reserve in the Model, and is destroyed whenever a payment is made to the bank by someone other than the Federal Reserve. (Transactions between the bank and Federal Reserve create and destroy reserves, not money.) The very small error in the mean and the small SPE of this money series indicate that the process of money creation and destruction in the Model works quite well.

Table 12 is a presentation of the financial assets and liabilities of the financial intermediary. It controls three of its accounts to some extent (cash, bank loans, and bond liabilities), but since it acts as dealer for treasury bills, bonds and mortgages, the other sectors control the financial intermediary's holdings of these assets. The financial intermediary issues its bonds on the same basis as nonfinancial firms and this series is tracked fairly well in the Model. The same is true for the cash account, which is moved to the desired level each round by paying off bank loans to the extent that such loans are outstanding. Thus the bank loans account (and the cash account if there are no bank loans) is a residual account for the financial intermediary which has a relatively large error because it catches all of the errors in the other accounts.

One can see from Table 12 that the errors of the means and SPE's for the financial intermediary's holdings of bills, bonds and mortgages are rather large. This is due to the accumulation in these simulated accounts of all errors in issues of these financial assets as well as errors in other firms' and individuals' demands for them. For bonds the errors appear more moderate than for the others, but this is due to the fact that the financial intermediary's desired holdings (approximately equal to the actual series) are large relative to the outstanding stock of bonds while the same is not true for the bills and mortgages.

TABLE 11

BANK ASSETS (END OF PERIOD FIGURES IN BILLIONS OF DOLLARS)

	RESERV		CON CRED		LOANS		BILLS		BONDS		MORTG	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	32	32	127	120	203	205	22	32	368	361	274	269
73 2	32	32	127	126	215	221	5	31	352	370	285	280
73 3	34	34	126	130	217	227	3	28	355	376	294	290
73 4	35	35	123	134	223	240	7	32	366	384	299	297
74 1	35	35	122	131	219	243	21	33	387	402	301	302
74 2	37	36	122	134	207	266	29	27	403	414	310	310
74 3	37	37	123	135	210	268	33	26	418	417	318	316
74 4	36	37	119	137	212	278	34	31	425	428	323	319
75 1	35	35	119	133	213	265	57	34	462	443	317	321
75 2	35	35	122	135	229	266	50	41	472	461	328	328
75 3	35	35	121	135	236	259	46	41	473	476	334	336
75 4	35	35	119	140	240	267	48	42	480	495	336	344
MEAN	35	35	122	132	219	250	30	33	413	419	310	309
SE (PCT)	.0112		.0925		.1432		.4974		.0336		.0124	

BANK LIABILITIES

	MONEY		SAV ACCT		BONDS		DISCOUNTS	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	262	256	603	591	151	161	2	2
73 2	265	265	612	610	157	169	2	2
73 3	259	259	627	623	163	188	5	5
73 4	268	283	639	636	169	188	1	1
74 1	268	270	651	657	176	203	2	2
74 2	276	278	664	673	183	216	3	3
74 3	293	274	678	680	190	229	5	5
74 4	287	292	693	695	197	224	0	0
75 1	295	273	712	725	203	222	1	1
75 2	321	291	742	748	210	214	1	1
75 3	312	291	759	765	218	220	1	1
75 4	305	305	771	787	225	217	0	0
MEAN	284	278	679	682	187	204	2	2
SE (PCT)	.0507		.0116		.1043		.0000	

TABLE 12

FINANCIAL INTERMEDIARY BALANCE SHEET
(END OF PERIOD FIGURES IN BILLIONS OF DOLLARS)

	CASH		BILLS		BONDS A		MORTG		LOANS		BONDS L	
	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT	SIM	ACT
73 1	16	17	11	3	280	283	37	39	38	31	133	133
73 2	16	18	11	3	295	289	34	40	41	33	135	136
73 3	16	18	11	3	300	294	37	41	41	34	137	139
73 4	16	19	11	3	302	301	40	41	40	38	139	144
74 1	16	19	7	3	292	307	40	41	28	34	141	145
74 2	17	19	0	3	282	313	30	41	5	38	143	146
74 3	32	19	3	3	266	321	25	40	0	36	145	147
74 4	23	22	7	3	277	330	27	40	0	39	147	150
75 1	29	21	0	3	272	338	40	40	0	37	148	152
75 2	41	21	3	4	269	343	35	39	0	38	150	156
75 3	30	20	4	4	285	349	34	37	0	34	152	158
75 4	20	21	0	4	302	359	38	36	0	38	154	163
MEAN	23	19	6	3	285	319	35	40	16	36	144	147
SE (PCT)	.3941		1.7093		.1329		.1766		.7605		.0287	

THE URBAN INSTITUTE – YALE MODEL

HYPOTHESIS FORMATION, TESTING AND ESTIMATION FOR MICROANALYTICAL MODELING

Guy H. Orcutt

1. THE SCIENTIFIC METHOD - A STRATEGY FOR LEARNING FROM EXPERIENCE

Fundamental Operations

The hope behind the scientific method considered as a strategy for learning from experience is that it is possible to do so. Acceptance of experience as a guide to the unknown is the prime element of this strategy and is reflected in the three fundamental operations which characterize it. They are:

(1) accumulation of experience,

(2) hypotheses making and

(3) testing or confrontation of hypotheses by experience.

Pursuit of Generality

As the number of accepted and rejected hypotheses increases, man is faced with a difficult problem of handling the store of knowledge. The problem of retaining and of finding appropriate parts of the knowledge when needed could be reduced by constructing a sort of well-indexed cookbook. However, the cookbook would soon run to hundreds of volumes, and it would frequently be necessary to scan many volumes to find what was relevant in particular situations. In order to avoid these difficulties, as well as for other reasons, considerable importance is attached to the discovery of a small number of hypotheses of broad generality which by their mutual application will yield as special cases the whole or at least substantial parts of the enormous body of specific hypotheses.

Now if the invented hypotheses of broad generality should turn out to yield as special cases of their mutual application accepted specific hypotheses, and no more, then this operation could be looked upon as of great practical importance but only dealing with the organization of existing knowledge.

However, there is more to it than this, for it is almost inevitably found that the mutual application of a set of hypotheses of broad generality will yield many specific hypotheses that have not been tested and perhaps have not been imagined. This process of seeking hypotheses of broad generality which are meant to be applied in combination with each other, is thus seen to be of importance, not only in systematizing our knowledge, but also in driving a science ahead by the generation of new hypotheses. These new hypotheses often demand testing. This testing, in turn, often requires and leads to the enlargement of experience in new directions.

After a body of accepted and rejected hypotheses has been built up, hypotheses are formulated which are meant to be applied in conjunction with other hypotheses. Their testing involves confronting implications of the hypotheses to be tested, plus the hypotheses already accepted. If a test is unfavorable to compound hypotheses, that component which has not previously been accepted is likely to be rejected. However, some suspicion may thereby be cast on the previously accepted components of the compound hypotheses.

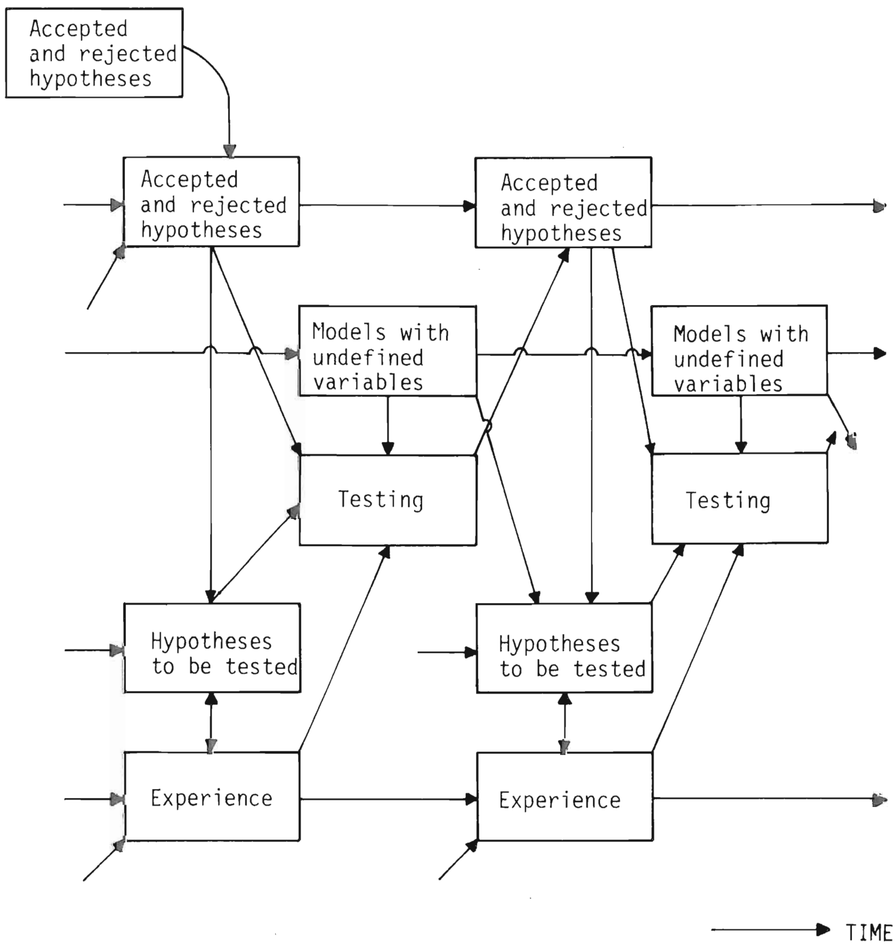
Axioms, Models and Theorems

One of the most important functions of mathematics and statistics in the scientific method is in furnishing models composed of relations between undefined variables. The equation $X = a + bY$, is a relationship between two undefined variables. As such, it is not a hypothesis, but it may furnish the form for many hypotheses. For example, if X is taken to indicate consumption expenditures of some group of families and Y is taken to indicate their incomes, then the above relation between two undefined variables may become a hypothesis of linear relation between two economic magnitudes. A relation between undefined variables may assert a mathematical axiom but no hypothesis is involved, and there is nothing to test. However, as soon as the undefined variables are given physical meaning, a hypothesis is created, and testing is in order. Mathematics and statistics furnish a large storehouse of relations and models, many of which have proved useful when given physical content. When faced with new situations, this storehouse of mathematical relations and models is often drawn on in forming new hypotheses.

In addition to assisting in providing the form of new hypotheses, this storehouse of relations and models plays an important role in the testing of hypotheses in at least two different ways. In the first place, testing involves comparing implications of hypotheses with experience. The labor of working out implications of hypotheses would frequently be prohibitive if it had to be done afresh each time. Mathematics and statistics not only provide a storehouse of models with undefined variables, they also provide considerable knowledge, often called theorems, about the formal implications of these models. This renders unnecessary the separate working out of implications each time a mathematical or statistical model is transformed into a hypothesis. The second way in which models with undefined variables play an important role in testing is in providing effective models for the collection of data. Thus, many very powerful statistical tests are possible and appropriate <u>if</u> data are collected in certain ways such as by random sampling, etc.

Diagram 1 presents our attempt at describing the broad outlines of the scientific method. Of course, many difficult problems of strategy have been glossed over. But while more detailed questions of strategy must be faced and answered, it is perhaps more fruitful to do this in a more specific context. Also, no matter how specific the context, it seems clear that the role of trial and error will be unavoidably large. For example, in the matter of picking hypotheses for testing, the great experimenter, Faraday, is reported to have said that he considered himself fortunate if but a small percentage of his experiments were successful. The central thrust of the scientific method is that we: (1) keep making hypotheses; (2) keep seeking data about which our hypotheses say something; and (3) keep confronting our hypotheses with accumulated data. Of course, we should try to choose fruitful hypotheses, and of course we should try to correctly reject or accept hypotheses on the basis of testing. However, these are operations which cannot be carried out without error, and it is only a sustained effort involving testing on a very broad base of experience that gives us much hope for success.

DIAGRAM 1


Accepted and rejected hypotheses
Accepted and rejected hypotheses
Accepted and rejected hypotheses
Models with undefined variables
Models with undefined variables
Testing
Testing
Hypotheses to be tested
Hypotheses to be tested
Experience
Experience
TIME

2. STATISTICAL MODELS

The focus of this section is on statistical models used in specifying models of economic systems. Statistical models are probability models and as such are mathematical models with variables defined only in terms of their formal characteristics. Interest in them stems from their usefulness in expressing economic models of relations, entities, and economic systems. Interest also stems from the fact that, if a statistical model can be regarded as appropriate in a given context, then quite a bit may be known about the properties of various estimating procedures.

There are innumerable ways in which statistical models may be differentiated and many ways of usefully grouping them into broad classes. However, the most basic distinction to be made is between models involving but one of each kind of entity and models involving many entities of each kind. (Of course in between and mixed types of models are conceivable but will not be considered here).

The second most important distinction to be made is a cross-cutting one. It is between models in which all variables except one in each equation may be regarded as predetermined at the time of application of each equation and models which may involve more than one dependent variable in individual equations. In the first case equations may be developed and applied separately and recursively. In the second case equations must be estimated and applied using simultaneous equation techniques.

The characteristic equation sets of each of the four basic types of statistical models obtained by using the above two classificatory principles are given below, followed by an explanation of the notation used.

A. One of each kind of entity models.

In both classifications A1 and A2 shown below, i is always 1 since there is but one entity of each type. r assumes successively the values 1 through R^e for each value of e which in turn takes on the values 1 through E, the number of entity types. R^e is the number of relations used to model the output generation of the e'th entity type.

A1. Recursive Equations Subcategory

$$Y_{e,1,r} = F_{e,r}(YR_{e,1,r}, YL, Z) + U_{e,1,r}$$

A2. Simultaneous Equations Subcategory

$$Y_{e,1,r} = F_{e,r}(YS_{e,1,r}, YL, Z) + U_{e,1,r}$$

B. Many of each kind of entity models.

In both classifications B1 and B2 shown below, i assumes successively the values 1 through N_e for each of the R_e relations for each of the E entity types.

B1. Recursive Equations Subcategory

$$Y_{e,i,r} = F_{e,r}(YR_{e,i,r}, YL, Z) + U_{e,i,r}$$

B2. Simultaneous Equation Subcategory

$$Y_{e,i,r} = F_{e,r}(YS_{e,i,r}, YL, Z) + U_{e,i,r}$$

Notation

$Y_{e,i,r}$ is the dependent variable of the r'th relation used to describe the behavior of the i^{th} entity of the e'th type.

$YR_{e,i,r}$ is the vector of all current dependent variables which can be regarded as determined by relations activated prior to the one used to generate $Y_{e,i,r}$

$YS_{e,i,r}$ is the vector of all current dependent variables exclusive of $Y_{e,i,r}$

YL is the vector of all lagged dependent variables

Z is the vector of all other variables which may be regarded as predetermined

$U_{e,i,r}$ is the unobserved error term in the r'th relation used to describe the behavior of the i^{th} entity of the e'th type

3. THE SIMULTANEOUS EQUATION APPROACH WITH ONE OF A KIND ENTITIES

This elegant approach was developed with a view to estimating structural equations using only macro time series data relating to an economic system composed of one-of-a-kind entities. It was developed after Elmer Working (1927), Trygve Haavelmo (1943), and Tjalling Koopmans (1945) succeeded in educating the economics profession that standard single equation estimation techniques, applied to data for one-of-a-kind entities, would not in general yield unbiased estimates of structural parameters. They and others also showed that except under favorable identifying conditions it would be impossible, even with infinite sample sizes, to sort out structural equations.

Unfortunately, despite the work of many gifted econometricians with the resulting output of scores of books and many hundreds of articles, this approach to model building and estimation of type A2 models has proved disappointing to economists because it has not led to effective testing of hypotheses about consequences of actions. <u>The basic difficulty is that too much must be known before it is appropriate to use it</u>. With respect to the systematic part of a simultaneous set of equations, it is first necessary to know:

(1) Variables that need to be included.

(2) Number of equations.

(3) Form of each equation.

(4) Variables to be included in each equation and variables to be excluded.

(5) Lags with which each variable is included in each equation.

(6) Which variables are exogenous to the system as a whole.

With respect to the stochastic part of a simultaneous equation set of equations it is, in general, necessary to assume that:

(1) Errors of observation are negligible.

(2) That the disturbances in each equation are uncorrelated with lagged values of themselves and of each other.

(3) That the disturbances in each equation may be considered as random drawings from a normal joint probability distribution.

(4) That the disturbances in the system that determines the exogenous variables must be distributed independently of disturbances in the model under consideration.

In practice, neither econometricians nor economic theorists are even in a position to make intelligent guesses on many of the above items. The upshot is that, after a reasonably complete and well validated system model has been arrived at by other means, simultaneous equation estimation methods may be helpful in improving its overall consistency with respect to available macro time series data. The fact that methods have been developed which could extract any information from macro time series about one-of-a-kind entities is in itself a great achievement. Unfortunately it is a fact that macro time series data do not themselves contain adequate information for much in the way of economic hypotheses testing. Complicated statistical techniques are made necessary by poor and inadequate data, but are not a satisfactory substitute for appropriate data.

If economic systems are modeled in terms of the behavior and interaction of one of each kind of entity then the need for simultaneous equation estimation seems apparent. But even without simultaneous equation complications, it is in the nature of things, as pointed out in the next section, that testing possibilities are extremely limited with respect to hypotheses about entities that must be treated as unique.

4. ON THE TESTABILITY OF HYPOTHESES ABOUT UNIQUE ENTITIES

Tinbergen type national income models and Leontief type, inter-industry models are all A type models in our classificatory scheme. That is, they are articulated in terms of the behavior and interaction of entities each of which is conceived of and treated as one of a kind. The development of the national income and product accounts and of the inter-industry accounts reflects the focus of model builders on one-of-a-kind entities. The dominant stream of econometrics during the last thirty years has focussed on developing estimation techniques suitable for estimating structural equations for models about systems of one-of-a-kind entities given time series data about such entities.

Models are embodiments of sets of hypotheses and hypotheses can be conceived about unique entities. But are they testable in any meaningful sense? And if not, of what use will they be? Our thesis is that hypotheses about entities that must be treated as unique are so close to being untestable as to be useless or even dangerous for prediction of policy responses.

By taking advantage of autocorrelation and inertial properties of our system, by taking advantage of observed expectations, intentions and plans, by taking advantage of leading indicators and extensive multicollinearity, and by use of frequently observed and up-to-date measurements, it has proved possible to develop Tinbergen type national income models which are useful for short run forecasting. But how useful are the embodied insights about behaviorally induced consequences of policy even in such worked over areas as policies thought to bear on inflation, unemployment and income and wealth distribution? And even if the reader is more generous in attributing success in these matters than we are, how much of the believed success stems from testing and estimation of hypotheses about one-of-a-kind entities and how much stems from some kind of carry over from what we think we know about micro-entities such as ourselves or firms?

One basic difficulty with testing hypotheses about one-of-a-kind entities can be seen by considering the most favorable possible circumstances for carrying out such testing. Thus suppose it were possible to carry out whatever planned experiments one might devise but they could only be carried out on but a single experimental animal, say a dog. The problem is that with but a single dog it would be impossible to simultaneously apply different levels of treatment to different dogs thought to be roughly similar and in roughly similar conditions except for the differential application of the treatment. It would thus be impossible to hold a myriad of things approximately equal while relating hypothesized differential responses to applied differential treatments.

Of course it would still be possible to apply different levels of treatment of interest at different points in time and seek to relate hypothesized differential responses over time to applied differential treatments. Nevertheless, the prospect for successful learning would be dim. Many things change over time in ways which cannot be controlled and their effects might easily be inadvertently attributed to the treatment. The experimental animal may be permanently affected by the treatment so that effective replication of the experiment might be impossible, etc. Also consider how hard it is to learn about the effect of diet, smoking, or exercise on health. Under favorable experimental conditions, it seems obvious that trying to test hypotheses about one of a kind entities is unpromising, to say the least.

For evidence of additional damage done to the possibility of effective testing by the prevalence of highly autocorrelated economic time series, the reader is referred to the Monte Carlo studies by Orcutt and James (1948) and by A. Nakamura, M. Nakamura, and Orcutt (1976). These studies, taken in conjunction with what is known about the nature of most economic time series, indicate that the evidence available in national accounts data for testing hypotheses is much less than even the fewness of observations suggests. It also is worth noting that while transformations designed to randomize error terms, such as suggested by Cochrane and Orcutt (1949) and Orcutt and Cochrane (1949), may be useful in estimation, they cannot undo the basic damage done to the possibility of effective testing by the ubiquity of high autocorrelations among macroeconomic time series. For evidence of the loss of estimation precision with aggregation of micro-unit data before estimation see Orcutt (1968), Orcutt, Watts and Edwards (1968), and Orcutt and Edwards (1969).

5. ON THE ATTRACTIVENESS OF RECURSIVE EQUATIONS WITH MANY-OF-EACH-KIND-OF ENTITY MODELING

Microanalytic models were devised to improve estimation and testing possibilities. The central reason why they do this is that although many microunits are introduced, all of these units are treated as members of one or another of a small number of populations of similar entities. A single model of a household and its component units can be used for every household. The number of observational points that can be brought to bear in estimation of such a household model can be thousands of times as large as the number of parameters to be estimated. Furthermore, at the microlevel it is possible to relate differential responses to differential treatment as a means of eliminating the biasing effect of major feedbacks and as a means of identifying casual relations.

Obviously, the ratio of observational points to parameters that must be estimated is not the only thing that matters. It is essential to work with the right variables for the same components for approximately the same points or intervals in time. Multicollinearity, autocorrelated errors, rapid feedbacks and errors of observation are problems associated with microdata sets as well as with macro time series. Nevertheless, all of these problems are more treatable with a high ratio of observational points to parameters. Furthermore the need for special simultaneous equation techniques in estimation is greatly reduced or eliminated.

The need for simultaneous equation estimation arises in models of the economy with one-of-a-kind entities because the existence of multiple equations linking the dependent variables ensures that error terms will be correlated with variables that a single regression equation approach would treat as explanatory or predictor variables. Consider the following simple two-equation system:

$$Y_t = \alpha_1 + \beta_1 X_t + E_t$$

$$X_t = \alpha_2 + \beta_2 Y_t + V_t$$

It is easy to see that by virtue of the first equation Y_t will be correlated with E_t. But since Y_t enters into the second equation X_t will be correlated with Y_t and so X_t will become correlated with E_t in the first equation by virtue of the second equation.

Because aggregate sales in every market are exactly equal to aggregate purchases in the market, it is easy to see how the above situation might well characterize economic system models with one-of-a-kind entities. But with many of each kind of entity the above situation need not arise or if it does might be handled by relating, when estimating, differential responses to differential treatment of similar entities. Aggregate spending does directly influence aggregate income but spending by an individual consumer does not feedback in any substantial and immediate way to influence the income of the individual consumer; of course covariance of error terms as between individual components might create simultaneous equation type problems. But even these could be dealt with using single-equation estimation techniques by working with differential responses instead of absolute responses.

Joint outputs of individual entities are likely to be a feature of models of either one-of-a-kind entities or of many-of-a-kind entities. However, it seems reasonable to model such situations in terms of a joint conditional probability distribution which is expected to remain invariant with respect to governmental actions of interest. If so it is well known that such a joint conditional probability distribution can be exactly expressed by a set of single dependent variable recursive equations with error terms which are uncorrelated with variables on the right hand side of the equation in which they occur and which are uncorrelated with each other.

Goldberger (1964, pp. 278-281), introduces what he refers to as the contemporaneously uncorrelated linear regression model. This statistical model is general enough to include the recursive form representation of joint determination models. In a development based on Chernoff and Rubin (1953), Goldberger shows that, if the assumptions of this model are satisfied, the classical least-squares estimators are consistent and hence asymptotically unbiased.

The importance of these findings is obvious for estimation of joint determination models which either already are or may conveniently be put in a recursive form. In addition, it should be noted that the attractiveness of carrying out estimation in a recursive form has been further increased by the fact that Wold and Jurêen (1953, pp. 200-215) have shown that the classical least square estimators remain consistent under fairly general assumptions, even if successive disturbances are correlated with each other. For still further generalizations the reader should see Wold (1961) and Lyttkens (1964) and Orcutt and Winokur (1969) for Monte Carlo evidence on small sample properties of autoregressive estimators and predictors.

Obviously, the same economic model may be represented in any one of a number of alternative forms. These forms differ from each other in several significant respects including the specification of stochastic terms. Because of this, estimation of the parameters of the same model in different forms will call for the use of different estimation procedures. Of all the possible forms of which a model might be put, those which leave as little information as possible concentrated in the stochastic part of the model specification have an obvious attraction. Thus there is some point in trying to formulate an equation set such that errors in different equations may be conceived of as essentially uncorrelated with each other.

The use of a recursive form, along with provision for an autoregressive transformation if needed, makes it possible to leave as little information as possible in the stochastic specification of a model. If such an approach to model specification does not result in unmanageable problems due to non-linearities or unduly inhibits a reasonable use of prior information, it would seem to be the obvious choice since it would permit the use of single equation least square methods. Furthermore, with such an approach, it would be reasonable to give some credence to standard tests of significance. The possibility of conveniently using a recursive form as the original form in which a model is stated is greatly enhanced if monthly time series data and panel data are available. Such data would be useful on many accounts but among other things they would greatly enhance the possibility of finding a recursive form in which individual equations could be associated with recognizable components. [1)]

6. ON THE DEVELOPMENT OF A TREATMENT-RESPONSE RESEARCH APPROACH FOR SOCIAL SYSTEM MODELING

The central research focus of most econometric research has been on accounting for and predicting the variation of one or more variables given current and lagged values of other variables. The "explained" or predicted variables are referred to as dependent variables or endogenous variables and the variables used

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1) This and the preceding three paragraphs appear in substantially the same form in Orcutt (1967).

in explaining or predicting the dependent variables are referred to as predetermined variables consisting of already determined dependent current or lagged dependent variables and exogenous variables. In fact the focus of econometric research has been on reduction of unexplained variance of selected dependent variables whether or not a single equation or a simultaneous equation approach has been used and whether or not the objective has been unconditional forecasting or the building of models for use in predicting policy implications.

In our view this mainstream preoccupation with reduction of unexplained variance reduction of selected variables is indeed valuable but needs to be more systematically preceded by and complemented by a treatment-response research focus and methodology. The need arises not because single equation and simultaneous equation statistical techniques don't do what is claimed for them. They do. The need arises because they presume much more than can reasonably be presumed and because they do not serve to focus research attention on the recognition, classification, and discovery of consequences of actions. They do not lead by themselves to the building of models which clearly serve to trace out the importance primary, secondary, and tertiary effects of recognizable and possible human actions, policy or otherwise.

Although our choice of name for the treatment-response research approach may be unfamiliar to some it will easily be recognized that the approach itself goes back to the dawn of recorded history. In areas in which controlled experimentation is possible it would be referred to as the experimental research approach. We have chosen a broader term because although greatly facilitated by the possibility of planned experimentation the approach can be and is used to good advantage in trying to learn from situations in which unplanned variations of treatments that could be applied are in fact applied. In any case let us now consider some of the elements that make up this approach and which we think should play a role in developing models which successfully model social system responses to recognizable public and private actions.[2)]

[2)] Planned experimentation, when feasible, can result in more readily interpreted evidence than is possible with any other approach. See G. Orcutt and A Orcutt (1968) for arguments supporting negative income tax experimentation. In this chapter we are primarily concerned with naturally occurring treatments.

Actions of interest Need To Be Specified So As To Be Recognizable in Practice

Models are expressed in terms of relations between variables but policy makers need to know about consequences of actions they might take. Policy makers are likely to have an operational understanding of actions they might or might not take; but do they know how such actions may be specified in terms of statements about input variables of supposedly relevant models? And for that matter do model builders have a clear idea of how policy actions of interest should be expressed in terms of input variables of the models they build in supposed service of policy makers?

Experimentalists frequently use the value of a variable as a measure of the level of application of some treatment but this does not prevent them from recognizing that actions are almost always complex and multidimensional physical phenomena. The value of a single variable such as weight, voltage, income, price, etc. may indeed serve to measure the level of application of an action but clearly does not fully describe it. Indeed is it not obvious that a given variable such as income or income change could serve as a measure of many different actions or even of many combinations of many actions?

Since the experimentalist is likely to have an operationally satisfactory idea of when an action of interest is taken and when it is not, the relating of outcomes to an action as measured by a single variable poses only manageable difficulty. The experimentalist knows, and users of the experimentalist's results are expected to know, that claimed relations between outcomes and the value of an action indicator variable are only meant to apply with respect to changes in the level of the indicator variable in response to the action. Nothing is asserted by the experimentally derived relation about movements of the indicator variable in association with other actions or in association with any of a variety of naturally occurring developments.

But what can we say about the non-experimentally oriented econometrician or statistician, or about the statistician who limits his attention to relations between variables but never clearly relates the movements of variables used as inputs to the occurrence or non-occurrence of actions of interest? For example it seems reasonable to believe that a person's disposable income might change because the person is fired. But it also might change because of a temporary layoff. Or it might change because the person decides to go back to school. Still another possibility is that it changes because the person takes on a job or a second job in order to finance the purchase of a house, the education of a child, or the payment of medical expenses. All of these actions or events might be associated with an income change. But will it be satisfactory to predict that all of these actions will have the same implications for expenditures, savings, etc. just as long as they are associated with the same change in disposable income? Clearly this is a matter for investigation and the user needs to be told the range of physically recognizable actions for which asserted relations between variables are expected to hold.

Movements of macro time series variables can seldom be clearly identified with specific actions since they represent aggregates of enormous numbers of varied and time-wise overlapping actions occurring at less aggregative levels. At the level of the person, family or firm it is possible to unambiguously determine when actions of interest are taken, by whom they are taken, where they are taken and so on. Thus it is possible to distinguish an income change due to a firing from one due to a wage rate change from one due to a temporary overtime employment. All of these treatments of persons, with their possible different implications for the relation of, say, expenditures to income, could be differentiated from each other and from actions taken by individuals to modify their own incomes. Possibly the first step in a treatment-response research approach would be specification, in an operationally satisfactory way, of one or more actions or treatments of central interest for the research in hand.

Sample Points Should Be Selected with A View to Learning Implications of Treatments of Interest

Econometricians used to working with macro time series have learned to use every possible observation in estimating any relation because they have so few effective degrees of freedom relative to parameters to be estimated. They also look with justifiable concern on the selection of sample points to be used in estimation by the elimination of apparently nonconforming sample points. They thus tend to try and use all sample points involving a set of variables hypothesized to be related in some way or other. But what experimentalist tries to pool data, even before estimation and testing, from quite different experiments? Just because the same or an overlapping set of variables happens to be involved is not enough. Clearly in trying to learn from naturally occurring treatments of persons families, or firms it is essential to at least recognize when treatments of interest were taken and when they were not. Clearly it is worth recognizing changes in the sales of a firm due to consumer actions from changes in the sales of a firm due to a teamsters' strike or due to a planned withdrawal from or entry into a given market.

In planned experimentation an attempt is made to apply an action of interest at at least three or more widely separated levels of application. If implications of two or more actions are being explored then an attempt is made to avoid or minimize covariation between assigned treatment levels. In an effort to avoid mistakenly attributing outcomes to treatments experimentalists make use of observations on carefully selected control groups. These groups of entities are selected so as to be as similar as possible to treatment groups in nature and with respect to environment. However they either do not receive the treatments of interest or receive different levels of the treatments of interest.

The experimentalist is thus extremely selective with respect to sample points. He or she selects, not on the basis of outcomes, but in such a way as to ease the problem of interpreting and learning from observed outcomes of selected application of treatments. The researcher who wishes to learn from naturally occurring applications of treatments of interest has every reason to be equally highly selective of sample points. If we knew enough about a social system all data points might be of some value. But when very little is known great selectivity is required in order to focus on situations and comparisons simple enough to be learned from.

Variable Transformations Could Be Useful In Isolating Treatment Effects

Variable transformations are widely used to obtain error terms that are more nearly homoscedastic and random in time. The objective is greater precision in estimation of parameters given that the underlying systematic and stochastic specification is correct. The autoregressive transformation suggested by Cochrane and Orcutt referred to in section 4 falls into this class.

The use of autoregressive transformation to improve precision of parameter estimation is based on the notion that the error term could be regarded as generated by a single autoregressive process. If this is true then, except for sampling variability, all regression parameters, save for the constant term, should have the same value no matter what autoregressive transformation is used. But if, as seems plausible, the error term was the sum of omitted variables with different autoregressive properties then autoregressive transformation of all included variables would serve to differentially suppress or amplify certain error components relative to others. Thus the underlying correlation between the error term and a treatment variable of interest could well be different when estimation is carried out with different autoregressive transformations. In this case estimated values of parameters would vary systematically with choice of autoregressive transformation. If this variation could be detected it would be good evidence of a significant structural misspecification, and would thus be useful in testing underlying assumptions.

A related but probably more important possibility is that by relating differential responses to differential treatment applications to closely matched entities, a variety of possible but unknown sources of response variable variation could be balanced out. The alternative way of handling this with a conventional single equation, unexplained variance reduction approach would be to include observations on all subjects in a regression of the response variable of interest on treatment and other variables.

Two things are involved here. One is the search for numerous small sets of entities which are closely matched except with respect to the level of treatments of interest. For some purposes, pairs of identical twins might be ideal. In other areas, neighbors matched in terms of personal, family, and job characteristics but working for different firms might provide matching except with respect to treatments of interest. The second thing over and above close matching within pairs or small groups is the transformation of variables so that differential responses are regressed on differential treatments and other variables. The number of sample points used in a regression equation will be greatly reduced since each small closely matched group will provide just one sample point for each point in time instead of several. However skillful matching of entities experiencing different levels of treatment can effectively balance out possibly large disturbing effects of variables which are not even measured, or which if they are measured might have non-linear and interactive effects which would make interpretation of typical regression results difficult and hazardous.

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MICROANALYTICAL MODELING AND SIMULATION

Guy H. Orcutt and Amihai Glazer

FOREWORD*

Human beings have created representations of that which interests them from time immemorial. Our objective is to facilitate and encourage such activity.

Our interests focus on social systems and their representation. We hope to contribute to social system improvement by encouraging the development and facilitating the use of microanalytic models of social systems.

Modeling or representation of something is done for extremely diverse reasons. However, when it comes to the modeling of social systems, utilitarian objectives may well be dominant. This is so since a useful model of our social system might permit a useful consolidation, integration and retention of understanding. It might facilitate imaginative thought processes, assist in educating the uneducated and give guidance to the collection of information and the testing of hypotheses. It might even contribute to wisdom in efforts to help shape our destiny by molding and controlling facets of our economy or of our social life.

In our view the microanalytic modeling paradigm is the most promising paradigm available for modeling of social systems given developments which have and are taking place with respect to computers and data.

Monte Carlo simulation is the particular approach to solution and use of microanalytic models presented and illustrated in this paper. It is not the only approach to solution and use of models of social systems but it remains the only tractable approach yet developed for solution and use of social system, microanalytic models of more than illustrative realism.

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1. MODELING PARADIGMS[1]

1.1 Introduction

Modeling are at the very hart of basic and applied economic research. A model of something is merely an embodiment of understanding about the thing in question and how it behaves. Whether models should be expressed verbally, graphically, in mathematical symbolism, or as computer programs is a matter of convenience and, to some extent, of audience. Whether models of the economy should be national income models, interindustry models, microanalytic models, or some other kind of model is a matter of argument and may depend on availability of data and specific objectives. These and many other questions about the kind of modeling that should be emphasized are debatable. However, unless one believes in oracles or believes that policy decisions should be made without regard to likely consequences, the use of models is unavoidable.

Predictions derived from a realistic model of the economy are needed as a basis for selection of governmental policies relating to taxation, spending, debt management, and so forth. If policy-makers are considering one tax law as compared to some other tax law, or one spending policy as compared to some other spending policy, they should know what the consequences are of the policies under consideration. One way to find out would be to try out the policies on the economy but it would not be very satisfactory from the standpoint of the participants. Policies should be selected on the basis of their fruit; but it would be preferable to sample the fruit before applying policies to the real world. If a sufficiently accurate model of the economy were available, it would make such sampling possible.

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[1] This and Section 2 draw upon and use passages from Policy Exploration Through Microanalytic Simulation by Guy H. Orcutt, Steven B. Caldwell, Richard Wertheimer II, and Stephen D. Franklin, Gary Hendricks, Gerald E. Peabody, James D. Smith, Sheila R. Zedlewski. Urban Institute, Sept. 1976, Washington, D.C. and from Microanalysis of Socioeconomic Systems: A Simulation Study, by G. Orcutt, M. Greenberger, J. Korbel, and A. Rivlin, Harper and Row, New York, 1961.

1.2 Approaches to Modeling Economic Systems

At the present time there are three quite different approaches to modeling economic systems; 1) the national income approach, 2) the interindustry approach, and 3) the micro-analytic approach.

Attempts to quantitatively implement the national income approach date back to the pathbreaking work of Tinbergen in the 1930's (for example Tinbergen, 1939). In this approach, major sectors such as the household and business sectors, are used as basic components. Macroeconomic relationships for these components are estimated and tested on the basis of annual or quarterly time series data of such variables as aggregate consumption and income of the household sector. The relationships developed have been finite difference equations of a stochastic nature. Both recursive and simultaneous equation systems have been developed. Examples of models of this general type include those constructed by Tinbergen, 1939; Clark, 1949; Klein, 1947, 1950; Klein and Goldberger, 1955; Duesenberry, Eckstein and Fromm, 1960; Smithies, 1957; and Suits, 1962, to name only a few. The Social Science Research Council-Brookings econometric model building effort (see Duesenberry, Fromm, Klein, Kuh, eds., 1965) represent a very ambitious attempt in this general direction, involving several hundred equations and an industrial sector with several subsectors. The Federal Reserve-MIT-Modigliani model is a significant current model of this general type which relates to the Flow-of-Funds Accounts.

The second oldest and the second most widely utilized approach to construction of models of the United States stems from Leontief's highly important work (1951, 1953). Industries are used as basic components in these models. Emphasis is placed on the cross-sectional structure of the economy rather than on its dynamic features. Physical outputs of industries are assumed to be strictly proportional to physical inputs classified by industry of origin. Models of this type have been stated in a nonprobabilistic form. Solution of such models with as many as one hundred industries has been achieved by the numerical inversion of a matrix of the same order. Richard Stone (1966) among others has contributed substantially to the extension of this modeling paradigm to social accounting.

The newest and least developed approach to the construction of models of socioeconomic systems is the microanalytic approach, developed by Orcutt (1957) and Orcutt, Greenberger, Korbel, and Rivlin (1961). While being of the same general statistical type as other models of national economies, microanalytic models are, nevertheless, the most general in terms of their statistical structure. Each major type of model of a national economy may include stochastic or random elements, each may use previous values of variables as part of what is treated as given, and each may be expressed as a system of equations. However, microanalytic models are more general in that they may contain one or more populations of microunits such as individuals, families and firms instead of but a single case of each kind of unit, as is true with both Leontief-type and aggregate-type national income models.

1.3 Potential Advantages of Microanalytic Models

The potential advantages arise because of the following considerations:

1. While much of social science theory, theorizing and research relate to the behavior of individuals, families, and firms we do not know how to aggregate nonlinear micro-relations into macro-relations. For example, if family saving depends on family income, wealth and life cycle variables, then aggregate saving will depend on the joint distribution of family incomes, family wealths, and family life cycle attributes. Not only would such a macro saving function be difficult or impossible to specify and estimate directly, but it would not be used appropriately in a macromodel without the availability of the joint distribution of all of these micro-variables. With microanalytic models, relations for microunits are used without aggregation. Instead, outputs of micro-relations are aggregated as desired and without difficulty.

2. Satisfactory estimation and testing of highly aggregative models cannot be achieved because of the relatively few macro time series observations available for testing implications of such models against actual developments, and because of the limited possibilities for effective use of controls in isolating effects of actions of interest. Multicollinearity, autocorrelation, feedbacks, and errors of observation only serve to complicate and worsen what is already a very precarious situation insofar as satisfactory testing is concerned. The information available for estimation and testing can be enormously increased by appropriate use of the data relating to microcomponents. In addition, the danger of inappropriately treating different actions as equivalent, just because they are associated with variation of a common variable, is reduced.

3. Models built only in terms of the interaction of major sectors cannot yield several important kinds of predictions. For example, not only is it important to predict how unemployment or income would be affected by alternative policies, but it also is important to predict how unemployment and income would be distributed among individuals and families by various characteristics. Such characteristics might well include previous unemployment, age, sex, race, and family size.

1.4 Conceptualization of a Microanalytic Model of an Economy

For research purposes, for structuring and programming of a simulation system, and for convenience of presentation, it is important and perhaps even essential to consider an overall model of an economy as an ensemble of interacting building blocks. Each type of block becomes a focus of research activity, and presentation of the overall model is facilitated by presentation of submodels of each type of block along with a description of the way in which interaction between blocks is to take place.

Alternative ways of breaking an overall model into blocks are possible, but some ways seem definitely preferable. In general, the objective is to select blocks in such a way that each block or type of block may be studied with a minimum of concern about interrelationships with other blocks.

The major building blocks are called "components". In microanalytic models of an economy the components represent recognizable entities met in everyday experience. The type of component occupying center stage is called a decision unit. Decision units include such components as individuals, nuclear families, spending units, household units, manufacturing plants, retail establishments, banks, insurance companies, labour unions, and local, state, and federal government units. Individuals are regarded as imbedded within more extensive family or household units. Plants and establishments are thought of as being imbedded within geographical areas such as counties or county groups.

The decision units in microanalytic models interact with each other either directly or indirectly through a second major type of component called a market. The markets in a model represent markets in the economy, and it is through them that the third type of component flows from decision unit to decision unit. For brevity, components of this last type will be referred to as "goods". But it must be noted that such components include money, bonds, shares of stock, deeds, mortgages, and various other things which may be produced, held, sold, bought, or consumed by decision units.

Variables used in the submodel of a component but given over time from outside of the component are referred to as "input variables for that component". Variables that flow from or are emitted by a component are called "output variables of that component". Variables that describe the state of a component are called "status variables of that component". Input, status, and output variables may refer to either stocks or flows, and of course all variables appearing in a dynamic model are dated.

A description of any component would include a listing of its own input, status, and output variables along with those relationships which are used in updating status variables and in generating output variables. The behavioral relationships used to generate values of the updated status variables and of the output variables, given the predetermined status variables and the input variables, are called "operating characteristics of that component". Other relations of a definitional or tautological character may be used as convenience dictates.

Finally, any variables used by an operating characteristic may be referred to as an "input of that operating charactertistic" and any variable determined by an operating characteristic may be referred to as an "output of that operating characteristic".

Let us now consider interactions between decision units. Some outputs of operating characteristics are end products and only require aggregation. Most outputs of operating characteristics, however, update status variables, and are directly used as inputs into other operating characteristics of the same component, and/or are outputs of the component. As will be recalled, the second major class of components in microanalytic models are markets, and the specific function of these components is to transmit the outputs of decision units and to distribute them as inputs to other decision units.

The information received by potential buyers is used as inputs into their operating characteristics, and in some cases orders to buy are the resulting outputs. These orders enter as inputs into the appropriate markets. Operating characteristics of each market summarize and classify the orders by region of origin, price accepted, etc. Other operating characteristics of the market then use this summarized information about orders, along with information about each potential seller considered in turn, to distribute the orders among potential sellers. Decision units respond to the orders which they receive as inputs and generate various outputs, among which in due course will usually be deliveries. These deliveries show up as inputs into an appropriate market, are transmitted and distributed by the market, appear as outputs of the market and as inputs into the appropriate decision units. These decision units then make payments or promises to pay which are again distributed through the market to the appropriate sellers.

Figure 1 illustrates how decision units such as persons might be conceptualized as imbedded in a more extensive decision unit such as a family. Figure 2 shows how the outputs of an entire set of N decision units may be visualized as transmitted and distributed by the M markets. The outputs of the decision units become inputs into the markets. After being summarized and distributed they appear as outputs of the markets. These market outputs then become inputs into the decision units again.

1.5 Probabilistic Operating Characteristics

Selection of a probabilistic approach to predicting the behavior of microcomponents does not reflect any particular philosophical position about the nature of causation or about the meaning or existence of free will. The problem is how to represent available understanding about the behavior of micro-components. No matter how many variables are taken into account in predicting the behavior of persons or other micro-components, a variety of actual behavior always occurs even for identical values of all input variables. What shall be done about unexplained variation which must be expected? A deterministic operating characteristic merely ignores it and at best yields something like an expected or average value for the output. A probabilistic operating characteristic goes a little further and states what is thought to be known about how, in a large number of trials, observed behavior will be distributed around the predicted average behavior. This provides a fuller prediction and often a much more useful and meaningful one. This is particularly the case when what we are really trying to predict are distributions of the behavior of micro-components. But even when the behavior to be predicted relates only to individuals or small numbers, it is still true that probabilistic operating characteristics are more appropriate because they give some reflection and treatment of real uncertainty.

Figure 1. Schematic Model of a Family

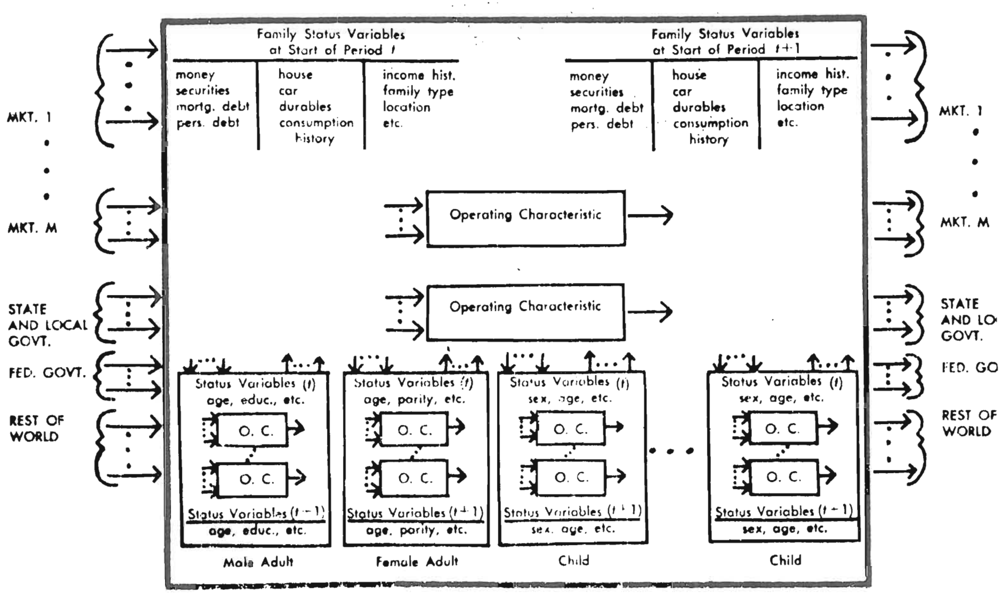
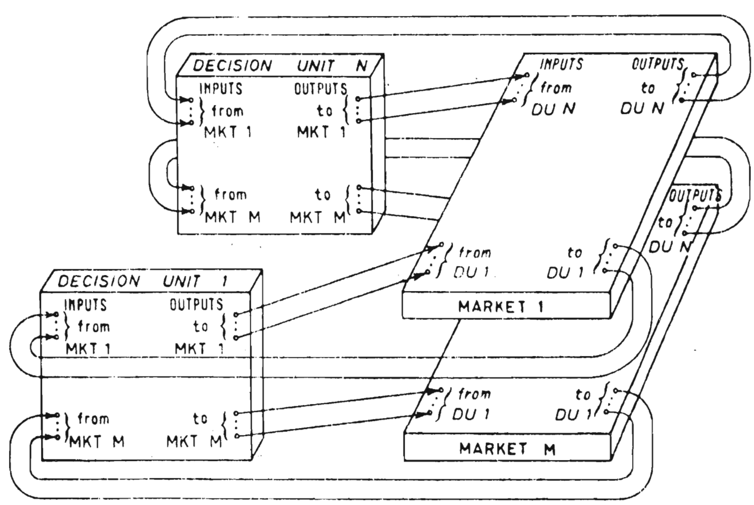


Figure 2. Flow Diagram of an Economic System



1.6 Treatment of Joint Outputs

In various places we have extolled the merits of recursiveness in system modeling. Nevertheless, introspection and personal observation strongly suggest that, even with microanalytic models operated on a monthly basis, it still is desirable to consider some variables as jointly determined. Thus it may seem reasonable to build models in which micro-components such as individuals, families, and firms respond only with a lag to output behavior of other components. However, when we come to different aspects of the same component's behavior, it no longer seems reasonable to do so. Thus, if a family buys a house during a period, it is also likely to incur mortgage debt during that period.

It may be that one family would first consider whether or not to buy a house and then how much mortgage debt to incur. But another family, or the same family at a different time, might easily follow a different sequence in arriving at a decision to purchase a house and to incur mortgage debt. Thus even in the case of an individual micro-component, and even using short time periods, it may happen that some outputs are truly jointly determined or that it is more practical and fully satisfactory to treat them as jointly determined.

Faced with a situation in which a set of output variables of a component are to be regarded as jointly determined, how should one proceed? The most familiar procedure would be to treat this situation as similar to the one which received so much attention from econometricians during the 1940's and 1950's.

The economic system is treated as composed of a relatively small number of major components such as the household sector, the government sector, or the firm sector. The behavior or output of each sector is viewed as determined by one or more equations, each containing an error term which is treated as a random variable of some kind. The set of equations used to generate or predict the behavior of the components of the model are termed structural equations. These equations are distinguished by the fact that several current endogenous variables may appear in each equation and the expected values for endogenous variables may be found only by solution of the set of simultaneous equations.

If the set of structural equations could be regarded as invariant over time, and if the exogenous variables and the variance-covariance matrix of the error terms could be regarded as invariant over time, then a much simpler procedure would be to regard the simultaneous set of equations as solved and to treat each endogenous variable as a function of exogenous variables and lagged endogenous variables. This procedure is not regarded as appropriate precisely because the anticipated use of the model includes predictions of what will happen if the government alters one or more of the structural equations or alters one or more of the endogenous variables in the model. For successful prediction of what will happen if the government controls total demand of a product, it is necessary to have the structural supply function. Some unknown mixture of the supply and demand functions will not do.

Now it may be that situations calling for simultaneous equation estimation procedures will arise in the construction of microanalytic models. Nevertheless, it is important to recognize that, while we may have to deal with joint outputs, the situation is drastically altered by the fact that in the typical case these will be joint outputs of micro-components taken individually. Typically, in this situation, it would seem reasonable to assume that the range of contemplated governmental actions would not actually alter the internal structure of micro-components. If the internal structure of micro-components could be regarded as relatively invariant over the range of contemplated actions, the following statement of the problem would be appropriate.

Given a set of simultaneously determined output variables, $X_1, \ldots, X_K$, the values of these K variables may be regarded as specifying a point in a K-dimensional output space. The multivariate probability distribution over the output space of such points is regarded as conditional on input variables of the operating characteristics used in specifying them but as otherwise invariant with respect to intended uses of the overall model. Treatment variables, if any, are included among the input variables.

1.7 MAM a MicroAnalytic Model

The microanalytic model briefly described in this section is one which has been implemented using MASS, the microanalytic simulation system described in Section 3 of this paper. Basically MAM is the DYNASIM model with minor modifications and a few additions. (For a description of the development, specification, and several uses of the Urban Institute DYNASIM model see Orcutt et al, 1976.)

MAM is a yearly probabilistic microanalytic model of the United States. The variables on which MAM can operate refer to either one of two types of units -- families, and persons who are members of families. Each individual or family unit is characterized by a set of attributes, such as age, marital status, income level, educational attainment, and so forth.

For each family or individual we are interested in the conditional joint distribution of a set of variables.

(1) $G(X_{1,t}, X_{2,t}, \ldots, X_{U,t} \mid X^{*}_{t-1}, Z_t)$

where X^{*}_{t-1} is the vector of variables $(X_{1t}, X_{2t}, \ldots, X_{Ut})$ lagged one or more periods and Z_t is a vector of exogenous variables. This joint probability distribution, G, can be written as a product of conditional probability distributions

(2) $G = \prod_{u=1}^{U} g_u(X_{u,t} \mid X^{*}_{u,t}, X^{*}_{t-1}, Z_t)$

where $X^{*}_{u,t} = (X_{1,t} X_{2,t}, \ldots, X_{u-1,t})$. To be more explicit, the g_u functions appear as

(3) $g_1(X_{1,t} \mid X^{*}_{t-1}, Z_t) = F_1(X_{1,t}, X^{*}_{t-1}, Z_t)$

$g_2(X_{2,t} \mid X^{*}_{1,t}, X_{t-1}, Z_t) = F_2(X_{1,t}, X_{2,t}, X^{*}_{t-1}, Z_t)$

.
.
.

$g_U(X_{U,t} \mid X_{1,t}, \ldots, X_{U-1,t}, X^{*}_{t-1}, Z_t) = F_U(X_{1,t}, \ldots, X_{U,t}, X^{*}_{t-1}, Z_t)$

Each g_u function is thus the conditional probability density function of a single variable and is a function of the value of that variable and of the variables on which the density is conditional. Equations such as these in MAM are used as operating characteristics. These operating characteristics specify for each entity, given its previous state and the new influences operating on it, the probabilities or probability density functions that a particular variable equals some values.

In addition to the family/person micromodel just described, MAM includes a marriage union model and a macromodel. The marriage union model determines the probability that a male and a female who wish to get married marry each other. In addition, the marriage union model determines the characteristics of a new family formed by marriage given that persons are getting married, and given their characteristics.

The macromodel is an auxiliary model of the macroeconomy operating in conjunction with the micromodel. The inclusion of such a model permits macroeconomic conditions to be inputs in the operating characteristics such as elements of Z in equation 3. It also allows an examination of the impact of behavior at the micro level on the macroeconomy. The macromodel determines the GNP, gross private domestic investment, the unemployment rate, and the price level given total family income, total family transfer income, total labour force hours, total hours worked, and population from the micromodel. The micromodel in turn determines the probability distribution for each individual or family of such variables as wage income, transfer income, wealth income, hours in the labour force and hours worked given the variables determined by the macromodel.

Figure 3 schematically describes the family/person micromodel. Listed along the lefthand side are the operating characteristics and the variables whose values they determine in the MASS implementation of MAM. Across the top are all the variables which are inputs to the operating characteristics. By reading across the row for an operating characteristic, the reader can see which variables are used as inputs to that operating characteristics.

Figure 3. An Overview of the Family/Person Model

rogram module name	Program Module Output Variables[1]		Program Module Input Variables[2]																			
	Inter	Intra	AGE	AGEYOUNGEST	CHILDSIX	WEDYEARS	KIDSBORN	PERSONS	DISABLED	GRADECATEGORY	SCHOOLSTATUS	WAGE	WAGERROR	LFORCEPART	HRSWORKED	HRSERROR	LFORCEHRS	UNEMPSTATUS	EARNINGS	FAMEARNINGS	UNEMERROR	UNEMFRACT
NCAGE	AGE (P) AGEYOUNGEST (F) CHILDSIX (F) WEDYEARS (F)		O	N	N	O																
IRTH	KIDSBORN (P) PERSONS (F)[1] AGEYOUNGEST[1] (F) CHILDSIX[1] (F)	PROBDESCHILD (P) BIRTHPROB (P) BIRTH (P) NUMBERBORN (P)	N				O			O												
EATH		DEATHPROB (P)	N				N			O												
ISAB	DISABLED (P)	PROBDISAB (P)	N						O	O												
DUCATE	GRADECATEGORY (P) SCHOOLSTATUS (P)	PENTERS (P) PSTAYS (P) POUT (P) POUTGRAD (P)	N							O	O											
AGE	WAGE (P) WAGERROR (P)		N							N			O	O								
ART	LFORCEPART (P)	TRPART (P) PRPART (P)	N		N				N					O					O			
OURS	HRSWORKED (P) HRSERROR (P) LFORCEPART[7] (P)	LFORCEHRS (P)	N		N				N	N		N		O	N	O			O			
RSEARN	UNEMPSTATUS (P) EARNINGS (P) UNEMERROR (P) UNEMPFRACT (P) HRSWORKED[8] (P)	FAMEARN (F) PRUNEM (P)	N						N	N					N		N	O			O	O
MARRIAG		PRMARRIAG (P)	N																			
LEAVE		PROBLEAVE (P)	N																			
TRANSF	SOCURY (F) TRANSFERINCOME(F)	PRSOSEC (F) PRPENS (F) PENSIONY (F) PRUWC (F) UNEMY (F) FOODY (F) PRAFDC (F) AFDCY (F)	N	N				N		N		N			O N		N			N		
FAMINC	ASSETY (F) FAMINCOME (F)																		N	N		
HOME	HOMESTAT (F)	PRHOME (F) HOMEVALUE (F) HOMRENT (F)	N					N														
TAXES		ADGRINC (F) DEDUCT (F) TAXINC (F) FEDTAX (F) DISPINC (F)	N					N														
WEALTH	ASSETS (F)	CONSUM (F)																				
DIVORCE		PRDIVORCE (F)																				
MOVE	REGION (F) LOCALESIZE (F)	PROBMOVE (F) MOVED (F) PROBMIGRATE (F) MIGRATED (F)				N		N		N												

rogram module name	SOCURY	TRANSFERINCOME	ASSETY	FAMINCOME	HOMESTAT	HOMRENT	DISPINC	ASSETS	REGION	LOCALESIZE		SEX	RACE	PARED	TIMESWED	WEDSTATE	RFAMHEAD	HEADNAME	WIFENAME	FEMHEAD
NCAGE												O	O							
IRTH												O	O			O				
EATH												O	O			O				
ISAB												O	O			O				
DUCATE												O	O	O						
AGE												O	O			O				
ART		O		O								O	O			O			O	
OURS				O								O	O			O			O	
RSEARN												O	O			O				
MARRIAG												O				O				
LEAVE												O	O							
TRANSF		O	O					O	O			O	O			O				
FAMINC		N						O				O								
HOME				N	O			O												
TAXES				N		N	N									O		O	O	
WEALTH					O															
DIVORCE															O			O		
MOVE									O	O		O				O		O		

1 (P) after a variable indicates it is person specific. (F) after a variable indicates it is family specific.

2 N means that the new or current value of the variable is the input and 0 that last year's value is the input.

Below we present a brief description of each operating characteristic in the order in which they are applied.

INCAGE determines the age for each individual and for each family determines the age of the youngest person in the family and whether there is a child under six years old in the family.

BIRTH determines the probability that each individual gives birth. It also determines the probability distribution of the number of children born, the sex of the children and the characteristics of the children conditional upon there being a birth.

DEATH determines the probability that a person dies.

DISAB determines the probability that a person is disabled.

EDUCATE determines the probability that a person has attained a particular education level.

WAGE determines the probability density function of a person's wage rate.

PART determines the probability that a person is in the labour force.

HOURS determines the probability density function for the number of hours during the year a person is in the labour force.

HRSEARN determines the probability density function for the fraction of labour force hours a person is unemployed. Given this unemployment fraction HRSEARN also determines an individual's earnings and total family earnings.

MARRIAGE determines the probability that an individual wishes to be married.

LEAVE determines the probability the persons leave home for reasons other than marriage or divorce.

TRANSF	determines the probability that a family receives AFDC income, food, stamps, pension income, and social security income. TRANSF also determines the amount of such transfers given that a family receives transfer income.
FAMINC	determines the probability density function for a family's income from its assets. FAMINC also determines total family income given its components.
HOME	determines the probability that a family owns a home. Given that a family does or does not own a home, HOME also determines the value of the home and rent for the home.
TAXES	determines the annual tax bill of a family.
WEALTH	determines the probability density function for a family's level of consumption. Given a consumption level, WEALTH also determines the family's wealth.
DIVORCE	determines the probability that a married couple gets divorced.
MOVE	determines the probability that a family will change its place of residence.

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2. SOLUTION OF MICROANALYTIC MODELS

Solution of a model consists of deriving implications from or with it. Although there are a wide variety of ways of solving a model, it seems convenient to group them into three broad classes, 1) the analytic approach, 2) the transitional matrix approach, and 3) the simulation approach. Each of these will be discussed in turn, but first let us consider alternative ways of representing the initial and subsequent stages of a population of entities. This is important to do since it turns out that the choice of representational mode ties in closely with the choice of solution method.

2.1 Representing the State of a Population

There are three widely used methods of representing information about the status or state of a set of entities such as families and their members. They are:

a. Use of an analytically specified multivariate distribution such as the multivariate normal or log-normal distributions.

b. Use of a cell frequency representation achieved by specification of cross-classification categories or cells into which entities may be classified along with the number or proportion of entities in each cell.

c. Full listing of attribute values for each entity.

Each of the above methods of describing the initial or subsequent states of a population of entities such as families and their members could be used in solving or using microanalytic models of socioeconomic systems. They differ, however, with respect to the precision with which detailed information is represented, the cost effectiveness and feasibility of representing the states of entities described by more than a very small number of attributes, and the flexibility and adaptability which they offer in use.

A major drawback associated with both analytically specified distributions and cell frequency representations is that when used for real populations they may introduce substantial amounts of degradation of available information. A second difficulty in this connection is that quantification and evaluation of introduced approximations may be extremely difficult even if possible. For small and modest sized sets of entities, full listing of attribute values for all members of such sets is the ideal approach unless questions of computational cost are of overriding concern. Fortunately, given the computer developments which have taken place, the cost of handling full listing of attributes for all members of a set of entities has become quite manageable even with fairly large sets with many attributes per entity.

There may be no necessary connection between the approach used to solve a model and the mode used in representation of initial and subsequent states of the set of entities being modeled. In practice, however, it does turn out that: the analytically specified multivariate distribution mode is used when an analytic approach is used in model solution; the cell frequency mode of representation is used with the transitional matrix approach to solution; and the full listing mode is used with the simulation approach to solution. Now let us consider alternative approaches to model solution and some of their advantages and disadvantages.

2.2 The Analytic Approach

In the analytic approach an attempt is made to deduce a relationship for each endogenous or output variable of a model that will express it explicitly as a function of initial conditions and exogenous or input variables of the model. The set of such relationships is the general solution of the model. Specific solutions of a model are obtained by evaluating these functions for specific sets of endogenous variables for specific time periods, and for given values of initial conditions and exogenous variables.

When feasible, the analytic approach has much to commend it and is usually preferred by mathematicians. However, this approach has not been successfully applied to social system models of moderate complexity and realism. Either it has proved impossible to deduce general solutions, or solutions deduced in a formal way are too complicated to understand or even to use as a basis for calculating specific numerical solutions, or unacceptable simplifying assumptions have been introduced to make solution possible.

In some cases in which a full analytic solution cannot be obtained, researchers lower their objectives and instead seek to analytically determine the dependence of expected or mean values of dependent variables on initial conditions and exogenous variables. Conditional probability functions are replaced by conditional expected value functions, and expected values of endogenous variables are sought instead of their probability distributions.

For some purposes approximation of probability distributions by their means is a sensible idea for arriving at a first approximation. And, if expected values of endogenous variables are all that are needed, then it may be ideal for single period prediction. The major practical difficulty with this approach is that for many purposes policy interest centers on distributional questions as well as on mean value questions. A potential user of a model will be upset to discover that, while he or she may have started with a model which was potentially capable of predicting the effect of policy on income distribution, the capability was lost in solving the model by replacement of distributions by mean values.

2.3 Transitional Matrix Approach

A numerical approach, which has been used effectively in obtaining specific solutions for some models, is the transitional matrix approach. It has been used by demographers, among others, and is the computational technique used by the United States Bureau of the Census in making population projections.

A transitional matrix is a rectangular array of transitional probabilities which, when multiplied by a vector (a one dimensional array) of frequencies representing the state of population at a point in time, yields the vector of frequencies specifying the state of the population one period later. There would be one transitional probability for each combination of initial and final values of the variables by which components are classified.

The following diagram may help in seeing how this technique might be used to update the state of the model population from t to t+1. X is the single variable. The P_{ij} are the transitional probabilities. $m_{1,t}$ is the number of components at time t that have the first of the three values of X_t. $m_{1,t+1}$ is the number of components at time t+1 that have the first of the three values of X_{t+1}. $m_{1,t+1}$ is the sum of products, $P_{11}m_{1,t}+P_{21}m_{2,t}+P_{31}m_{3,t}$, and similarly for $m_{2,t+1}$ and $m_{3,t+1}$. The state of the model population at time t+1 is thus obtained as the product of a vector of frequencies times a matrix of transitional probabilities.

Matrix of Transitional Probabilities

X_t	$F(X_t)$	$X_{t+1}=1$	$X_{t+1}=2$	$X_{t+1}=3$	
1	$m_{1,t}$	P_{11}	P_{12}	P_{13}	
2	$m_{2,t}$	P_{21}	P_{22}	P_{23}	
3	$m_{3,t}$	P_{31}	P_{32}	P_{33}	
		$m_{1,t+1}$	$m_{2,t+1}$	$m_{3,t+1}$	$f(X_{t+1})$

With restricted models the transitional matrix approach may be an attractive approach to their solution and use. In the first place, it is easily specified in terms of repetitions of simple matrix operations. Secondly, if the number of components is very large relative to the number of cells into which components are classified, this technique groups components to minimize computation costs. The difficulty which prevents this method of solution from being satisfactory for solution of large-scale, socioeconomic, microanalytic models arises because the number of cells essential for a suitable specification of the state of a population of decision units would be many times larger than the number of decision units in the United States economy.

The transitional matrix technique seems attractive because it appears to avoid unnecessary repetition of calculations by grouping those components which are to be similarly treated. However, this grouping and regrouping becomes less and less attractive as the number of groups into which a population must be classified becomes large relative to the size of the population.

Even an extremely modest microanalytic model of the economy would involve substantially more than ten endogenous variables per family since even specifying ages and educational levels would take two variables for each family member. And, even if only ten values were permitted for each variable, the number of cells needed to classify families without loss of information would be 10^{10} or ten billion. The full matrix of transitional probabilities would then have ten billion squared elements! No doubt, if one were determined to use the transitional matrix technique, one would look for methods of avoiding the handling of empty cells and the calculation of transitional probabilities which would apply only to empty cells. Of course, any notion of direct estimation of each transitional probability from any conceivable body of data no matter how large would have to be abandoned. The computational problem would be increased by the fact that while most of the cells would be empty at any point of time, it would not be the same set which would be empty in successive time periods. Even if one were able, without great cost, to reduce the number of cells used at a point in time to one-millionth of ten billion, one would still have ten thousand cell frequencies and the matrix of transitional probabilities would have one hundred million elements. Since current microanalytic attempts to model the economy involve several times as many variables per family as used in the above example, and since one-digit specification of variables would be highly unsatisfactory, it seems clear that the transitional matrix technique will not provide a satisfactory technique for solution of microanalytic models involving any serious attempt at realism. It seems equally clear that explicit estimation and testing of hypotheses relating to individual transition probabilities would not be a very attractive general approach to microanalytic modeling of social systems.

2.4 The Simulation Approach

Simulation, a general approach to the study and use of models, furnishes an alternative approach to that offered by conventional mathematical techniques. In using conventional mathematical techniques to solve a model the objective is to determine, deductively and with generality, the way in which the model relates endogenous variables to initial conditions and time paths of exogenous variables.[1] By contrast in any single simulation run the solution obtained is highly specific and consists of only a single set of time paths of endogenous variables. To determine how behavior of the endogenous variables is more generally dependent on initial conditions, parameters, and exogenous variables may require many simulation runs; and even then induction from specific results to general solutions will be required.

An individual simulation run may be thought of as an experiment performed upon a model. A given experiment involves operating a model after first completely specifying a set of initial conditions appropriate to the model, a set of values of the parameters used in specifying relations contained

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[1] There are many areas in which simulation is of importance to social scientists and to policy makers and the interested reader is referred to such useful starting points as provided by Adelman (1968), Clarkson and Simon (1960), Guetzkow (1962), Orcutt (1960), Shubik (1960a, 1960b).

in the model, and the time paths of those variables used in the model and treated as exogenous. Additional experiments would involve operating the model after respecifying the initial conditions, the parameters, and/or the exogenous variables. The problem of inferring general relationships from specific results obtained in individual experiments performed on a model is the same as that of inferring general relationships from specific experimental results in the inductive sciences. The scientist studying natural phenomena has no alternative. In principle the research worker, studying or using a model, could conceivably use a purely deductive approach, but with many models, this alternative has not proved feasible with known mathematical methods.

The simulation approach does permit, in principle at least, the solution of microanalytic models of economic systems. However, two methodological difficulties must be dealt with.

2.5 Monte-Carlo Simulation

The first is that the operating characteristics of the microanalytic models we wish to develop do not produce events such as death, but rather the probabilities of such events. For purposes of within period tabulations, having the probability of each event for each microunit is ideal. However, it is not a substitute for updating the initial population so that it may be used as an initial population for the following year's simulation. This need is met by use, along with simulation, of what is widely known as the Monte Carlo technique. For example, the occurrence of death is determined, in effect, by a random draw from a container of black and white balls containing the same proportion of black balls as the predicted probability of death. If a black ball is drawn, as it were, the person is simulated to die. In actual practice this is done by assigning death if the predicted probability of death is greater than a random number drawn from a uniform distribution running from zero through one. A similar procedure is used with other predicted probabilities. This method of dealing with probabilities is an unsophisticated yet powerful method which has come into wide use as a result of the development of the modern computer. This method capitalizes on two facts: first, it is possible to empirically approximate a multivariate probability distribution as closely as desired on the basis of an adequate number of random drawings from the distribution; secondly, it is frequently a great deal easier to obtain random drawings from a distribution than it is to analytically deduce the form of the distribution.

The following very simple example may be of help in seeing the potentialities of the Monte Carlo method in solving microanalytic-type models.

Example

Suppose that the density function, or some moment of the density function, of x/y is desired. Let this density function be denoted by: g(x/y). Also, let the following two single variate density functions be known:

$$f_1(x) \text{ and } f_2(y/x).$$

By the usual rules relating to density functions it is obvious that the joint density function of x and y may be expressed as the product of these two density functions. Thus,

$$f(x,y)=f_1(x)\cdot f_2(y/x).$$

A Monte Carlo procedure for obtaining an empirical approximation of g(x/y) would be as follows:

1. Draw random samples of x from the distribution specified by $f_1(x)$.
2. Use each such sample x to obtain a random drawing of y from the conditional distribution specified by $f_2(y/x)$.
3. Each x and associated y obtained in this way will be the coordinates of a point drawn at random from the bivariate distribution specified by f(x,y).
4. For each point drawn from the bivariate distribution, calculate the ratio x/y.
5. Form a relative frequency distribution of values of x/y and use it as an empirically derived approximation of g(x/y). The approximation may be made as close as desired, in a statistical sense, by use of a sufficiently large number of random drawings.

2.6 Sample Representation

The second remaining difficulty to be dealt with is that we wish to simulate the behavior of very large populations composed of entities characterized by many attributes. But as a practical matter how can the state of a population be specified or updated if it involves, say, ten or more variables for each of, say, 200 million components?

The solution is as simple as it is obvious. Any current or updated population may be represented by a random sample drawn from it. Means, variance, covariance, and other functions of the sample will be estimates of the corresponding functions of the population sampled. Fortunately, sampling variability of probability samples is a well understood function of sample size and has almost nothing to do with population size. Sample sizes of 10,000 or more families can be handled easily with modern computing equipment and are large enough to provide fully satisfactory accuracy of population representation for a very large variety of applications. In addition full accuracy of representation at the individual microunit level is retained.

2.7 Output Possibilities

In microanalytic simulation, as in the Ruggles & Ruggles (1973) approach to national accounting, samples of microunits are conceived of as representing corresponding populations. One convenience of this in national accounting is that any possible aggregation or tabulation of the microdata can be done on request at low or moderate cost. This is not generally feasible with a cell frequency approach to representation of a multivariate population since, as pointed out in discussing the transitional matrix approach to solution, even a ten-way, single-digit classification scheme would require ten billion cells if loss of flexibility and information is to be avoided.

Projections. In MASS the population of families and component individuals is represented at every stage in a simulation by a probability sample which can be made available to users on request for any analysis and tabulation which could be made of a corresponding sample of a real population of families and component individuals. Since a microanalytic simulation uses a behavioral model which advances a sample representation of a population in time, future states of a population can be projected by carrying out a simulation. Thus, it is possible to analyze, tabulate, or otherwise aggregate the sample representation of a projected population in any way which was feasible with the initial sample of an actual population.

Microunit Histories. A second possibility, which is distinct, but follows closely on the first, also emerges. A microanalytic model, such as ours, can be used to advance an initial sample based on, say, the 1960 Census Public Use Sample, year by year until the present. Time series outputs can be compared with available national accounts time series, and cross-sectional outputs can be compared with sample and census data over the years since 1960. The model can then be aligned so as to yield results in agreement with actual developments, the actual initial state of the real population in 1960, and what is known about accounting and behavioral relations. When this has been achieved, running the aligned model over the historical period since 1960 would yield a pieced together microunit data bank of a historical period in terms of time paths of a sample of microunits.

This way of merging and molding many disparate bodies of data and of available understanding could be regarded as yielding an augmented census-type public use sample of individuals and families for each year starting with 1960 up to the present. Such generated samples could be used in ways similar to the ways actual public use samples are used. The advantages would lie (1) in having such samples for years not otherwise possible, (2) in having samples for successive years actually linked between years at the individual and family level, which may be desired for considering tax averaging schemes, for example, and (3) in having a richer description of microunits than is possible on the basis of any single survey. Inclusion of wealth and portfolio attributes along with income and demographic attributes would have obvious advantages for exploring the burden at the family and individual level of different approaches to taxation.

Policy Experiments. A third class of output capabilities which is inherent in our microanalytic simulation approach is that of carrying out policy experimentation by altering the time paths of input variables of the model or by altering the parameters or other specifications of the model. Tax laws, social security laws, or income maintenance arrangements might then be simulated - both with and without changes that are being considered - so that the likely consequences of proposed policy changes could be estimated.

Sensitivity Experiments. The capability of predicting implications of policy changes also means that sensitivity studies can be made of the dependencies of simulation outputs on parameter specification. Results from such studies can help guide subsequent behavioral research studies in fruitful directions by showing where improved precision in estimation would really matter.

2.8 Holding Monte-Carlo Variation Constant in Experiments

For a number of reasons, it is desirable in policy experiments to control the Monte Carlo variability of the microanalytic simulation. The variability results from the use of pseudo-random numbers to decide which events are simulated to occur and which are not. We use a technique of dispensing random numbers which causes the same decisions to be made with the same random numbers from run to run. This procedure yields three related but distinct advantages.

The most important advantage is the separation of the Monte Carlo variability of the simulation from the effects of a treatment or experiment. This allows the social scientist to approximate the method used by a physical scientist, whose experiments consist of a control group and a treatment group. The only difference between the two groups is the fact of the treatment. The environments, including the random numbers, are the same for both groups. Our technique means that an observed change between a control run and an experiment run can be attributed to the effect of the treatment with more certainty.

A second advantage is that alignment of the model with historical data is easier and more precise. With Monte Carlo variation controlled from run to run on identical populations, a changed probability for an event such as a marriage or death will reduce the number of occurrences of that event proportionally. Thus, if we find that the model simulates too many births in a particular year, we can reduce the birth probabilities by the proper percentages to align the model as closely as desired to historical marginal distributions or cross-tabulations.

The third advantage of the method is that it permits smaller sample sizes. Since the total Monte Carlo variation declines with increasing sample size, we might normally desire to run with as large a sample as possible. But when we are looking at differences between control and treatment runs, the Monte Carlo variability will be replicated in the two runs.[1]

---

[1] In mathematical terms, we have taken two previously uncorrelated random variables (the control run determination being X and the experimental value being Y), and correlated them by using the same random numbers to make the stochastic decisions. For uncorrelated X and Y, the variance of the difference is the sum of the variances:

Var(X-Y) is given by Var(X) + Var(Y)

For correlated random variables, however, the variance of the difference is the sum of the variance minus the covariance:

Var(X-Y) is given by Var(X) + Var(Y) - Cov(X,Y)

The covariance of X and Y is almost equal to the sum of the variances because the random numbers used to determine X and Y are the same. (It is not quite equal because a treatment might result in different people dying or being born, but that effect is small for most treatments.)

For an excellent review of the literature and a discussion of random number assignment in simulation and distribution sampling experiments see Schruben and Margolin (1976). The two simulation variance reduction techniques which they find to be very helpful and which they focus on are the use of <u>common pseudo-random numbers</u>, and the use of <u>antithetic pseudo-random numbers</u> for different experimental points. Our procedure seems to be an example of the first of these. The second could easily be used if desired.

The random number technique described above may be implemented by giving each population member (person, family, and interview unit) a random number stream of its own. Random numbers are taken from this stream at the same rate whether or not events are simulated to occur. The stream is defined by a kernel or seed that is used to generate subsequent random numbers. When an operating characteristic requires one or more random numbers, it uses the current value of the appropriate seed to generate them and then stores the seed associated with the last random number drawn as an attribute of the population entity for use by the next operating characteristic.

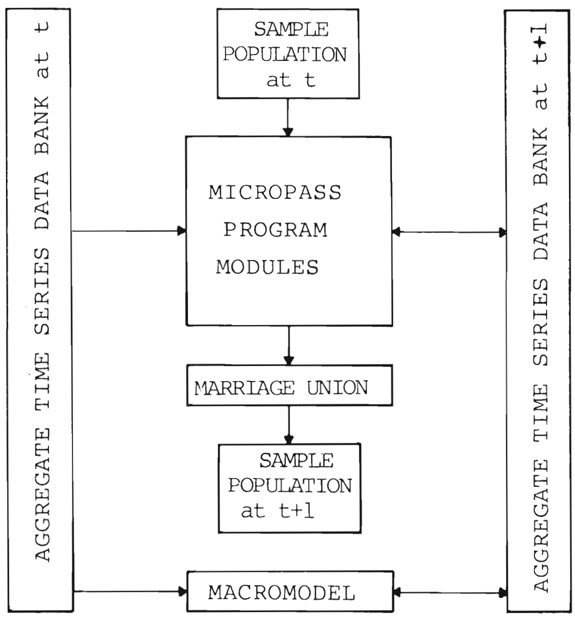
2.9 Solving MAM

It is now easy to see how a model such as MAM can be solved. First a sample population for year t is obtained. The operating characteristics are then applied to the families and individuals of the sample to obtain the probabilities of events. These probabilities are compared to random numbers, and if the probability is greater than the random number drawn the event is simulated to occur. In this way, a sample population for year t+1 is obtained and the process can be iterated.

In addition, the marriage union model and the macro model can interact with the operating characteristics of the micro model through common data bases. For example, the aggregate unemployment rate can affect the probability of a person's being unemployed, as calculated by an operating characteristic.

The relationship of these models and the data is schematically shown in Figure 4. MASS, a microanalytic simulation for the computer execution of microanalytic models is described in the next section.

Figure 4. Relation of Major Program Sectors to Updating of Micro and Macro Data Files



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3. MASS - A MICROANALYTIC SIMULATION SYSTEM

3.1 Introduction

MASS (MicroAnalytic Simulation System) is a set of computer programs designed to execute microanalytic models. In particular, MASS can execute MAM, a version of DYNASIM which is a microanalytic model developed at the Urban Institute and described by Orcutt *et al*.

MASS has several attractive features.

- Low cost of execution. A ten year simulation of the complete MAM model, with an initial population of about ten thousand persons costs under one hundred dollars. Indeed, if smaller populations and a subset of the model are used, MASS is inexpensive enough to be used for student exercises.

- Ease of modification. MASS was *designed* with the idea that most researchers will want to modify or expand it. Such modification is both simple to conceive, and inexpensive to program.

- Modular organization. MASS is highly modular. Program modules can be added or deleted with little need for modification of other modules. The user need only run those modules he wants, and need not pay added execution and storage costs for those modules he does not use.

G. Orcutt et *al*., *Policy Explorations through Microanalytic Simulation* (Washington, D.C.: The Urban Institute, 1976). But MASS is a general system, and with some modification can support models other than MAM as well.

The initial simulation system developed to execute DYNASIM is a powerful but costly system named MASH. It is described in George Sadowsky, *MASH: A Computer System for Microanalytic Simulation for Policy Exploration* (Washington, D.C.: The Urban Institute, 1977).

- Simplicity. Although by necessity a moderately long program, each MASS module is short and simple. No convoluted programming "tricks" are used and the precepts of good structured programming are followed throughout. Aided by the documentation provided, a programmer should be able to read and understand MASS's inner workings.

- Standard language. MASS is written solely in PL/I. There is no need to learn any new language peculiar to MASS.

- Portability. MASS can be run on any IBM 360/370 computer which has the PL/I optimizing compiler and about 300K of memory available.

- Interaction with other models. MASS not only executes a microanalytic model, but can also couple this micro model with models at a higher level of aggregation. DYNASIM's macro model is one example of such an interaction between a macro model and the microanalytic model.

- Simultaneous use of different bodies of data. By having available in core different bodies of data, all these data can be used simultaneously. For example, data on health statistics organized on the country level can be brought to bear on data from the Census Public Use Sample for individuals from the same county.

The basic idea of executing a microanalytic simulation is simple. Each micro unit in a population (e.g., a family, an individual, a firm, a neighborhood) is sequentially read into memory. The variables pertaining to the micro unit are then updated by the application of various modules. A new population has thus been created after all the micro units have been processed. This new population can then serve as an input for the next year's simulation. In addition to the model incorporated in the operating characteristics, MASS implements two other models. The marriage union model is executed at the end of a year's simulation (after the operating characteristics have been applied to all individuals) to form new families from individuals who were selected to be married. The macro model, also executed at the end of the year's simulation, imputes values to such variables as aggregate unemployment and the price level based on statistics gathered at the micro level during the course of the simulation.

3.2 Core Environment

The interface between the operating characteristics, and between the micro model and other models, is performed by the storage of variables in core.

The updating of variables by operating characteristics is also performed in core. This makes an understanding of the core environment essential for comprehension of how MASS works, and of how MASS can be extended. Each core area described here is illustrated in Figure 5.

The MACRO TIME SERIES area of core stores historical and generated macro time series data required by the OPERATING CHARACTERISTIC modules and by the MACROMODEL module. MACRO TIME SERIES data for the current year and for two past years are present in core. At the end of each pass, data are brought into and taken out of core to maintain the appropriate values.

Parameters used by operating characteristics are stored in the OPERATING CHARACTERISTIC PARAMETERS.

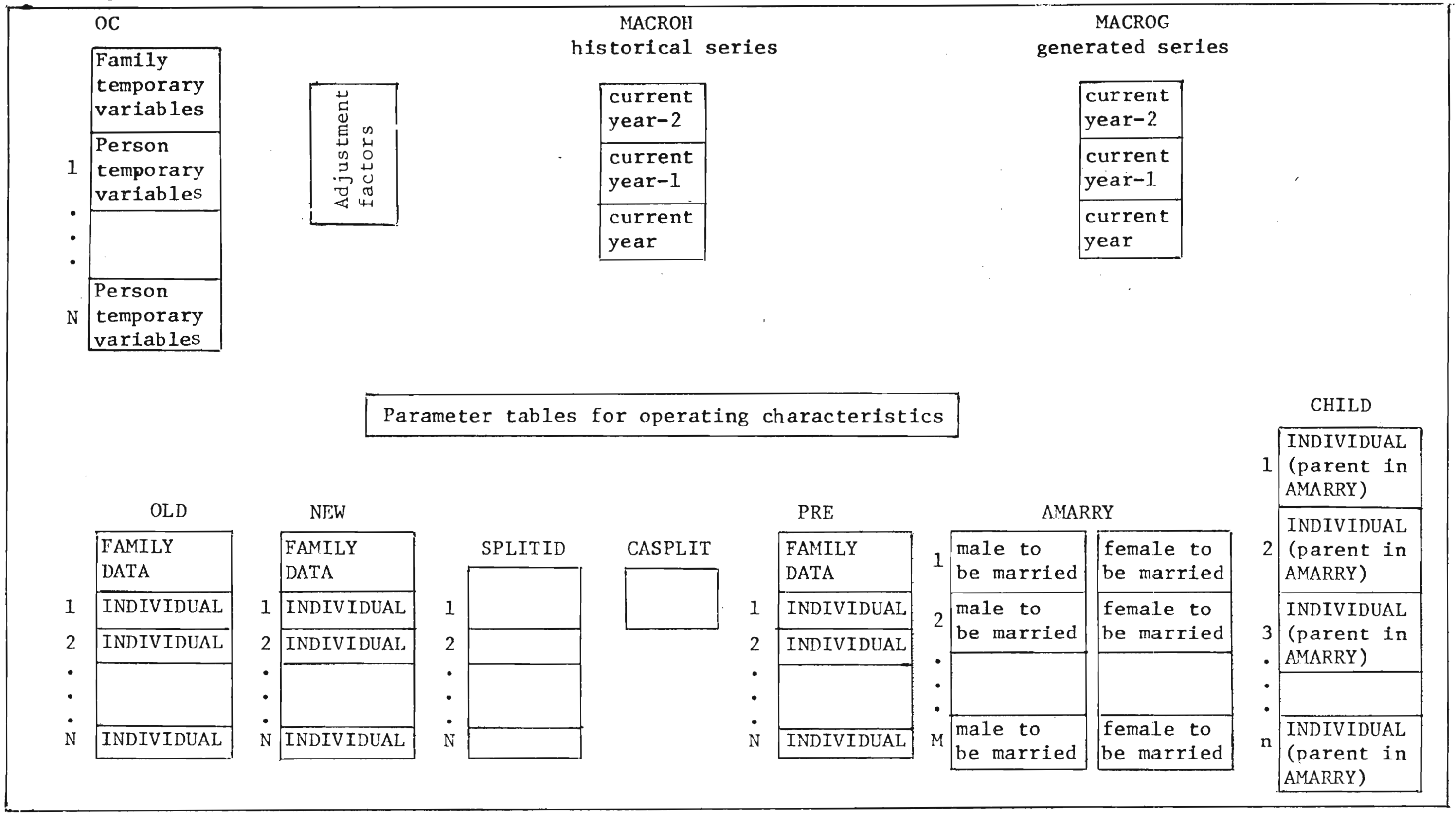
User control variables, which permit the user to adjust the probabilities associated with operating characteristics, are allocated an area of core entitled ADJUSTMENT FACTORS in Figure 5.

Records of females and males to be married at the end of the year are stored in AMARRY. CHILD is a separate list of children whose parents are to be married.

Other areas of core store new and old attribute data for a family and its members. The data belonging to a family are read from the input file into the OLD core storage area. The data are then copied into the NEW area of core.

When operating characteristics are applied to a family, the data in the OLD area are not changed. Updated values of variables are entered in the NEW area. Thus, any operating characteristic can refer to data in either the OLD or NEW areas. At any point in the simulation, the values in the NEW area depend on which operating characteristics have been previously applied to the family.

Figure 5



OC
Family temporary variables
1 Person temporary variables
N Person temporary variables
Adjustment factors
MACROH historical series
current year-2
current year-1
current year
MACROG generated series
current year-2
current year-1
current year
Parameter tables for operating characteristics
CHILD
1 INDIVIDUAL (parent in AMARRY)
2 INDIVIDUAL (parent in AMARRY)
3 INDIVIDUAL (parent in AMARRY)
n INDIVIDUAL (parent in AMARRY)
OLD
FAMILY DATA
1 INDIVIDUAL
2 INDIVIDUAL
N INDIVIDUAL
NEW
FAMILY DATA
1 INDIVIDUAL
2 INDIVIDUAL
N INDIVIDUAL
SPLITID
1
2
N
CASPLIT
PRE
FAMILY DATA
1 INDIVIDUAL
2 INDIVIDUAL
N INDIVIDUAL
AMARRY
1 male to be married
female to be married
2 male to be married
female to be married
M male to be married
female to be married

If any splits occur in the family (for example divorce, or a child leaving home), the fragments of the family are written sequentially into PRE. Data for the original family are left intact in the OLD and NEW areas. SPLITID (a substructure of OC) and CASPLIT are used in implementing splits.

After the family is processed, the PRE or NEW structure, whichever is applicable, is written out on tape.

The OLD, NEW and PRE areas are PL/I structures.

The number of individuals per family stored in core is limited to 10. This limitation is unimportant in practice, because it is rarely exceeded.

OC stores variables generated by the operating characteristics. These variables are temporary ones and are not written out on the output file.

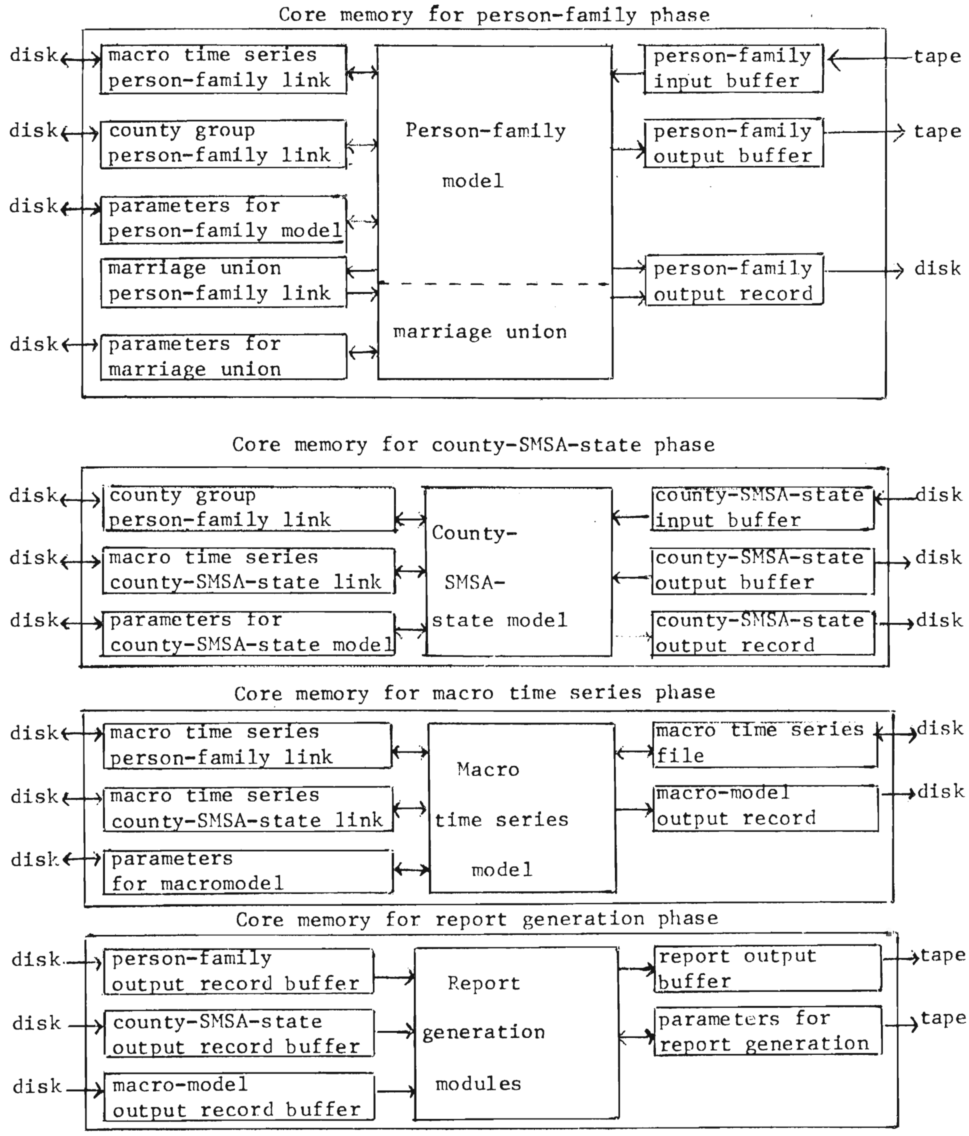
3.3 Area Specific Data and Macro Time Series

Researchers may find it useful to run models other than a microanalytic one in interaction with the person and family data generated by the micromodel. MASS in fact does this in the case of the macromodel. The macromodel and the micromodel interact through the availability in core of data generated by one model while the other model is being executed.

The same approach can be used with a county-SMSA-state model. During the execution of the micromodel, area specific data can be made available which serve as inputs to the micromodel. Similarly, summary statistics generated by the micromodel can be used as inputs to the county-SMSA-state model.

Figure 6 schematically shows this arrangement. At any one time only one model can be executed. But this model can interact with the other models by data links. (Note that in the present version of MASS there is no county-SMSA-state model).

Figure 6. Gross Features of Core Memory Structure



3.4 User Modification of MASS

Program Control

MASS is unadorned, almost to the point of being primitive. An unskilled user cannot operate MASS without the assistance of a programmer.

Control of MASS execution rests with simple control modules. The specification of a simulation run consists of the user writing some control modules (in the programming language PL/I), compiling (translating the program written in PL/I into machine language), and link editing with other modules (resolving the cross references between modules). For example, to specify the order in which operating characteristics are to be applied the user writes an appropriate EXECUTIVE MICRO-EQUATIONS module.

MASS runs only under batch and does not at present support interactive use. Therefore, a user oriented command language, allowing control specification during execution of the simulation, is not provided. At a later date, however, these features could be introduced with little modification of the bulk of MASS.

The provision of a user oriented command language could make use of MASS more convenient in some cases. But, there are some advantages to our system.

1. Ease of development. The implementation of an elaborate command structure can be an expensive and time consuming process.

2. Flexibility. By having the user write his own command routines, MASS does not limit the user to any predetermined command types nor to those types of changes that we could have thought of. MASS permits the simple introduction of new operating characteristics, almost unlimited reordering of these operating characteristics, and easy implementation of interaction between subroutines.

This approach means that a programmer is needed to install or modify MASS. Such a programmer should know PL/I and Job Control Language. This knowledge need not be at the systems programmer level, but it should be above the level of an introductory computer course. Because we were aware that changes will be made in the program, MASS was written to allow modification in a simple and error-free way. The Programmer's Reference Manual discusses in detail how modifications and extensions can be made.

Modularity

MASS is highly modular. Indeed, rather than viewing MASS as one massive program, it should be seen as a collection of modules. The modules are relatively independent of each otHer, so that modules can be added, deleted or modified with ease.

The advantage of modular programming are well known and will only be reviewed briefly.

1. Efficiency and Flexibility. A simulation run uses only those subroutines it actually needs. By proper link-editing and loading of the modules into core, no core storage is wasted on subroutines that are not called during the simulation.

   Modularity permits the user to substitute a module of his own making for one which he finds less satisfactory, while still employing the other modules of MASS. Such flexibility adds to the overall efficiency of the MASS system.

2. Program development. Modular programming greatly eases the problem of developing a system. Not only is it simpler to write any one module, but several programmers can work on different modules simultaneously.

3. Overlaying. Although MASS does not overlay modules, by using modules, program segments can be overlaid in core, thus conserving storage. For example, the output routine for printing could be loaded into core only when it is called, rather than residing in core during the entire course of the simulation run. In addition, if overlaying is used in MASS the system could fit on small computers.

3.5 Microdata Sequencing

One Pass System

MASS uses a one pass per year system. For any one year of simulation, only one pass is made through the data; in a ten year simulation, the family data are read into core ten times, and written onto tape ten times. There are two cost advantages to a one pass system compared to a multiple pass per year system. First, the number of input-output operations required is reduced. Second, a one pass system facilitates the retention of both old and new value of variables in core. In contrast, a multiple pass scheme requires such operations as writing out on tape the old as well as the new values of variables, and then rereading this data on the next pass.

Sequential Processing

MASS stores and processes data sequentially, rather than using a random access capability. MASS reads data into core in the same order as it is found on the input tape. This ordering is preserved during processing, so that the output tape has the same ordering as the input tape. An entire family is processed before proceeding to the next family.

The primary advantage of sequential processing in the cost reduction of input-output operation for the run. A second advantage is that sequential processing allows the use of tapes rather than disks for on-line storage; at many computer installations, disks are less readily available and more expensive than tapes. A third advantage is the simplicity of sequential processing. The programmer knows at all times where a particular item of data is, and how expensive it is to access that item.

The major disadvantage of the sequential method is that operations involving interactions between family units are somewhat difficult. For example, special arrangements must be made for the transfer of wealth from one individual to another. One solution to the problem is a Post Office device described in section 3.7. The Post Office is a location in memory where a person can leave messages for another person. The messages will be picked up by the individuals on the next pass.

There are some simulation activities, such as marriage unions, that cannot be implemented in a strictly sequential manner. Such operations require the use of a separate tape, disk, or core, for the storage of temporary data. This does not affect, however, the sequential nature of the rest of the program.

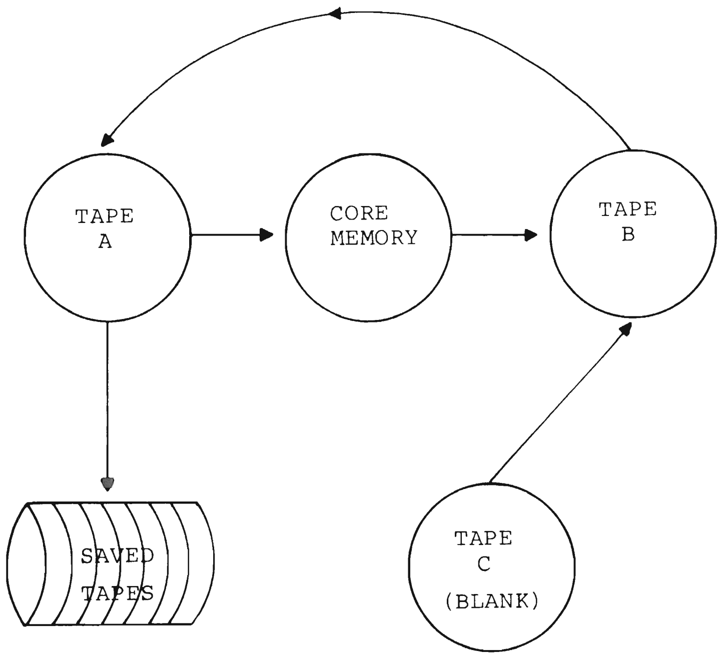
Multiple Tapes

MASS employs a multiple tape system. As illustrated in Figure 7 family and person data are read into core memory from tape A, updated when resident in core, and then written on tape B. For the following year, tape B serves as the input tape. Either tape A, or another tape, can serve as the output tape. For many purposes, it is useful to save each output tape and not to write over the data on it. The resulting series of tapes provided by the simulation contain the data necessary for a panel study.

One attraction of a multiple tape system is that it protects the user from many of the losses associated with computer or program error. In the event of failure during a simulated year, the previous year's results are still left intact.

It should be emphasized that the formats used in the input and output tapes are identical. Any output tape can be used as an input tape.

Figure 7



3.6 Data Organization and Attributes

1. Importance of Data Organization. It is envisaged that typically MASS will be run with samples of 10,000 - 200,000 individuals, for simulations of 10 years or more, and with samples of 200,000 - 2,000,000 for short runs. Because input-output (I/O) is a significant expense for runs of this magnitude, the form of data organization is important.

   In addition, the data scheme must allow for changes in family composition such as births, deaths, divorces, marriages, or home-leaving. The essential features of the MASS form of data organization on tape are presented below.

2. Hierarchical Organization. MASS uses a hierarchical organization of the population data; the population is composed of families; families in turn are composed of individual members of the family. No provision is made for interview units, although MASS can be easily modified to accomodate them. Members of a family reside sequentially on tape. Therefore, there is no need for pointers to link the members of a family, or for random access of within family members.

3. Modular Data Organization. Data on tape consist of a series of fixed length FAMILY and INDIVIDUAL records. Schematically, the tape organization is shown in Figure 8.

   Figure 8

FAMILY 1 DATA RECORD	INDIVIDUAL 1	INDIVIDUAL 2	FAMILY 2 DATA RECORD	INDIVIDUAL 1

   The data for a family consist of a sequence of records. There is no physical delimitation of a family. That is, family data do not constitute a physical record or block on tape. The first record belonging to a family is the FAMILY DATA record. Each FAMILY DATA record is followed by INDIVIDUAL records, one for each member of the family. The FAMILY DATA record contains such information as the family's identification number, a seed for the random number generator, or the family's income.

Such data referring to the entire family will not be duplicated in the INDIVIDUAL records. The FAMILY DATA record also contains the number of individuals belonging to that family. After the FAMILY DATA record is read into core, a DO loop is set up to retrieve sequentially the individual records of all members of the family. Note that a FAMILY DATA record need not be of the same length as INDIVIDUAL records.

Records are blocked for efficient I/O. (A block is a collection of records. Blocks are separated on tape by inter-block gaps.) The blocking is done automatically by PL/I, and is transparent to the programmer. The programmer, however, can control the size of records and blocks through the use of Job Control Language cards.

Modular data organization is flexible enough to permit variable family sizes without wasting space. The number of INDIVIDUAL records for a family is exactly equal to the number of members in the family. The composition of a family can be easily altered. An individual is removed from a family by not writing out the individual's record on the output tape, and by updating the FAMILY data record to reflect the new number of members in the family. Addition of an individual to the family is accomplished by the reversal of the deletion process.

Figures 9-11 schematically show MASS's sequential operation. Figure 9 shows the initial situation, there being two families on the input tape. Assume that individual B dies, and that E leaves home to form his own family.

Figures 10 and 11 show that each family is read into OLD in turn, and the updated families are written on the output tape.

Figure 9

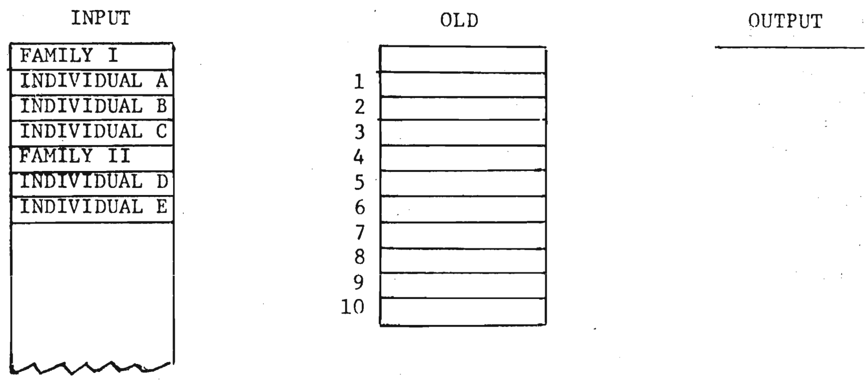


Figure 10

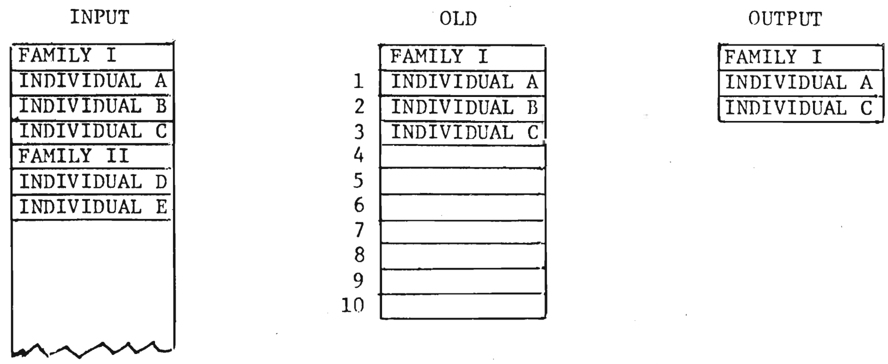
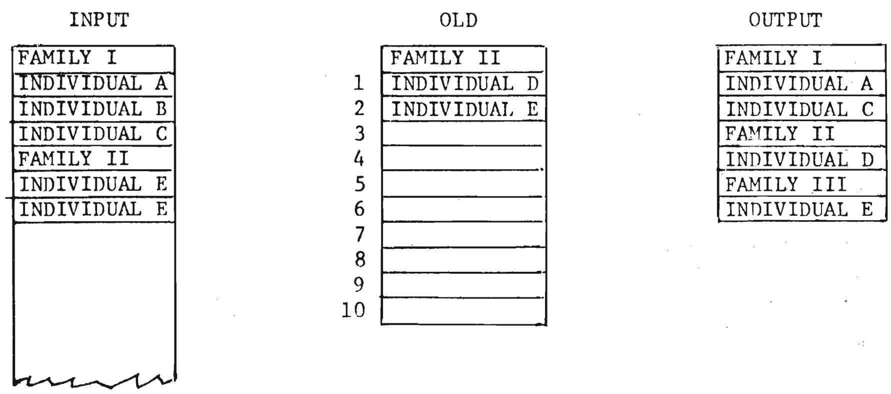


Figure 11



3.7 Specialized Facilities

File Restructuring

In addition to implementing simulation models, the MASS core environment provides an easy method of restructuring files. Given an initial data tape, the user can use MASS modules to generate another tape; the generated tape can then be used as input for subsequent simulations.

There are three mechanisms which modify input tapes.

1. MASS can allow the NEW area of core to be different from the OLD area in content, length, and structure. For example, values of NEW attributes can be generated on the basis of the data in the OLD area. These new variables can then be stored in the NEW area of core. Or, variables coded in one format in the OLD area, can be coded in a different format in the NEW area. The data in the NEW area are then written on the output tape.

2. The data read into the OLD and NEW areas can come from different sources. This allows data from two tapes to be aggregated.

3. Not all the data in the NEW area of core has to be written out. For example, by selective writing the user can easily generate from the input tape a sample of the population, consisting of,say,all families with income less than $5,000. Similarly, a subset of the variables on the input tape can be selected to be written on the output tape.

Post Office

It is often convenient to permit communication between individuals during a simulation. For example, we want to implement a mechanism for transferring wealth from parents to their children.

In the sequential operation that MASS uses, it is impossible to randomly access an individual. To overcome this limitation, we use a Post Office scheme. At each pass, the individual accesses the Post Office to both receive and send messages.

A Post Office requires an addressing method. Therefore, each INDIVIDUAL record contains a unique identification number. This number remains invariant during the run, no matter where the individual is physically located on tape. In addition, each INDIVIDUAL record contains an address book; the address book consists of the identification numbers of the parents, children, or former spouses of the individual.

The Post Office is a two dimensional array, as shown in Figure 12. To illustrate how the Post Office works, let's assume that a parent wants to give $10,000 to a son who has left home. At the pass for year t, the parent looks up in his address book the identification number of the son. The parent then enters in the next available slot in the Post Office array the identification number of the son (the addresses), and the message he is sending.

At the end of the pass, MASS sorts the post office by identification number, from the lowest number of the addressee to the highest number. The sorted Post Office permits efficient retrieval of messages during the next pass.

During the pass for t + 1, each individual accesses the Post Office. If the individual's identification number does not appear in the addressee field of the Post Office array, then that individual receives no message that year. If the individual's identification number does appear, then the corresponding message is retrieved.

Figure 12

Addresses Identification Number	Message
53872	received $8,500
28194	received $500

Some of the limitations and extensions of the Post Office scheme are:

1. It takes a year (i.e. a pass) for a message to be transmitted from one family to another. This compares favorably with the performance of the U. S. Postal Service.

2. Different types of messages can be sent. For example, a son who had previously left home can inform his parents that he has been married.

3. More than one message can be sent or received by a family.

Increasing the Population at Negligible Cost

For some purposes, very large populations are needed. For example, the top 1% of wealthholders own some 20% of the country's wealth. To have an adequate sample of this one percent, a very large population is needed. This can be quite expensive. In some cases there is a simple and elegant solution. For many purposes, individuals in wealthy families resemble individuals in other families. Thus, instead of increasing the number of individuals in the simulated population, we can replicate families. Each such replicated family has the identical characteristics and individuals as the other families, except for wealth associated variables. A family unit, representing n families, would be depicted as:

```
FAMILY record
    Wealth subrecord 1
    Wealth subrecord 2
    Wealth subrecord n

INDIVIDUAL 1

INDIVIDUAL 2
```

Except for operating characteristics applicable to wealth, the simulation would be unchanged.

Tracking

The user may want the simulation to track some exogenously given time series. For example, the user may want to see what the population would look like with different death and birth rates. A version of MASS easily provides such a tracking facility. Tracking is performed by having two passes for each year of simulation. In the first year a complete simulation is performed and a tally kept of the number of events of interest generated, for example the number of deaths. Based on these tallies and the values which are to be tracked, adjustment factors can be calculated for the probabilities of events. For example, if the first pass generates a death rate of 1%, and the desired death rate is 1.1% then the adjustment factor is about 1.1. These adjustment factors are then used in the second pass of a year's simulation. By replicating Monte Carlo variation, the output of this second pass can be made to closely tract the desired values and the output tape from the second pass can be used as the input tape for the following year's simulation.

Controlling Monte Carlo Variation

As discussed in Section 2 the researcher may find it desirable to control the Monte Carlo variability of the simulation. MASS incorporates a facility for doing this by providing random number seeds for each family and individual so that the same random number stream can be generated on different runs.

3.8 MASS Hardware and Software

Hardware

Because MASS is written in PL/I, it can run on virtually all IBM 360/370 computers, but usually not on other computers. An advantage of using IBM computers is their wide availability. For example, researchers at the universities of Alberta, Toronto, Cornell, Pennsylvania State, and Yale have ready access to IBM equipment but not to other manufacturer's computers. Note that charging algorithms differ widely among computer centers. Therefore, the cost of running the identical simulation under MASS will vary between different installations.

Software

1. PL/I

MASS is written in the programming language PL/I. We think it desirable to use a general purpose programming language, rather than a language specially designed for simulation. Compared to simulation languages such as SIMSCRIPT or GPSS, PL/I offers greater flexibility in programming, and increased efficiency in execution. The alternative language considered most seriously was FORTRAN. FORTRAN has the advantage of being more widely known and available than PL/I. But, PL/I does offer some advantages.

(i) Input-output. PL/I has several I/O options. I/O can be stream oriented (data stored in EBCDIC form) or record oriented (data stored in internal machine form on tape). Buffering is done automatically, with the programmer controlling the number and size of buffers. Logical records need have no relationship to physical records. These features, and others, make PL/I highly efficient in I/O operations.

(ii) Data structures. PL/I offers data representation in structures, which is unavailable in FORTRAN. A structure provides convenient hierarchical organization of data. Moreover, elements in a structure need not all have the same attributes. For example, a person's data could be organized in a PL/I structure as follows:

```
1 PERSON
  2 EDUCATION CHARACTER (1),
  2 AGE BINARY FIXED,
  2 JOB EXPERIENCE,
    3 JOB 1 BIT (1),
    3 JOB 2 BIT (1).
```

All elements of a structure are called by name. Also, PL/I permits the construction of an array of structures. This is useful for storing all the individuals in a family.

(iii) Manipulation of bit strings. PL/I has language features that simplify the storage and manipulation of bit strings.

(iv) Management of storage. PL/I allows the core storage for variables to be automatically allocated and freed upon entering and leaving blocks or subroutines. Variables can also be individually allocated or freed at any point in the program. For example, assume that subroutine A uses an array of length 100 words; subroutine B uses an array of length 90 words. With proper management of storage, only 100 words of memory are needed by the program, rather than 190 words which might otherwise be needed.

(v) Structured programming. PL/I facilitates structured programming. Proper programming style can increase the readability, efficiency, and maintainability of programs. In particular, the use of structured programming can improve the efficacy of programming, both in the time needed to program, and in the final product.

Structured programming emphasizes only three logical constructs:

a. sequential (no branching or GOTOs).
b. selection (if condition a, then...., otherwise....)
c. repetition

PL/I makes structured programming convenient, by offering the following features:

a. Grouping of program statements by the use of BEGIN blocks or DO groups.

b. A simple selection syntax - IF condition THEN group of statements ELSE group of statements.

c. The DO WHILE statement which repetitively executes a group of statements as long os some condition is true. The DO WHILE syntax is more flexible than FORTRAN's iterative DO loop. Indeed, MASS does not have even a GO TO statement.

(vi) Debugging facilities. The PL/I compiler provides a listing of all identifiers and their attributes. This allows misspelled identifiers to be spotted easily. The CHECK option allows the programmer to trace through the changes in values of a variable. A PL IDUMP provides a count of executed statements and a listing of branches executed. Finally, the PL/C compiler offers a wealth of debugging aids.

MASS is written with the PL/I Optimizing compiler. The optimizing option is disabled during program development to increase compilation speed. For the production of an efficient object code, the optimizing option is enabled. The PL/I Level F compiler is not used. It is outdated and produces inefficient code. Furthermore, object code produced by the Level F compiler cannot be linked with code produced by the Optimizing compiler.

PL/I is able to link with object code generated by FORTRAN, COBOL, or IBM 360/370 ASSEMBLER. Thus subroutines written in FORTRAN can be incorporated into MASS.

(vii) Assembler language. The use of any compiler results in the production of some inefficient code. But experience has shown that about 90% of the possible increase in execution efficiency can be obtained by improving only 5% of the code. To ease the programming efforts, MASS does not contain program segments written in assembler language. At a later stage, however, critical portions of MASS can be rewritten in IBM 360/370 ASSEMBLER.

2. TPL*

(i) Introduction. Although the user can write his own small programs to produce statistical tables containing MASS output, it is probably easiest to produce well labeled tables by linking MASS to an existent statistical package. After some experimentation with different statistical packages, we concluded that the Table Producing Language, TPL, was best for our purposes. In particular, TPL has the capability of producing nicely labeled tables, which contain large numbers of observations and variables, very cheaply.

(ii) General Use of TPL. TPL has two components, a codebook and the language which produces tables. The codebook contains a description of the physical characteristics and content of the input data file. TPL converts the data, using the information contained in the codebook, into a format used by the second component. The language which produces tables contains many formatting commands which give the user great flexibility in producing tables. By using NESTING and CONCATENATTING operators, the user can produce layered tables. For example, the command REGION, AGE THEN INCOME BY SEX produces a table of the form:

	AGE=1		AGE=2		INCOME=1		INCOME=2	
	SEX=1	SEX=2	SEX=1	SEX=2	SEX=1	SEX=2	SEX=1	SEX=2
REGION=1	X		X	X	X	X	X	X
REGION=2	X	X	X	X	X	X	X	X

* This statistical package was programmed by the U.S. Department of Labor, Bureau of Labor Statistics, Office of Systems and Standards, Division of General Systems.

(iii) Linking TPL with MASS. Two types of tabulations are envisaged. First. TPL can be run on data provided by the MASS output tapes. Second, TPL can be used to format and print tables created in core when NEW, OLD, OC, MACROH, MACROG, and PRE are available. For example, the average probability of death can be tabulated by sex and age if the appropriate tallies are included in INCREMENT REPORT GENERATOR. After all individuals have been processed, the cell values can be written on a disk as a data set, which can be input into TPL to produce well formatted tables.

THE SWEDISH MODEL

A MICRO SIMULATION MODEL OF A NATIONAL ECONOMY

Gunnar Eliasson

This micro based macro model has been built with the primary intent to use it as a tool to investigate two problems in particular, namely

(1) the micro basis for inflation - assuming that this is a relevant and interesting area of inquiry and
(2) the interaction over time between inflation, profitability and economic growth.

As we will soon find out below a byproduct of this ambition will be a skeleton theory of an economic system in total disequilibrium at the micro (market) level being bounded upwards each time by an exogenous technology constraint. We will find (and especially so in the later application papers) that we are particularly interested in the stability properties of the total system that also define the lower limits of the activity domain of the entire system.

The model is of the microsimulation kind in the sense of Bergman (1974), Orcutt (1960, 1976) etc. The major difference is that we study business decision units (= firms) in an explicit market environment, rather than subindustry aggregates or households, and perhaps that we have allowed very little detail to enter the model.

The philosophy behind the model is that we need more knowledge of the interaction between micro agents (firms, households, etc.) in markets to understand important aspects of <u>macro</u> behaviour. This is thought to be particularly so when it comes to studying the mutual influence over time between changes in the general price level and aggregate economic activity levels.

The two purposes overlap and general experience is that the second purpose requires a micro approach to be meaningful. The first question requires a complete model covering all relevant sectors of the economy, however, with limited detail in specification. As long as we abstain from asking for numerical estimates or forecasts the empirical requirements on specification are reasonable.

They are, however, much higher if we want to deal with the second problem: "inflation, profits and growth" in a relevant way, although, this time, demands on economywide coverage are not so large. Emphasis is on the business sector. We may reformulate this second problem somewhat as an analysis of the interaction between long-term growth and the business cycle.

Of course, if we have built a model that can handle the above problems to our satisfaction it should be capable of handling several others as well. In fact, one ambition of ours is to catch as much as possible of the true market based economic system at work through being as explicit as possible in modelling the market process at the micro level and how market price information is interpreted by firms. In order not to take on an overwhelming task we have struck a convenient compromise in specification that, however, does not - I believe - reduce the explanatory potential of the model or subject us to extreme empirical hardships. For the time being we have constructed a conventional, and in no way complex, macro model within which a micro (firm) specified industry sector operates. This approach allows us to keep our special feature, namely a micro specification of the behaviour of two types of markets: The labour market and the product market and to some extent also the money market.

We have to keep in mind that the prime ambition with this modelling project is to have a richly specified model structure capable of responding to a spectrum of interesting what if questions. The purpose is analysis, not forecasting. The idea, however, is not to model every possible circumstance of some interest or to forecast minute details. The potential of this model is that it can capture essential dynamic features of a fully specified market process, never in equilibrium, and to study what this core-mechanics of a market based industrial economy means for macro behaviour.

This paper will contain a non-formal overview of the model.[1] There will also be an account of the estimation or calibrating principles involved and a few words on the empirical philosophy of the method: does it differ from conventional econometric method? A partial mathematical specification concludes the paper.

This paper is self-contained for those who are only interested in what the model is all about, without understanding exactly how it behaves at the macro level.

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1) A full description of the model as it stood in November 1976 is found in Eliasson (1976 b). Since then a full public sector with a tax system and a money sector have been entered together with a number of improvements and revisions. This overview covers these extensions and a full report is in preparation. See also Eliasson-Heiman-Olavi (1978).

2. MODEL OVERVIEW

Table 1 sums up the main blocks of the model and its connection with the outer world.

It should be noted that besides policy parameters there are three important sets of exogenous variables; foreign (export) prices, the interest rate and the rate of change in productivity of new investment.[1)]

The model operates by quarter on a set of future quarterly values on the exogenous input variables. The model will generate a future of any length, by quarter, on the national accounts format, excluding certain sectors like agriculture, shipping, construction, etc. that we have lumped together as an exogenous dummy sector, that interacts with the model as a cell in an input output matrix only (see below).

The choice of period in the model is stepwise and involves gradual bindings. In the long run firms are seen as planning their investments for a five year period[2)]. This leads to

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1) There are several, additional exogenous variables that are not important for the kind of problems we have chosen for analysis. They are left for the technical description under preparation. The rates of entry into and exit out of the labour force and Government employment, for instance, are exogenous.

2) This investment (long term) planning sequence is not yet in the model program. It has, however, been presented in much detail in Eliasson (1976 b, chapter 3). It should also be mentioned that the overall periodization choice for the model very much adheres to practice at the Corporate Headquarters level as described in Eliasson (1976 a). Further breakdown of periods than by quarter generally do not correspond to centrally coordinated decisions but are delegated down and sideways, and are generally buffered centrally, to allow some stability in the realization of top authorized decisions. This suggest that "undated tâtonnement" within the quarter should be a fair representation (see below).

final decisions for long-term borrowing. Profit targets and expectations are semi-hardened for the annual budget period but adjusted partially for outside unexpected influences by quarter - the period for which production decisions cannot be changed.

This may seem too long a period for some activities to be fixed, like buffered supplies out of inventories and short-term market pricing. Such further gradations of the finalization of decisions can be entered if we so wish. In order to keep the model structure and computing time within manageable dimensions we have, however, abstained from further detail here, for the time being. This means that finalization of decisions into action takes place through an undated and elaborate "tâtonnement" process within the shortest time period (the quarter) made explicit in the model.

For all practical purposes the problems we have in mind mean that the time horizon should be around five years or one full business cycle. We will come back to the horizon problem later. However, even if our attention is restricted to a 5 year time span, much of the calibration work that we will perform, requires that we check model behaviour over a much longer period (see section 3 below).

The best way to proceed from here is to go through the central model blocks one by one.

a) Total system

One way of describing the total model would be to associate it with a so called Leontief-Keynesian (L-K) model, which is a fairly well known class of models. Let us begin from the L-K model by:

(1) reducing the Leontief structure to 7 sectors (see Table 1 and Figure 1).

(2) Adding a Stone-type linear expenditure system on the Keynesian side together with all the conventional national accounts identities.

From this:

(3) Add saving and some non-linear features to the consumption system.

(4) Define all manufacturing industry sectors in micro terms as populated by individual firms.

(5) Make individual firm export ratios (coefficients) endogenous and responding to relative foreign-domestic price changes.

(6) Ditto for import side but at macro-sector (market) level.

(7) Introduce non linear production structure for each firm that makes labour coefficients in I/O matrix variable and endogenous.

(8) Ditto on investment side.

(9) Add buffer stocks of input and output goods for each firm in each sector.

(10) Make business expectations forming, profit targeting and production and sales planning explicit for each firm.

(11) Merge real - price - and money parts of model with:

(a) micro based labour market where wages are determined on the basis of the action taken by all agents in all sectors

(b) Semi-micro, product market where product prices are determined, and

(c) Macro-money sector that allocates financial flows and determines domestic interest rate.

(12) See to it that (in the process defined by (11)) business profits are determined endogenously and fed into each firm's investment function.

One could also say that the model has been built around a theory of firm behaviour, partly developed already in Eliasson (1976a), aggregated to the macro level through individualized labour, product and credit markets, the whole thing finally being encased in a Leontief-Keynesian macro structure.

The industry sector is conceived as the primary generator of material wealth in an industrial economy. Since an explanation of growth is a primary ambition of this project a relatively heavy emphasis has been placed on the industry sector. This also goes for the micro specification.

The real production and delivery structure of the model is pictured on a macro format in Figure 1. In the middle the four sectors that contain micro units (firms) are seen;

(1) RAW materials production

(2) IMED, intermediate goods production

(3) INV estment and durable consumption goods producing sectors

(4) CON sumer goods (non durable) producing sectors.

Each firm relates backwards, (leftwards) in this structure with its own set of input-output coefficients, some of which vary because of "non-proportional" stock formation.

There is an exogenous production sector (agriculture, housebuilding, etc.) that interacts with the other sectors only in the capacity of being a dummy cell in the I/O matrix.

The service and government sectors are denoted Z and G respectively in the input output matrix.

Left and vertically a vector of imports feeds into each production sector that includes finished goods for each sector (competitive products, endogenous I/O coefficients) and primary commodities as imports that are not produced in model economy.

Down and horizontally total product in each sector emerges. Part of each sector output is exported, the export ratio being endogenously determined. Summing X horizontally and IMP vertically and taking the difference gives the trade balance to the left. Correcting total supplies for the trade balance gives GNP to the right.

In the upper horizontal vector total labour input in each production sector is shown. Combined with wages determined endogenously they give total disposable household income before all taxes, including the payroll tax (DISP top right).

After subtraction of taxes that feed into public sector, the rest is disposable to households and feed back as demand to producing sectors through product and service markets. Part of it is saved and deposited in money sector.[1)]

Figure 1 gives the static, national accounts structure of the total model together with the Leontiefan delivery structure. The dynamic elements enter through the micro specified business sector and its interaction with all other sectors. One typical feature of the entire model, and the business sector in particular, is that its dynamic properties depend fundamentally on volume responses (within and between periods) to ex ante and transitory price signals. Hence, the core of the model is typically classical, shaped in an ex ante expectations framework. The entire model is a true general disequilibrium system although not based on marginalistic decision criteria. There exists no long run ex ante or ex post equilibrium position independent of the evolution of the system to the total model or parts of the model, except by chance. The position point in space towards which the system tends each point in time moves with the solution (actual position) of the system each time. Experiments carried out so far, however, suggest a strong tendency with the entire system to stabilize around a long run steady growth rate if the exogenous input variables are defined as constant growth rates. When aggregation is made across and over some time a typical Keynesian system can be shown to emerge.

b) Business sector - short-run production planning of one firm

Figure 2 gives a flow-chart overview of the short-term decision system of one firm. For the time being this is the only micro(firm) section of the model. Figure 3 gives

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1) I have not managed to picture firm investment demand and the ex post savings investment accounting equality in Fig 1.

some detail of the production system. Each production sector holds a number of such individual firm (planning) models.

In Figure 2 an experimental run begins at the left hand side from a vector (P, W, M, S) of historic (5 year annual) Price, Wage, Profit margin and Sales data respectively. These data are transformed into expectations in the EXP module. Here we use conventional smoothing formulae.[1)]

The profit margin variable is translated into a profit target in the TARG block. Here we also use a conventional smoothing formula. The length of historic time considered is longer than in EXP sector.

Growth expectations feed into the investment module to generate long-term plans as explained below. Long-term expectations are also modified to apply to the next year and are fed into the production system.

Each period (quarter) each firm is identified by a production possibility frontier (QFR(L)) defined as a function of labour input as in Figure 3 and a location within that curve. The distance between A and B measures the increase in output Q that the firm can achieve during the current period with no extra labour input than indicated by the L coordinate in A. In practice a vertical move between A and B cannot be costless. For the time being we will have to abstract from this. Suffice it to note that in those experimental runs, where we have investigated this aspect, there seems to be a general tendency among firms to be operating in the A to B range, which is constantly shifted outwards by investment.[2)]

[1)] Applied to the quadratic feed-back learning EXP-function developed in Eliasson (1974,pp.79ff.). See further section 4.

[2)] This obviously is an instance of what Leibenstein (1966) has called X-inefficiency or a form of slack. Note here Carlsson's (1972) measurement of the presence of such slack in Swedish manufacturing, especially as regards the degree of capital utilization or (A-B)+(C-D) in Figure 3.

The distance CD measures (for the same period) the extra increase that the firm is capable of, with the application of extra labour, but staying within a commercially viable operating range. Approximate data on A, B, C and D were collected in the annual planning survey for 1976 and 1977 by the Federation of Swedish Industries.[1)]

The production function QFR(L) in Figure 3 is of the putty-clay type. New investment, characterized by a higher labour productivity than investment from the period before is completely "embodied" with the average technical performance rates of the period before through a <u>change in the coefficients</u> of QFR(L).

The first sales growth expectation from the EXP module (see Figure 2) now starts up a trial move from A in the direction indicated by EXP (S). After each step, price and wage expectations are entered and checks against profit margin targets are made. As soon as the individual firm M-target is satisfied, search stops and the necessary change in the labour force is calculated. If it is a decrease, people are laid off. There are various checks to prevent a too fast shrinking of the labor force (see pp. 244-251). If it is an increase, the firm enters the labor market to search for new people (see below). After this search has been terminated the firm can calculate its output for the period. The wage level has also been determined and feeds back to update the historic vector (dotted lines in Figure 2).

The firm now checks up against finished goods stocks to determine how much to supply in the market. A certain fraction, determined by the last period's relative domestic and foreign price differential is shipped abroad.

The final distribution between sales and inventories for each market and the price level is determined in a confrontation with imports and household demand (middle right

1) See Virin (1976) and Albrecht (1978).

end of Figure 2 and lower end of Figure 3) to be described later. Final price, profit and sales data are now determined and also feed back into the historic vector (dotted lines).

How rationally are these firms behaving in view of the fact that they deliberately abstain from moving on to the location where profits (in expected value terms, margins or rates of return) are at their highest in each period. (For details see section 4.5 on pp. 244-249.)

The answer is that corporate headquarter management of each firm in reality does not know even if the model specification would say so. Firm management knows, however, that (if necessary) better solutions can be found but not exactly how and where. Such better solutions require an extra management effort and support from below, which is only forthcoming when the profit performance situation is deteriorating sufficiently rapidly, and more rapidly than the firm adjusts its own targets. Such behaviour is quite well supported by empirical evidence (Eliasson 1976a). If one so wishes, one may say that profit maximizing behaviour is approximated in some long run dimension or under limited information, which lends an air of rationality to the use of simplified decision rules.

Part of this limited information consists in awareness of the fact (being an important property of the model) that if firms start departing from routine planning solutions en masse they will soon find that their expectations are much more unreliable than before. Search routines in production planning are geared so that the model firm strives to find solutions that allow it to maintain past output levels, when subjected to profit target pressure. However, if we force firms to raise their profit margin targets[1)] they will have difficulties finding a satisfactory solution without cutting out unprofitable production lines (reducing output). The same thing happens when profit margin targets stay put but price and wage cost development generate an expected profit squeeze.

1) by raising ε or TARGX(M) in (1b) in section 4.

On the other hand, if we want firms with high profit margins to produce and sell more to earn more profits they have to get more people. If many firms start searching the labour market for additional people they very easily push up wages so that, on the whole and after a while, profits, investment and growth come down. This is the same as to say that for some numerical specifications of the model there exists no profit maximizing solution to the model at one point (quarter) in time. And the idea of the model is that this is a relevant aspect of real life and that it is slightly irrelevant to be concerned about the problem.

Some might argue that firms should maximize sales under a profit constraint. First, this is not meaningful in the short run. Second, there is no good evidence that firms really are that concerned about their sales. Third, in the long run it is also a rather empty proposition but the outcome might yet be very similar to what can also be derived from a profit maximizing or profit satisfying objective. In fact it is almost impossible to make a meaningful distinction between profit maximization, profit satisfaction or sales maximization under a profit constraint over a longer time period since the rate of return of a firm, as demonstrated by the targeting formula (1a) in section 4 below, relates directly to the value growth of the firm. If firms want to raise their value to the stockholder they should raise their rates of return and invest the proceeds at those higher rates of return. Since that will normally mean to grow faster also in output or sales, profit maximization, satisfaction or sales maximization under a profit constraint are hypotheses that normally cannot be discriminated between in empirical tests. As matters stand, satisfying behavioral rules of the kind modelled here match actual corporate practice much better than the other, above mentioned alternatives. Since these behavioral rules are furthermore much easier to model and since they also give rise to somewhat different and more realistic behavioral forecasts in the <u>short run</u> we have used them.

c) Labour market

The labour market process is represented in micro in considerable detail. At this level, however, the requirements on relevant specification are still higher. Hence, the version now to be described should be considered a provisional one. Experiments conducted so far have taught us that model behaviour is too sensitive to variations in the random search sequences (in combination with a small number of firms) to be reasonable.

All labour is homogeneous in the present version of the model.

The first step each period is an adjustment of "natural" decreases in the labour force of each sector and each firm unit through retirement etc. This adjustment is applied proportionally throughout. Then the unemployment pool is filled with new entrants to the labour market. After that the service and Government sectors enter the labour market in that order. They offer last period's average wage increase in the manufacturing sector and get whatever is available from the pool of unemployed. This sounds a little bit arbitrary and it is. We have had to enter this erroneous specification provisionally to allow for the fact that wage and salary levels differ a lot between sectors despite the fact that labour is homogeneous. The assumption that industry is the wage leading sector is quite conventional in macro modelling. It is probably not quite true at the micro level. With no explicit separation of wage levels (because of skills etc.) and little knowledge as to how the Government, service and industry sectors interact in the labour market this macro simplification should do for the time being.

After the service and Government sectors, firms enter one by one in the order by which they desire to increase their labour force. They scan all other firms inclusive of the pool of unemployed. The probability of hitting a particular location of labour is proportional to its size (labour force compared to total labour in industry and the number of unemployed). The probability of search leading to the pool of unemployed can been set higher than the fraction of the total labour force being unemployed. In fact, this probability can be interpreted as a measure of the allocative properties of the labour market. The institution of an employment agency should tend to increase that probability and the more so the more efficient this institution is. With no unemployment and/or no efficient search tool for the firms to find the unemployed the labour market consists only of people employed in other firms. We have found that macro model behavior is sensitive to specifications here and we will pay considerable attention to this in our analysis.

The firm offers a fraction of the expected wage increase. From the pool of unemployed people are forthcoming at the wage offered if a firm is searching that pool.

If the firm meets a firm with a wage level that is sufficiently below its own, it gets the people it wants up to a maximum fraction of the other firm's labour force. The other firm then adjusts its wage level upwards with a fraction of the difference observed.

If a firm raids another firm with a higher wage level it does not get any people, but upgrades its offering wage for the next trial. After the search is over, firms with relatively low wages, that have learned about the market wage levels around them, have had to upgrade their own wage level by a fraction of the differences observed. This is the way labour market arbitrage operates in the model.

Firms can be given any predetermined number of trials. Obviously the size of wage adjustment coefficients and the number of trials (= intensity of search) each period determines the degree of wage differentiation that can be maintained in the labour market under the homogeneity assumption. We have experimented with various impediments to this adjustment process. We have learned that overall macro behaviour of the model is very sensitive to the numerical specifications entered here.

d) Business system: Investment Financing (micro)

As the model now operates the investment financing[1] section is quite simple.

The frame of the investment decision in each firm is the investment budget.[2] Firms, defined as financial units, are typical plow-backers. After subtraction from profits of interest payments and dividends (that enter household income) and taxes part of the residual is set aside for mandatory financing demands from current asset (inventories, trade credits, etc.) accumulation associated with growth. What remains is what is internally available for spending on capital account. This financial "frame" is increased by borrowing. The rate of increase in outstanding debt depends on the difference between current nominal returns to investment and the nominal (endogenously determined) interest rate.[3] There is, however, one constraint that prevents this rate of

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1) In Eliasson (1976b, pp.75-103) a complete long term planning and financing model has been specified in outline. Since this sector has not yet been made ready and programmed we only present the provisional investment module currenty in use.

2) The specification rests very much on the capital budgeting theory of investment planning developed in Eliasson (1969). This formulation in turn incorporates several features from the Meyer & Kuh (1957) "residual funds" theory of investment. It should be added that despite all good fits of the neoclassical investment function reported on over the last 10 to 15 years evidence strongly suggests that the above, financially based sequence of decisions best pictures the investment decision process at the firm level.

3) This is how the rate of borrowing function looks:
DBW = F(RR+DP-RI), F' > 0 (see p.242).
DBW = rate of change in outstanding debt
RR = real rate of return on total assets
DP = rate of change in investment goods prices
RI = nominal borrowing rate.
Since both RR and DP figure importantly behind the current profit inflow, the profit and cashflow (plow back) hypotheses are merged into one, as they should of course be.

Table 1 MODEL BLOCKS

1. Business system (firm model) - four markets (sectors).
   (A) Operations planning (short term)
       Production system
       Inventory system
       Expectations
       Targeting
       (Cash management)

   (B) Investment-Financing (long term)
       Investment plan
       Long term borrowing*

2. Household sector (macro)
       Buying
       Saving

3. Service sector (macro)

4. Public sector (macro)
       Employment - exogenous
       Tax-system (value added, payroll and income taxes + transfers)
       Economic policy - fiscal & monetary parameters.

5. Other production sectors - exogenous

6. Foreign connections
       Foreign prices - exogenous
       (Exchange rate)
       Interest rate { foreign - exogenous; domestic - endogenous }
       Export volume
       Import volume

7. Markets
       Labour market
       Product market
       Money market

8. Exogenous variables (summary)
   (a) Foreign prices: one for each of the four markets
   (b) Interest rate: foreign
   (c) Technology: The rate of change in labour productivity of new investment, i.e. between vintages.
   (d) Government policy parameters, labour force, etc.

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*Conceived, but not yet programmed. See pp. 75-103 in Eliasson (1976b).

Figure 1 The INPUT-OUTPUT and MARKET STRUCTURE

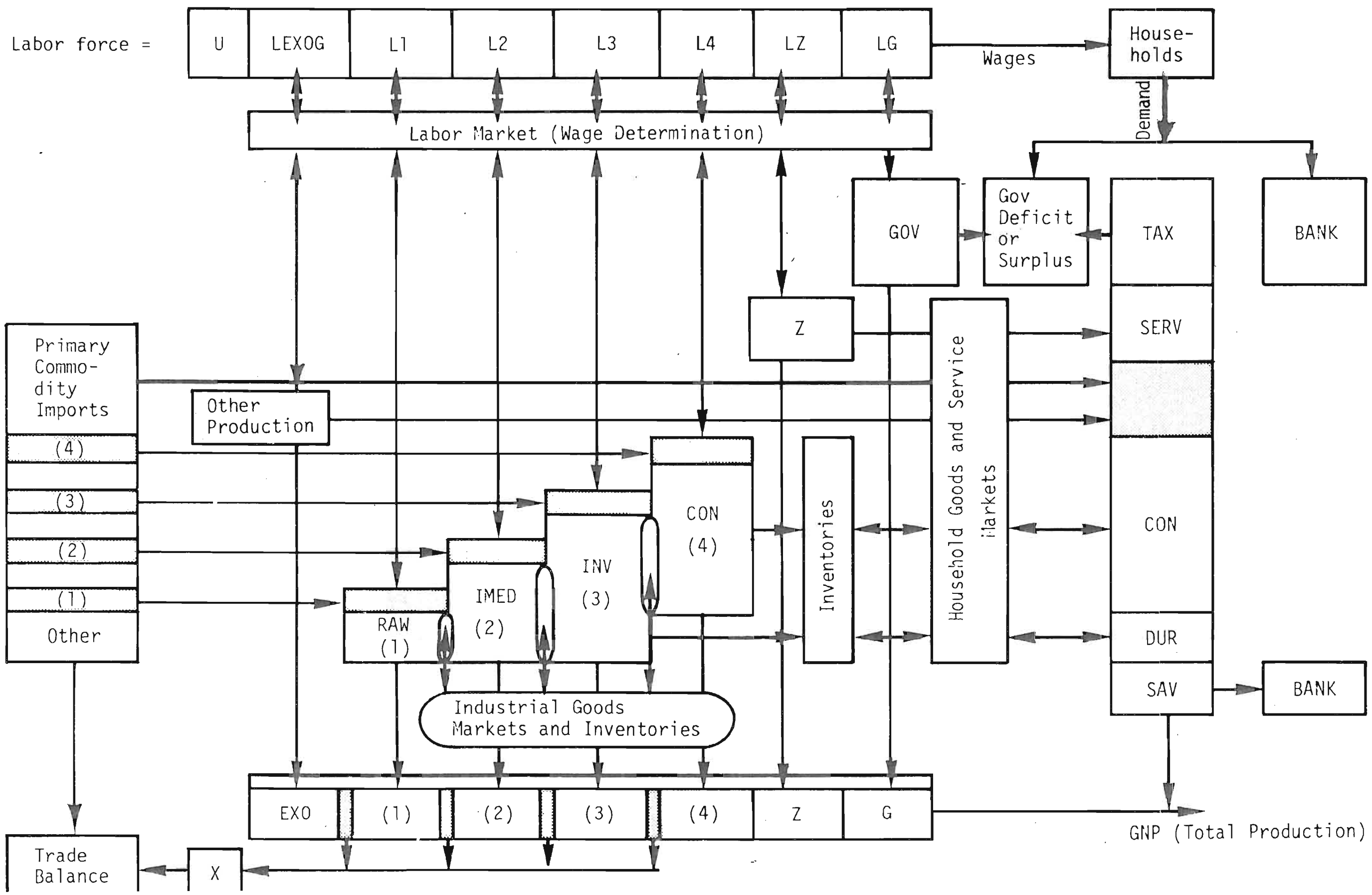


Figure 2 Business Decision System (One Firm)

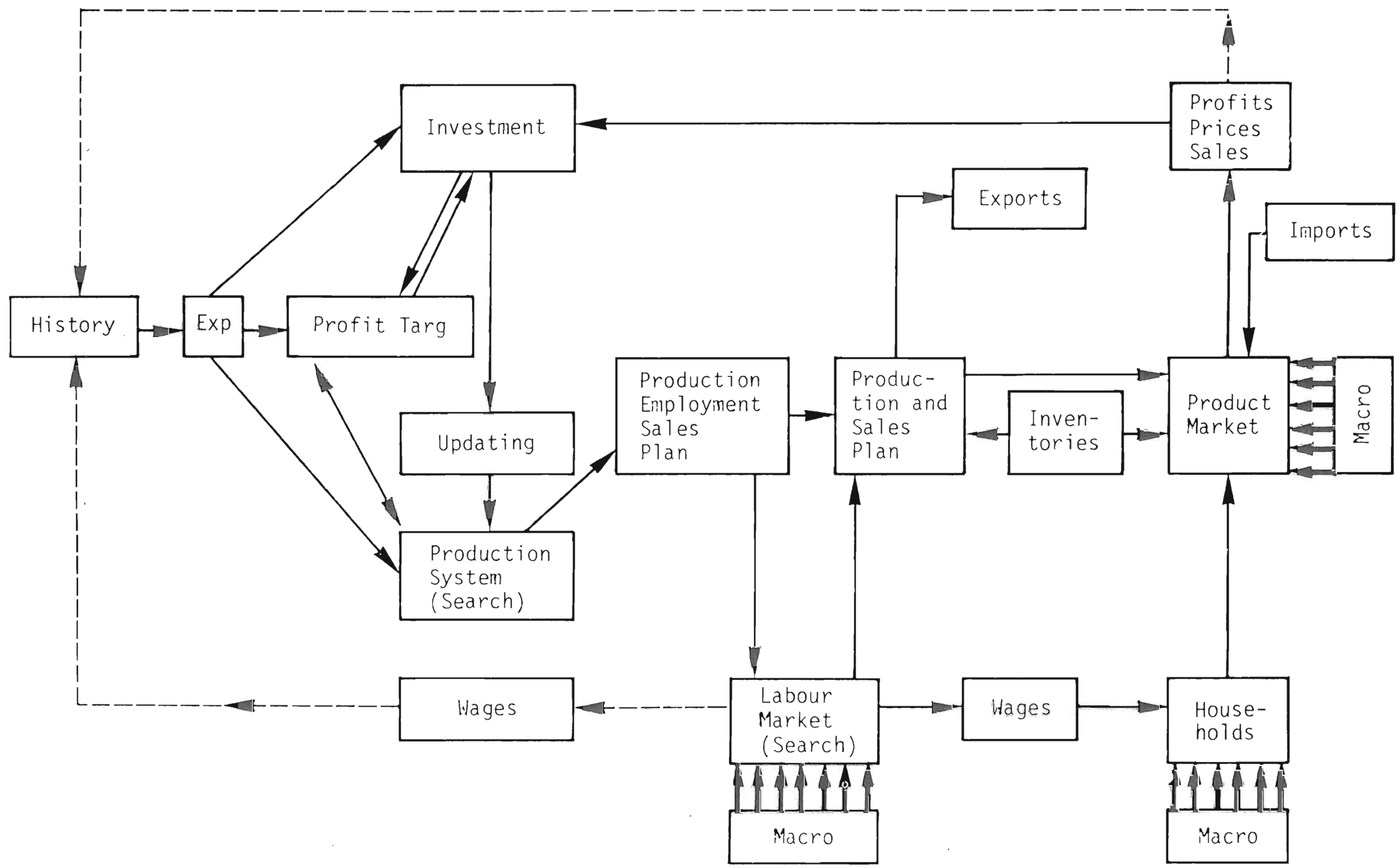


Figure 3 Production System

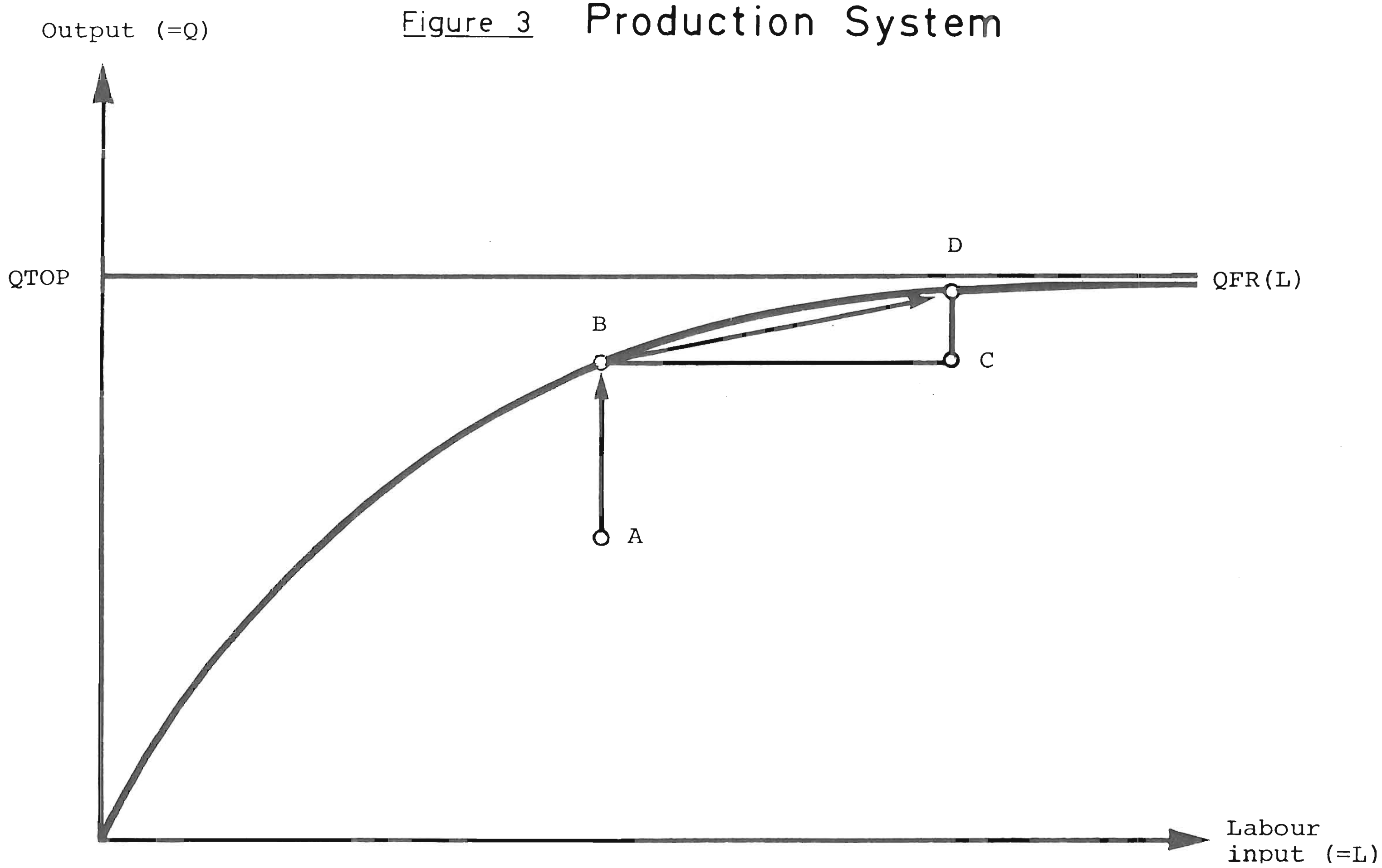
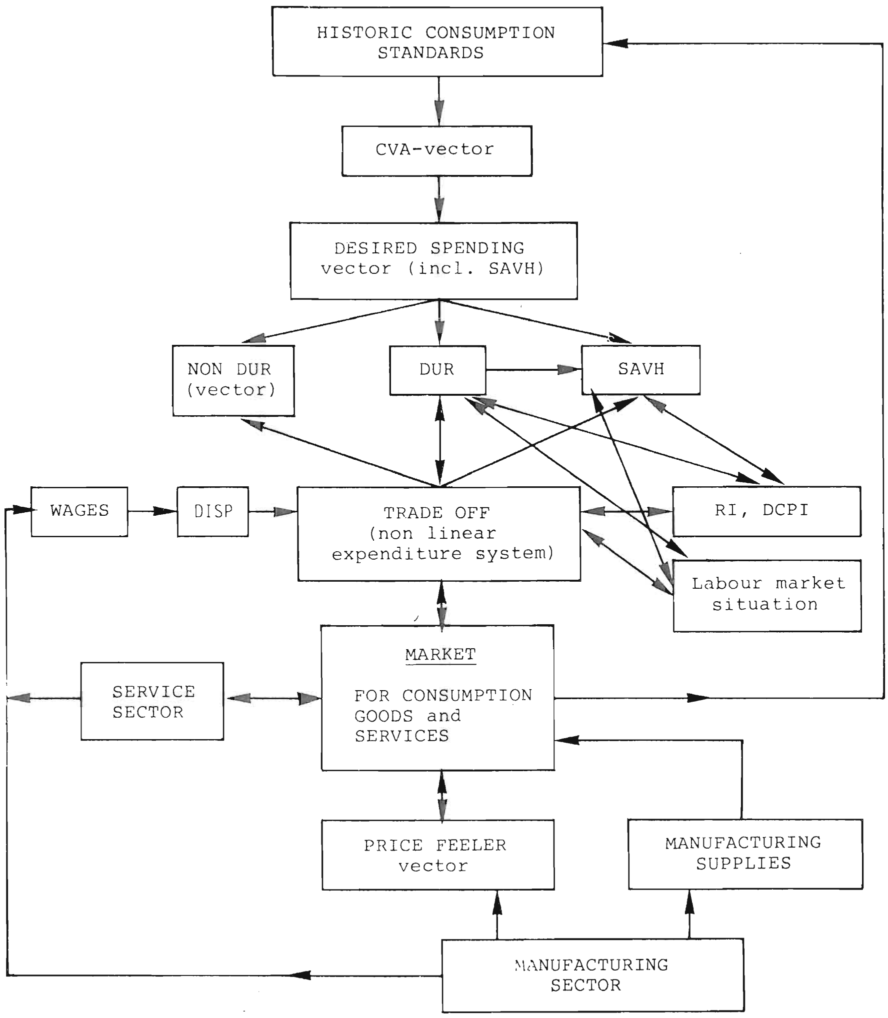
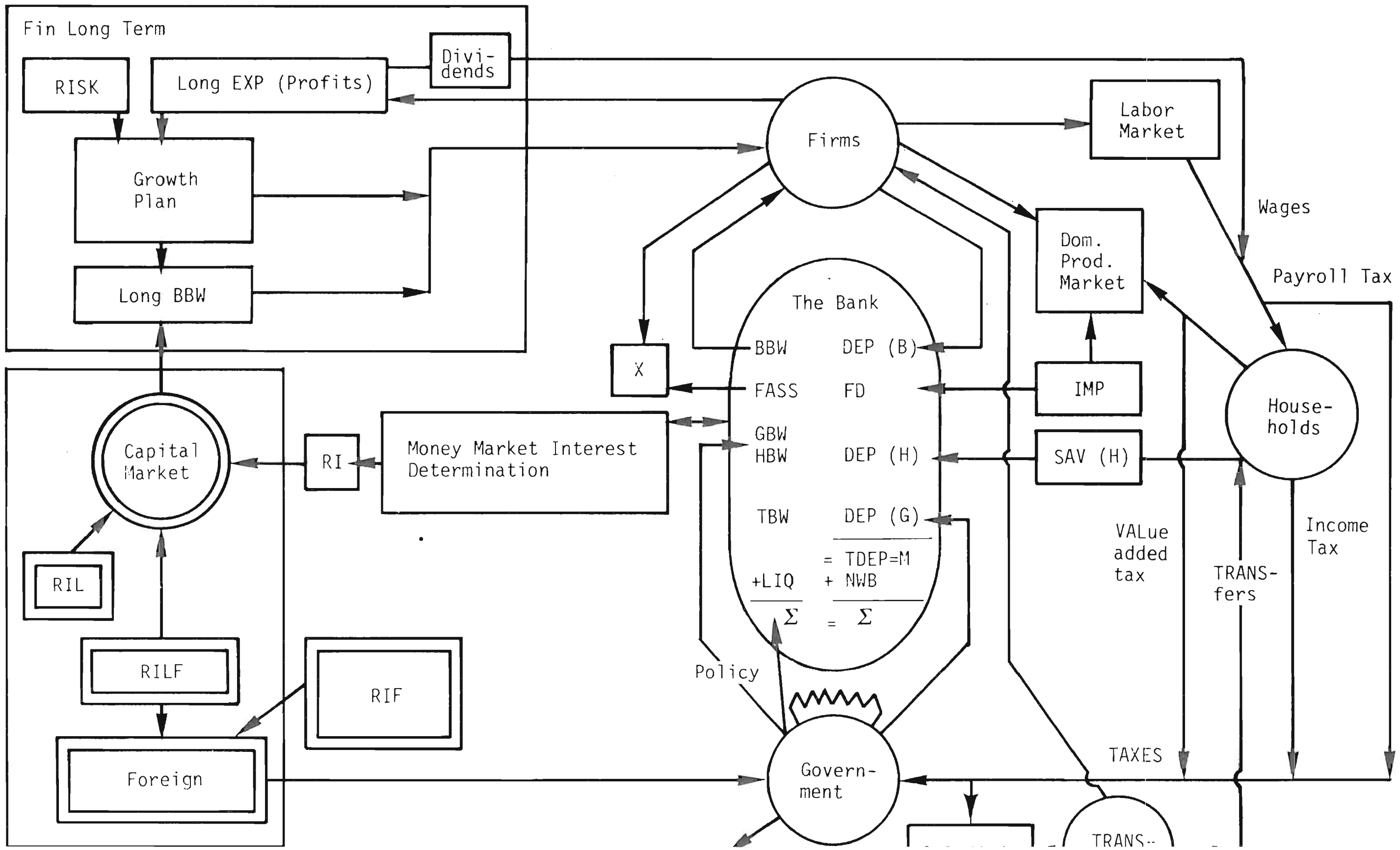


Figure 4 CONSUMPTION SYSTEM AND PROD-MARKETS



Note: A somewhat simplified formal presentation is found on pp. 252-255.

Figure 5 The Money System



borrowing from materializing fully. The firm is checking back at its rate of capacity utilization. The total investment budget calculated as above is corrected for the rate of capacity utilization of equipment and the rate of borrowing is reduced accordingly. Hence if no borrowing takes place and surplus internal funds emerge firms deposit such funds in the bank (see Figure 5).

c) The household consumption system (macro)

The household sector today is only specified in macro. However, the module as such is prepared for an easy transfer into micro, in the sense that macro behaviour will be assumed to be formally identical for each micro unit (household), the only difference being the numbers we place on various parameters. The prime reason for staying at the macro level here is empirical. There are practically no empirical micro data for Sweden available on which to base empirical estimates. This is in marked contrast with the situation in the U.S., where most of the work in this area has been done on the household sector by Orcutt and others. Besides, the author himself does not have the same kind of background experience for the household sector as for the business sector.

The consumption function is a Stone type expenditure system with some non-linear features. One additional novelty is that saving is treated as a consumption (spending) category. There is also a direct interaction (swapping) between saving and spending on household durables, entered as the relation between the rate of interest (RI), inflation (DCPI) and unemployment changes. (See (8c) p.254).

The household spending decision process is described in Figure 4. For the time being we are concerned with macro, the entire economy. Each period a vector of historic consumption data is transformed into a vector (CVA) of "addicted" spending levels which in turn can be translated into "desired" spending. This is very simply done through linear transformations. Desired spending is decomposed into several kinds of nondurable (NON DUR) consumption (incl. services), durables (DUR) and "saving" (SAVH).

In another end of the model the manufacturing, service and Government sectors generate income that feeds into households as disposable income (DI).

There is a residual (positive or negative) between desired spending and disposable income. This residual is allocated on different spending categories by way of marginal elasticities that differ from those that divided up total desired spending.

The production sectors announce their supplies in each market and put out price feeler vectors.

Households tell what they will buy at these prices and there follows a predetermined number of confrontations. The last price feeler vector is then taken as the price for the period (quarter) and firms split their available goods between sales and inventories on the basis of this price. When firms decide on preliminary supply volumes to offer in the market they each check back at their finished goods inventory positions. The guiding principle is to maintain the price level that has entered the production planning-supply decision and to try to move inventories towards optimum levels within a predetermined min-max range.

f) The money-sector

The real and price determination (market) parts of the model described so far have recently been integrated with a money system.[1)]

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1) This block and the input-output system described before was not ready in the full description of the model reported on in Eliasson (1976b).

The money system is there to handle the interaction between quantities, prices and financial flows, notably the determination of the absolute price level and the rate of interest. We do not (as yet) aim at explanatory detail in the credit market.

Figure 5 gives an overview of the money system. Its core is called The Bank and is made up of all financial accounts (debit and credit) that other sectors hold with financial institutions. The Bank represents all financial institutions (commercial banks, savings banks etc.). Firms borrow (BBW) from and hold deposits (DEP(B))in the Bank as described earlier. The Government does the same (see below).

One important feature is export and import credits (FASS and FD respectively). For reasons of simplicity we do not explicitly allow individual firms to have their own financial ties with the rest of the world. An export transaction always gives rise to a temporary credit to the rest of the world. This asset on the part of a firm is always sold to the Bank for Swedish crowns and the bank holds an aggregate of not liquidated trade assets vis-ã-vis abroad called FASS in Figure 5. The size of FASS (or rather net changes in it) depends strongly on the outflow of export deliveries (X) and (NB!) the difference between the domestic (RI) and the foreign (RIF) interest rate.

A similar relationship holds on the import side. Before imports have been paid for there is a temporary debt called FD vis-ã-vis abroad. Also this debt is transferred to the Bank and the aggregate depends on the inflow of imports (IMP) and the foreign-domestic interest differential.

Households, finally, also deposit their savings (SAV(H)) in the bank as DEP(H) in Figure 5. Since the household sector has been treated in aggregate terms we do not here distinguish between gross depositing and household borrowing but rather treat saving net.

There is, however, one real fact of money life that we have to account for. Who is going to absorb the effects of a money constraint, if there is one, and if the Government chooses to carry out restrictive monetary policies? As to the size of the total effect on money supply we let the model decide through the total system. If the money constraint cannot be accomodated elsewhere in the system (by an interest rate increase or a reduction of liquidity in the banking system) households take the first impact, up to a limit. To accomodate this we have a household borrowing variable (HBW) that becomes negative when such things happen. Beyond a limit the impact spills over on firms through a reduction in their investments as definitly planned. This is treated as a flat rate reduction as the model now stands and any firm that then finds itself with liquidity "to spare" automatically deposits it in the Bank.

As is well known, and quite trivial, the public sector excercises a monetary policy impact through its spending and tax decisions that cannot be strictly separated from other monetary policy measures. We will return to this in the next section. Except for fiscal policy the Government can carry out monetary policies (in the model) in 4 ways.

(1) It can fix the interest rate and adjustments take place through liquidity flows throughout the money system.

(2) It can tighten up liquidity requirements (LIQ) of the Bank.

(3) It can borrow abroad (see Figure 5).

(4) It can (also) impose a trade margin requirement on the Bank.

The reader should note here that the Central Bank as a separate and semi independent policy agency has not been made explicit. For this to make economic sense we would have to have open market operations explicit in the model.

Since the whole capital market and long term borrowing is not in the model, open market operations do not figure, and the Government is the sole policy maker.

Suppose that the Government does not aim at directly controlling the interest rate (RI)[1] but rather uses the other monetary policy parameters mentioned.

Any change in the model then affects the economy in four ways.

The first impact is a liquidity effect. Under normal circumstances the Bank should be able to buffer it through its own liquidity reserves.

Next, these liquidity effects work themselves into the interest rate.

Total deposits in the Bank by definition makes up the money stock (= M). Together with bank liquidity it defines total money supply. Total demand for money is made up of total borrowing requirements on the Bank, and the domestic interest moves in response to the change in total supply and demand for money (middle of Figure 5). In effect the entire model operates on the Bank vis-à-vis the in- and outgoing accounts that make up the supply and demand for money.

There are three important, and unsteady, components, that allow the rest of the world to affect domestic interest determination.

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1) Our model will not allow us to analyze whether this is possible or not and to what extent. We can only study the consequences of a given, below market rate of interest. This we have to do in our historic runs, since the Central Bank actually managed to keep the official interest rate substantially below the market rate well into the 60ies (see Eliasson (1969)). The sad thing is that the current version of the model will not be able to catch the market rate of interest very well since we have not entered a "grey" inter firm credit market.

The first and most immediate impact comes through the net trade credit position (FASS-FD=FNASS). FNASS reacts directly on the foreign-domestic interest differential.

Second comes business borrowing that responds to rates of return in individual firms and the domestic interest rate. The rate of return - in turn - depends on foreign and domestic prices and productivity and wage change (unit wage cost change) in individual firms.

Third comes household saving that depends on the cyclical growth and inflationary situation of the entire economy that in turn, in a very complex way, falls back on past profit and investment performance in industry.

In fact the model will allow us to study the Keynesian - Monetarist controversy on e.g. the origin of inflation in much detail. Is there a difference? To what extent can the policy authorities determine (policy) money stock, and, if they can, do we have to run our analysis or our explanation in money terms rather than using a mirror terminology of Keynes?

The reader should finally note that money is now in the model but not financial behaviour, except in a quite crude way. Long term expectations on the part of firms, long term borrowing and financial risk aversion, in particular caused by negative short term experiences are not yet there. The missing sector called long term planning and financing, including the capital market, has been indicated by two rectangles to the left in Figure 5.[1)]

g) The Public sector - policy making

The public sector (local and central) figures in a rather simple, aggregate way. The public employment decision is

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1) Part of it has been conceived and specified in Eliasson (1976b, Chapter 3).

treated exogenously as a policy variable together with the financing decision; three tax rates (payroll, value added (VAL) and income taxes) and total transfer payments (TRANS) to households or firms. We are explicitly modelling the possibility for the Government to hand out tax money free, or partly free, to individual (one or several) firms, for instance those who are experiencing profitability problems.

The tax and transfer flows are also shown to the right in Figure 5.

At the bottom of the same diagram, just below the Bank, the public deficit or surplus is determined. The exogenous public employment decision combines with endogenous, market determined public wages and public purchasing[1)] into a total spending (SPG) variable. If more or less than tax income it has to be cleared through Government borrowing (GBW) or depositing in (DEP(G)) the Bank or through borrowing abroad (bottom left in Figure 5). Quite naturally the Government deficit or surplus should be expected to be the most powerful monetary policy factor on the money side of the model.

h) Summing up

The entire model has been built on a module system. As long as one sticks to the organization of these modules, the possibilities of modifying the model are virtually unlimited. For several modules more or less complex alternative versions are ready or planned and can be combined in a way that fits both computer capacity and research budget. Before the model is finally estimated, or calibrated, as we prefer to call it (see next section), there are three (earlier) stages of completion. First, conceiving

1) A fixed coefficient to employment in real terms, then spread to our seven sectors according to the Swedish input output matrix and then transformed into money terms through endogenously determined prices.

the "economics" of the model module. Second, to get it systematically coded in a way consistent internally and with the rest of the model. Three, to program the code (with us in APL) and to test the program. For the time being one simple version of the model (called the 96 model version) has been ready for more than half a year. This model does not include intermediate goods and stocks. There are no Government or monetary sectors and no exogenous (dummy) production sectors. This model has been described in full in Eliasson (1976b); including a complete technical code. This version of the model has been run on an internal IBM Computer in the U.K. and is now installed in the IBM Computing Center in Stockholm. We have also, recently, managed to get a slightly slimmed version of the 96 version operational in the IBM 5100 desk computer (the largest version with 64K). The disadvantage is that a simulation run takes a very long time, about an hour for a year. An extended version (called the 350 series) with the full input-output structure is ready and installed in the IBM Computing Center in Stockholm. So is also a further extended version (the 500 version) with a full Government sector. Finally the money sector is ready but not yet programmed (September 1977).

3. ESTIMATION METHOD

Even though based on a micro foundation this model addresses itself to typical macro economic problems, related to inflation and the determinants of economic growth. The advantages of this approach are many. We can move specification down to typical decision units (the firms) instead of having to deal with relationships between statistical artifacts at a more aggregate level, when it comes to observation and measurement. As always, it is imperative to get the assumptions correctly specified. Here the assumptions are defined at the level of micro behavioral units even though most of our analytical attention will be paid to the behaviour of macro aggregates and cross sectional correlation patterns in simulations. To get at the micro assumptions we can draw upon the wealth of relatively high quality statistical information that exists at the firm level on the business sector. We introduce measurable concepts that are well known and easily understood among others by business decision makers, and, above all, we construct a consistent "measuring grid" by which known micro information is organized within the framework of the national accounts.[1)] This in itself is worth the modelling effort, and for such statistical organizing purposes the model is already useful.

If we entertain the higher ambition, as we do, to use the model eventually for empirical analysis of the Swedish economy, the approach presents us with one large obstacle. Realism in micro specification in combination with explicit modelling of market processes necessitates that we give up well known, standardized econometric estimation techniques, as far as several sections of the model go. In a way this is no unusual thing today. Practically all large scale macro modelling projects in existence have been forced by formidable statistical problems to break text-book rules of clean procedure much in the same way as we do, and rely

1) This is the idea of the synthetic data base method. See below.

on extraneous information and intuition to get out of what would otherwise have been an insoluble task. The problem is that we may be able to generate time series data by the model that fit macro time series data of the Swedish economy to our satisfaction. But the way by which we have reached the parameter specification that generated these results makes it difficult for us to describe the stochastic properties of our parameter estimates and hence to give conventional rules for generalizations. This is in no way unique to us. Most large macro models have the same problem of generalization. However, we cannot avoid facing it directly by virtue of the very method we use.[1)]

Our model addresses itself to macro problems. This means that their solution should meet the same requirements as those of conventional macro models. This in turn means that requirements on realism in micro specification are less demanding than what would have been the case if our attention had been focussed on some particular micro problem. We do not have the ambition to explain individual firm behaviour over time, only cross sectional patterns. Neither do we aspire to explain actual movements over time in all variables that the model can be told to generate. We can nevertheless argue that our model is general enough so that we can assume, a priori, that it is likely to contain the correct macro hypotheses, albeit together with a whole lot of incorrect numerical specifications or irrelevant features. At least we should be able to reach agreement for some particular decision problem what risk we are running of not having the correct specification within our general model system, or that the model does not contain an acceptable approximation to the correct specification. Our first and fundamental empirical postulate, hence, is that as we confront the model with new empirical information we discard irrelevant (incorrect) alternatives only, at a predetermined acceptable risk of throwing out the correct alternative.

1) Also see paper by Olavi and myself in this conference volume.

Alternatively, we could also say that we have a very general theory with many alternative "structures". We are interested in one of them. The more diverse the range of observation or experiments (the more sample variation) the faster we should be able to narrow down the parameter domain (read: the more narrow the "confidence intervals"). This is the precision aspect of our estimation procedure and it emphasizes the usefulness of "shock experiments" like the "Korean boom" and the more "recent oil crisis" experience to get the parameters right. With an infinite number of observations (an infinite sample) we are certain to get a consistent estimate, i.e. to come out with the correct one under the maintained hypothesis.

Theoretically consistency can only be obtained if the infinite sample is there at one point in time. In practice, however, the modelling effort will have to be seen as a never ending (sequential) process that is hopefully continually improved - or abandoned - as it is confronted with new test information. By this simple reformulation we manage to make a virtue out of the difficulties we faced initially.

Although also a theoretical problem (inflation might be due fundamentally to a micro phenomenon that we have simply forgotten to specify) in practice we have to deal with a numerical (estimation) problem. Which (numerical) parameter combination, among many possible ones that satisfy our requirements of fit, is the correct one? This is no uncommon problem in econometrics although the least squares method provides a procedure to choose, namely the parameter combination that gives the best fit in terms of minimizing the sum of squared deviations. In theory we can use that principle of choice also,[1)] although it is rather arbitrary if we happen to have a cloud of parameter combinations of equal power in the close neighbourhood of the combination that happens to be picked.

This means that our estimation problem might be even more crudely empirical, namely to choose, without conventional rules of thumb, from a very large number of well defined combinations between which we cannot discriminate easily. Fortunately, our experience so far has not been of that kind. We have rather found it difficult to find one good alternative that meet our standards of goodness of fit.

Hence, we have to turn our problem formulation around again. For those specifications that we are, so to speak, satisfied with in terms of their ability to trace economic development according to our criteria, we have to devise techniques to check carefully that we have not happened to come upon a specification that is incorrect. The economic turmoil of the last few years has turned out very useful in screening parameter sets. This is of course exactly what should have been expected since ours is a true disequilibrium model. While we find profound disequilibrium situations explained within the model this should not be expected from conventional model structures. If we happen to find several specification alternatives among which we are unable to discriminate, we simply need more empirical knowl-

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1) Search techniques to fit simulation models automatically have been developed for simple cases, see e.g. Powell (1964 & 1965). A similar estimation procedure is being prepared for a restricted set of parameters of this model. See paper by Eliasson & Olavi in this conference volume. The flair of objectivity that such a procedure would lend to the project is, however, largely illusive. The question is whether the computer is more efficient than we are in tracing down the parameter set(s) that generates acceptable model behaviour over history. It is my firm conviction that the micro simulation method will have a low survival value, if we leave too much of the thinking to the computer.

edge, that we don't have, in order to choose. In science, as in decision making, it is often more important to see clearly what one doesn't know than being able to account for one's knowledge. This is the way we go about estimating the parameters of the model.

There is one final problem that has to be dealt with here before we go on. Our model is very rich in specification. There is now way of ensuring that all endogenous variables trace history in an exemplary manner. The choice of problems we set about to study will define what sort of irregularities we will accept. We will return to this in more detail in its proper context of application. Suffice it to note here that even though we concentrate on a limited set of national macro variables to ensure historic tracking, similar although less stringent conditions will apply to sector behaviour and at the micro level we will see to it that known and stable cross-sectional correlation patterns remain through simulations. For the time being we would like to say that the model has been loaded with numbers that makes it behave like a Swedish like economy.

a) Problem (objectives)

This model has been designed to deal with two problems that are not well handled by conventional approaches.

These problems are:

To formulate a micro explanation for inflation

and to

study the relationships between inflation, profits, investment and growth.

The two problems obviously overlap to some extent. The first is a typical macro problem and constitutes the core of current economic debate against the backdrop of more than half a decade of experience of much above normal inflation on a global scale. The second problem requires a micro approach to be tractable for analysis in a meaningful way.

Once ready to handle these two problems, as mentioned earlier, the model will also be capable of handling other problems, that we will leave out here to simplify the exposition.[1)]

The inflation task requires that we identify the channels through which foreign price impulses are transmitted through the Swedish economy and the micro parameters that are important for the speed and magnitude of that transmission. We also have to identify domestic sources and how they create inflation. The way in which expectations are formed is thought to be especially important here. We also have to identify how various inflationary processes may affect macro behaviour in real terms, like employment. The labour market is of particular interest. Finally, we want to identify the strings that can be pulled by policy makers to affect the process. We have included the conventional fiscal and monetary weaponry in the model. More importantly, the model will offer a unique possibility to experiment with e.g. the structural parameters of the labour market. Some trial experiments of that nature have already been made although the model is not yet complete. There will also be a possibility to introduce rough schemes of wage, profit and price controls and to study their impact within the domain of the entire model.

There are two levels of ambition involved here.

We may be satisfied with getting a feel for the magnitudes and direction of effects involved. We might also want to trace time profiles of various effects more precisely. The two dimensions normally cannot be kept apart as is commonly

1) See e.g. the labour market experiment described in Eliasson (1977a).

assumed in comparative static analysis. We have found through experimentation, however, that some sets of parameters have a unique influence on long-run trends, others on cyclical behaviour around these trends and others again operate both in the long and the short run. We have used this experience to devise a two stage "estimation" procedure for our two problems.

The first step is to calibrate the model so that it traces a chosen set of long-term trends of the Swedish economy well, disregarding altogether the cyclical aspect. The test variables are chosen in order of importance. When the first variable satisfies trend requirements we move on to the next trend variable requiring that the earlier trend fits be maintained within a narrow range. Table 2 gives the reference trends and tracing performance of some early experimental runs. To exemplify the procedure between RUNS 67 and 96 in Table 2 trend fitting started with total industrial production (Q) as test variables. Experimentation aimed at getting it close to actual 1950-1974 growth performance with no upward or downward long-run drift in profit margins and capacity utilization rates. The next step aimed at getting the long-run drift in price levels (industrial prices (P), wages (W) and CPI) in line with 1950-1974 experience, while approximately preserving the trend fit of Q obtained earlier. As can be seen from Table 2 a number of test variables fell into the observed growth spectrum together by November 1976. The only apparent deviation is the rate of unemployment.[1)]

The second stage involves tracing the cyclical behaviour of the same variables satisfactorily, changing the parameter

[1)] We are not overly concerned about that. The labour market contains enough parameters to allow separate fine tuning. Since an extended version (with intermediate goods, public sector and a money system) was to be incorporated in the model during 1977 we have found little reason to waste time on fine tuning the unemployment variable since we expected new specifications to disturb part of the calibration obtained by November 1976.

set so that the result on trend fits is roughly maintained. Again we will proceed from test variable to test variable in order of importance, requiring that earlier results (fits) be maintained.[1)]

The precision requirements at this second stage are probably quite small, since most of the cyclical features of inflation seem to originate outside Sweden, by way of our exogenous variables. The second stage becomes important if we want to include other problems in the formulation of our model as well. This is only tentative within the present project, so we leave it out for the time being.

This delimitation of the level of ambition is even more appropriate for the second problem, the relationships between inflation, profit, investment and growth. Here the medium-term development becomes more central together with micro specifications. It is a well recognized experience that these relationships cannot be identified in macro approaches. Lags between cause and effect are usually long, involving, as a rule, an intricate feed back machinery between experience, expectations, planning and technical delays. This means that macro aggregates are a blend of firms in different stages of development that erase the relevant relationships while a momentary cross-section picture does not identify the time dimension.

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1) Two comments are in order here. First, if we so wish, the test (or estimation) procedure described can be given a clear mathematical formulation to use as an automatic trend and sum of squared deviations stepwise minimization algoritm in a computer to search for a parameter specification that gives the best fit. Computer time requirements would, however, be enormous. We are currently investigating the feasibility of such an application. See the paper by Eliasson & Olavi on "stepwise parameter estimation of a micro simulation model" in this conference volume.

Second, the priority orderings imposed a priori of course implies the risk that search would lead away from the "best fit". However, we will certainly notice if search leads us nowhere. This is where our experience and intuition comes into play in an important way.

Since the model imitates the whole machinery we can bring out the desired time and cross-sectional features as we wish. In a way the analysis will consist in describing what happens to a cluster of variously composed firms when the economy is subjected to various macro happenings, occasioned exogenously, by policy making or by inconsistent, joint behaviour by the firms themselves. We are especially interested in identifying the role of profits for macro behaviour (growth) in an economy (model) populated by individual firms joined together by an explicit market process.

Again, the first calibration stage, mentioned above, (satisfactory trend tracing) is all we need to reach in order to handle our second problem.

b) A priori assumptions

Let us now deal with the a priori inclusion of knowledge in our model. Empirical information enters model in seven ways:

(1) The causal or hierarchical ordering of model modules. What depends on what and in what order (see e.g. Figure 1).

(2) Structural parameters, e.g. defining the relation between maximum possible inventories and sales or trade credit extensions associated with a given value of sales.

(3) Time response parameters, e.g. how exactly are historic observations transformed into expectations.

(4) Start-up positional data (like capacity utilization rates).

(5) Start-up historic input vector (e.g. on which to apply time reaction coefficients to generate expectations in EXP sector).

(6) Macro parameters and accounts identities[1] (e.g. in consumption function).

(7) Exogenous inputs (like foreign prices).

The hierarchical ordering is the first step from a completely empty formal structure to saying something about the world. All theory in economics has to have something of type (1) in it to be called economic theory. Without the use of operational, meaningful or measurable variables not much empirical knowledge is brought in. Consumer preference schemes and the marginal productivity of capital are concepts or variables that are close to being empty since we have no good measuring instrument or senses to touch them. We refer to the concept of a Keynesian model and immediately bells start to ring. Keynesian models represent a general class of causal orderings of economic variables that all correspond to a measurement system (the national accounts) that we are familiar with.

The great advantage of our model is that we bring the hierarchical ordering very close to two excellent measurement systems. At the micro firm level we are dealing only in terms of the firm's own accounting systems and at the macro level we are truly Keynesian. It is not necessary to be a professional economist to assess and understand most of the structural micro parameters of type (2) and to provide the start-up historical and positional data (4) and (5). This is definitely an advantage that outweighs the loss of econometric testing potential. This information is brought in as a priori assumption. We take it for given (true) in the causal specification.

Most evidence brought in here is based solidly on internal planning and information routines within firms as described by Eliasson (1976a). The specification there-

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1) To the extent possible we use outside information from econometric studies here.

Table 2 Trend comparison (MACRO - INDUSTRY), 20 year simulations (average annual change in percent)

	Sweden 1950-74 (24years)	RUN 67 (July76)	RUN 88 (Oct76)	RUN 96 (Nov76)
1) Production (Q)	4.6	2.7	3.5	5.0
2) Hours of labour input (L)	-0.9	-3.9	-2.3	-2.4
3) Productivity (PROD)	6.1	6.8	5.3	6.7
4) Value productivity (PROD x P)	10.0	-	-	11.7
5) Product price (P)	4.7	5.4	3.3	4.7
6) Wage level (W)	9.7	13.6	9.4	11.9
7) Investments, current prices (INV)	9.5	7.7	5.4	8.3
8) Ditto, constant prices (INV/PDUR)	4.3	1.1	2.7	3.8
9) Rate of unemployment (RU)	1.8	17.6	11.9	10.0
10) Sales (S)	8.8	8.2	6.0	9.8
	-	(R=0.4)	(R=0.4)	(R=0.8)

Constraints

Profit Margins (M) } Horizontal trend

Capacity utilization rate (SUM) }

Note: This table has been inserted for illustration only. It makes very little sense for an outside reader until a full description of the experimental set up has been presented.

In the bottom row of table the simulated rates of change have been correlated with the real ones for the period 1950-74.

fore appears to be as close as one can get to the buttoms that are actually being pushed in the decision process.

The causal ordering (1) is essential for the properties at the macro level. Such orderings between periods replace many time reaction coefficients in macro models.

Structural parameters (2), positional data (4) and historic input data (5) either have to be fetched from a micro data base (see below) or refer to the macro part of the model, like the household expenditure system. We are either taking our parameters directly from the individual decision units or we are using conventional econometric techniques.

Under this model specification scheme the estimation problem that is unique to this model is in practice isolated to the time response parameters under (3). Here we have practically no outside knowledge to draw on except trying out various sets of combinations and to check so that the total model behaves as an economy of our choice. Were it not for these time reaction parameters we could have said that our whole model exercise consisted in analysing the macro implications of a set of "known" or "measured" micro assumptions. Confrontation with macro data would then have been a second check that the numerical information had been realistically put together in the model. As we see it now the macro information will have to be made use of to "estimate" the time reaction parameters, until we have found a way to get also that information directly from the firms. Before we discuss this calibration phase we will introduce the micro data bases on which the model operates.

c) Data base

Two sets of data are needed; one set to operate the model and another set to assess performance (test variables).

The second set of test variables is partly macro statistics from the Swedish national accounts that will uncritically be said to represent Sweden and partly micro data on real Swedish firms from various sources.

The first set is more specific to our model. We need a micro firm data base of at least 5 years (annual data) and a set of positional data for the last year to get the model started. And we need a forecast or an assumption (or historic data if we trace history) for the exogenous data for the simulation period. We would also like to be able to start simulation at a date of our choice, which means that the micro data base should, preferably, stretch far back in time. In practice this means that except for the last few years, we will not have all the data we need.

Model building, model calibration and data collection must take place simultaneously. Thus much of the data we need for model testing will not be available until most of the calibration work has been done. This is how we solve this dilemma.

d) The synthetic micro data base

Through 1976 and spring of 1977 we experimented with the model on historic, five year input vectors for the years 1970-74 for each firm. Fortunately, 1974 was the peak of an inflationary profit boom in the business sector. The simulation run then begins under conditions that are very similar to those prevailing during the year when our historic national accounts test data begin, namely 1950 (the Korean boom).

To get a micro data set at an early time we had to be satisfied with synthetic data. Until spring 1977 macro subindustry data for 1970-74 (four subindustries) have simply been chopped up into 50 firms, applying a random technique that preserves the averages of each subindustry and introduces known cross sectional correlation patterns. On the basis of this start-up information we have performed a series of preliminary calibration experiments according to a procedure to be described below. Occasionally we have included one or several real firms in a simulation run to see what happens to them.

The next step, that began this spring, was to prolong the micro data base back in time, using essentially the same synthesizing technique, to introduce a new type of firm that only operates in inter industry markets and to enter a purchasing and input inventory function. We have also made it possible to enlarge the number of firms. There are two reasons for this. We have to check stability properties of the model when we vary start-up data by moving back and forth over historic time. In addition we need better and more precise test (historic) data to evaluate model macro performance. The change-over to this data base took place at a time when the new, extended version[1)] of the model described here was ready. Several parameters of the system have had to be recalibrated after this changeover and when this is being written the model has not yet found its way back to a good trend tracing performance of the quality already achieved with the more primitive, earlier version. The reason partly lies in inconsistencies between the various official statistical data sources used to put together a macro data bank on the industrial classification scheme used for the model. For instance, the national accounts based break down of total industry on sub-sectors does not seem to match the input-output matrix well. The model responds immediately by adjusting the size of the sectors in a way that creates turbulence for several years.

The final stage is to feed the model with a set of real firms and to apply the same synthetizing technique on the residual that remains between the subindustry total and the aggregate of the real firms in each market. We are thinking in terms of eventually having the 200 largest Swedish firms in the model. When and whether we will reach that ambition, or higher, depends not only on the amount of work associated with arranging a proper data base but also on the exact nature of internal memory limitations on the computer side. For various reasons this stage will be reached very late in the project. We are now experi-

1) As compared with the simpler version described in full detail in Eliasson (1976b).

menting with a sample of 30 to 100 firms. We have run a few test experiments on 350 firms. Besides making it possible to organize model work efficiently the idea of a synthetic data base in fact has a much greater appeal. Future builders of models like this will certainly find that much real information that they want is missing. Furthermore, the idea of micro-macro interaction, in our model at least, is not to feed the model with exactly the right micro measurements. The model operates from micro to macro on realistic cross sectional variations. Exactly identified firms are not needed. If we make all firms in each sector equal, markets disappear by definition and the model collapses into a more conventional, ten sector Leontief-Keynesian macro model. The maintained hypothesis is that if the synthetic sample of firms can be seen as a sample from a population of real firms with roughly the same variational properties, then the model should exhibit the same macro behaviour when fed with both sets. Both these presumptions; (a) that the synthetic sample is representative and (b) that the model behaves as described, will be subjected to tests in due course. But we are of course taking the risk of an unpleasant surprise when we reach this stage. However, a research venture of any meaning is risky by definition.

e) Calibration

We are here concerned with "estimating" the time reaction parameters (3) under paragraph (b) above - altogether about 20 for each individual firm. So far we have assumed that they be equal for all firms. All other parameters enter as a priori maintained hypotheses. We now need a set of criteria for a good "statistical fit" at the macro level to guide our calibration. These criteria, of course, relate back to the precision requirements we have in dealing with the problems we have selected, described already above. In econometrics this corresponds to choosing the level of significance and to some extent the estimation method.

We need a procedure of selection that guides us towards a specification alternative that satisfies our criteria and (NB) that is not a spurious one. These two steps are summarized in Tables 3 and 4.

Table 3 MASTER CRITERIA FOR FIT

A.	Certain macro industry trends approximately right (within ± 1/2 percent) over 20 year period (see trend chart Table 2). This criterion is essential.
B.	Same inter-industry-trends. Same criteria for 5 year period.
C.	Micro. No misbehaviour of obvious and substantial kind, if it can be identified empirically as misbehavior.[1)] Maintain known and stable cross-sectional patterns over simulation.
D.	Identify (time reaction) parameters that work uniquely (or roughly so) on cyclical behaviour around trends. (This criterion is not essential to handle the two chosen problems.)

1) Since the model has not been designed to exhibit such behavioral features there is no other way to detect them, if they are there, than by carefully analysing each experiment. There is no use giving a "suspicion list" and then limit attention to that list.

Table 4   CALIBRATION PROCEDURE (TREND AND CYCLE FITTING)

1. Find first reference case. Assess its qualities in terms of A above.

2 a) Perform sensitivity analysis with a view to finding new specifications that improve performance in terms of A.

b) Ditto with a view to investigating the numerical properties of the model within a normal operating range (analysis). Check and correct if properties can be regarded as unrealistic.

c) For each new reference case, repeat the whole analysis of 2 b) systematically. The purpose is to ensure, each time, that the new reference case is really a better specification and not a statistical coincidence, and that the properties of the system revealed by the sensitivity analysis above, and judged to be desirable, are present in the new reference case. This step is important and is there to prevent us from moving away from a relevant specification achieved.

d) Subject model to strong shocks. Check for misbehaviour. (Especially fast, explosive or strong contractive tendencies that are generated from shocks that are obviously extreme but just outside the range that contains a real but rare possibility.)

3. Define new and better reference case. Repeat from 2.

This is only another way of describing the estimation "program" presented earlier. There we gave the criteria to move from one reference case to another. Here we describe how to find another and better reference case in an intuitive way. In the absence of an automatic search-estimation program this trial and error procedure is the only alternative.

As emphasized several times, there are so many dimensions to consider in this model work that everything cannot be handled simultaneously. What is important depends on the problem choosen. Hence it is quite possible that the efficient handling of several problems demands that several versions (subsets) of the model be developed. Furthermore we will have to leave some check-ups for later consideration. Not until the macro trends (and cycles) are satisfactorily traced (A. in Table 3) will we look into industry trends (B. in Table 3). For some problems we can quite well live with bad tracking performance at the sub-industry level.

A final test will have to consider micro performance as well. Here the test will be consistent with the idea of the synthetic data bank. Even if we use a real firm data bank to run the model on we do not require that the model traces historic development of individual firms or predicts their future development. This would be unreasonable to require.[1)] However, we should require that known cross-sectional patterns are preserved in model simulations. For instance, if we know that there is no or little correlation between initial profitability rankings and profitability rankings, say, twenty years later but that the distribution across firms remains stable, this knowledge should first be featured in the synthetic data bank[2)]

1) If we want performance of this quality, we would have to build an expanded, tailor made model of the firm in question, but fitted, as all other firms to the total model. This is again an illustration of the fact that each problem choosen requires special model tooling.

2) And of course also in the real firm data bank if we have one.

used to run the model on. Second, the same patterns should be preserved in simulation runs over 20 year periods. In fact there exist a host of well known statistical methods to test if simulated cross sectional patterns differ significantly from real ones. The problems, as usual, lie in the availability of data.

f) Conclusions

We may say that the model we have designed is a combined medium-term growth and cyclical model although the two prime problems we have chosen only require that it imitates macro reality (Sweden) well over the medium-term, say five years, exhibiting a business cycle although not necessarily a typical Swedish business cycle. This is why we are talking about a Swedish-like economy.

Some may say that with these "empirical" requirements we have not moved far above a purely theoretical inquiry into problems of inflation and growth. However, we have done much more in so far as our numerical approach has allowed us to say something not only about the directions of change but also about the relative numerical magnitudes involved, based on data from the Swedish economy. Let us say that we want to study how disturbances are transmitted through an economy. The nature of this transmission must then be ascertained before one attempts to measure the effects involved. This task in itself requires a substantial amount of empirical specification. This is also how the ambition of the current project has been defined.

Towards the end of the project we also hope to be close to the following model performance; a specification that traces a chosen set of five year macro trends in Sweden according to A above quite well, irrespective of where in the period 1955-1970 we begin the simulations, (if we have the necessary start-up data), and that reproduces a typical business cycle in all the variables in A, if exogenous variables, including policy parameters and start-up data are correctly specified. For the model to be useful as a support instrument in a forecasting context achievement of this goal is a minimum requirement.

EXAMPLE OF MICRO EXPERIMENT - NEW FIRM ENTRANTS IN MARKET FOR INTERMEDIATE GOODS

Figures 6A-D have been inserted to illustrate the micro analytical possibilities of the model.

Figures 6A and 6C relate real rates of return (RR)[1] of individual companies of our data base year 5 to RR in year 10 in a simulation run. If all dots had been on the 45° line, rates of return would have been the same for each company in the two years. We see that the scatters exhibit the same kind of dispersing one observes in real life. This is a result that has been obtained without recourse to any randomization procedure within the model.

Figures 6B and 6D illustrate the correlation pattern between annual rates of growth in output (DQ) during a 5 year period and the average real rate of return during the same period. Again deviations from the 45° line have to do with changes in capital structure within the firm, in financing patterns and dividend distribution practice and the timing of investment during the period. If these changes are normal, one should expect to find a fairly strong positive correlation between average rates of return and growth in output over a five year period (cf pp. 234 ff below).

Finally, the diagrams also illustrate a particular experiment on the model. During the first 5 years new firms have been entered in the intermediate goods market in sizes and at a rate typical of that industry[2]. In figures 6A and B all new entrants have been given average performance characteristics of the industry, in figures 6C and D above average performance characteristics. Performance is here measured as labour productivity at full capacity operations on the QFR(L) curve at point B in Figure 3. New entrants are assumed to base their price, wage and sales growth expectations on average, past data for the industry. We can see that performance of the new entrants disperses somewhat during the simulation, but that the group as a whole still maintains its introductory quality (average or superior) towards the end.

One can also notice (at least on the original drawings) that the new entrants in the two cases (cf Figures A and C, and B and D) displace the other firms in the scatter somewhat differently, both within their own market (intermediate industrial goods) and in other markets.

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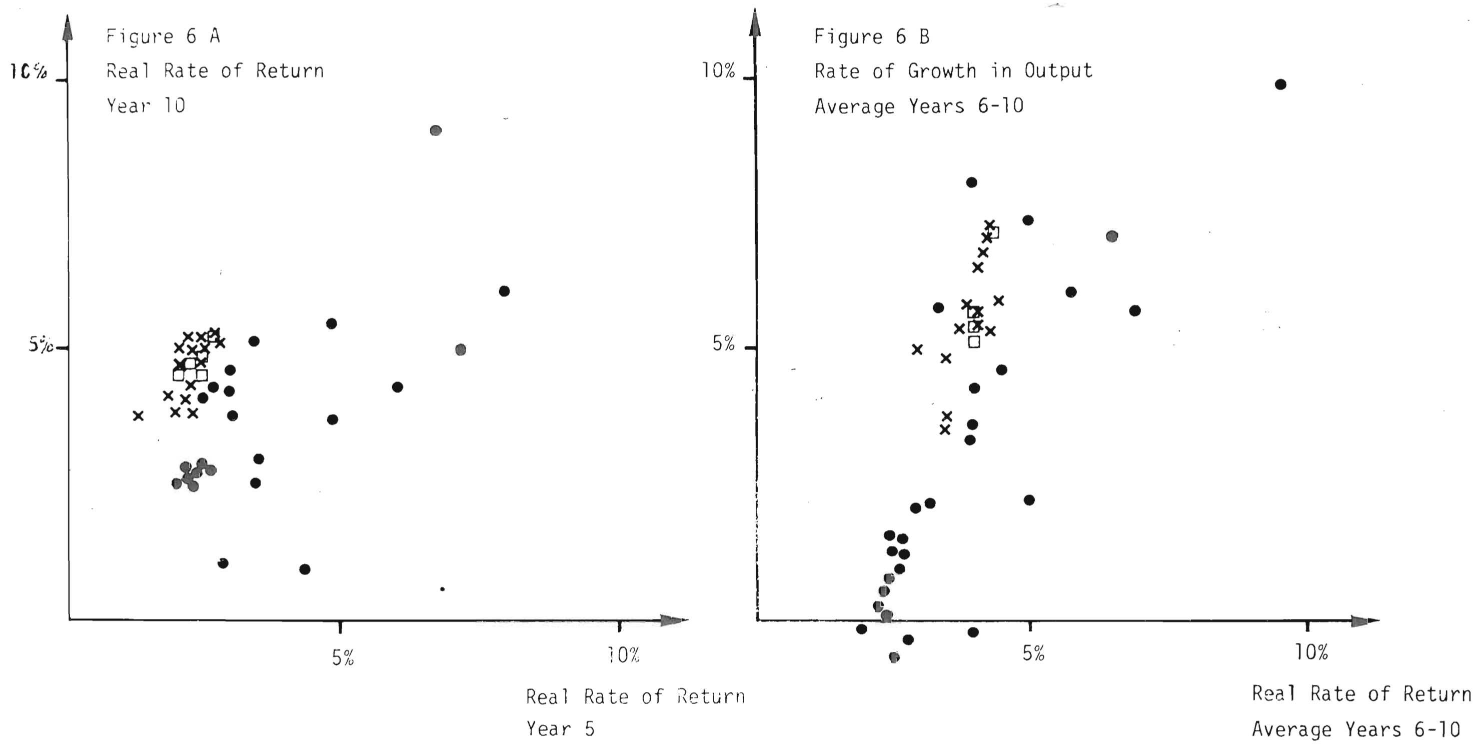
1) For a definition of RR see p. 257.

2) According to data from a forthcoming IUI study on new entrants in Swedish manufacturing.

Figure 6 A-B

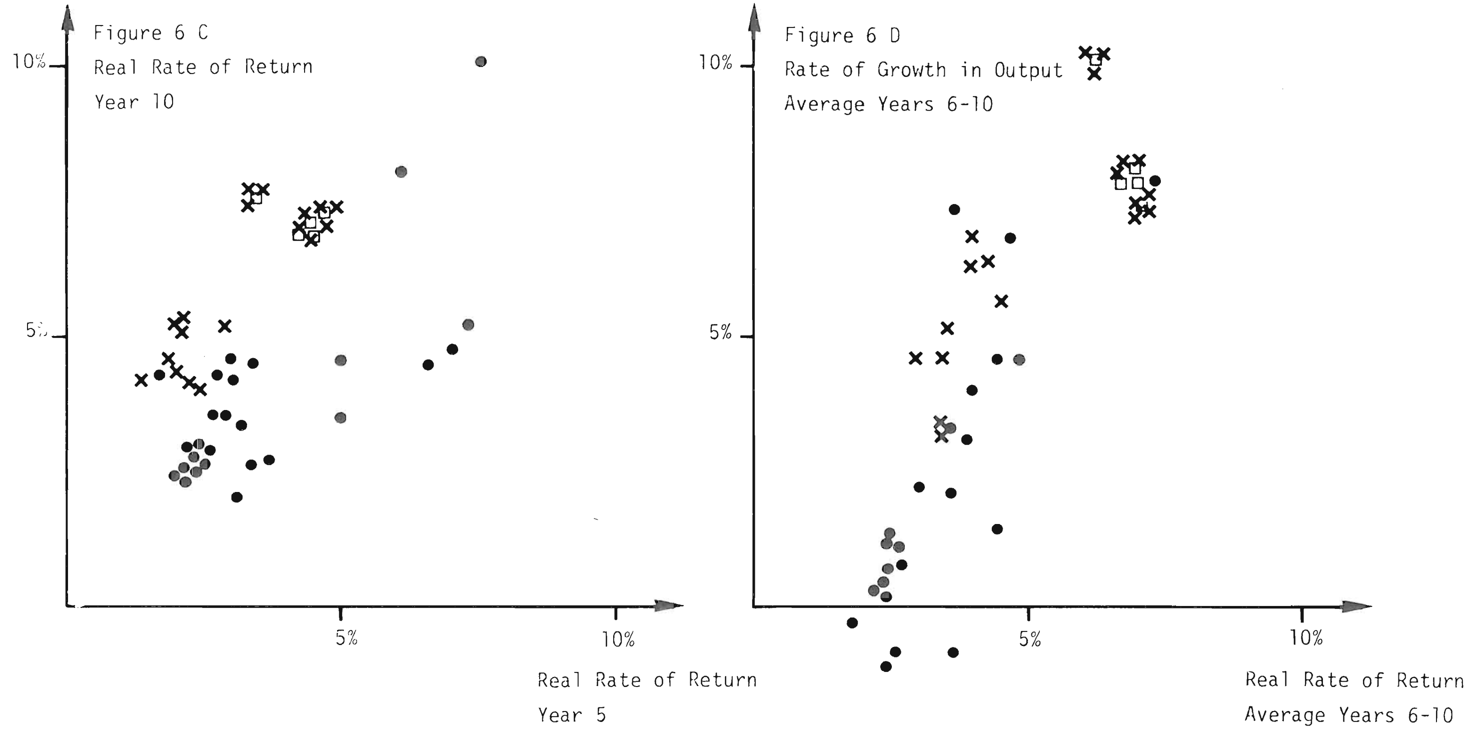
Entry of New "Average" Firms in Market for Intermediate Products



Legend: □ New "Average" Firms in Market for Intermediate Products
× Original Firms in Same Market
● Firms in Other Markets

Figure 6 C-D

Entry of New "Above-average" Firms in Market for Intermediate Products



Legend: □ New "Above-average" Firms in Market for Intermediate Products
× Original Firms in Same Market
● Firms in Other Markets

Figure 6 E Output effects of new entrants

Index 100 = Reference Case

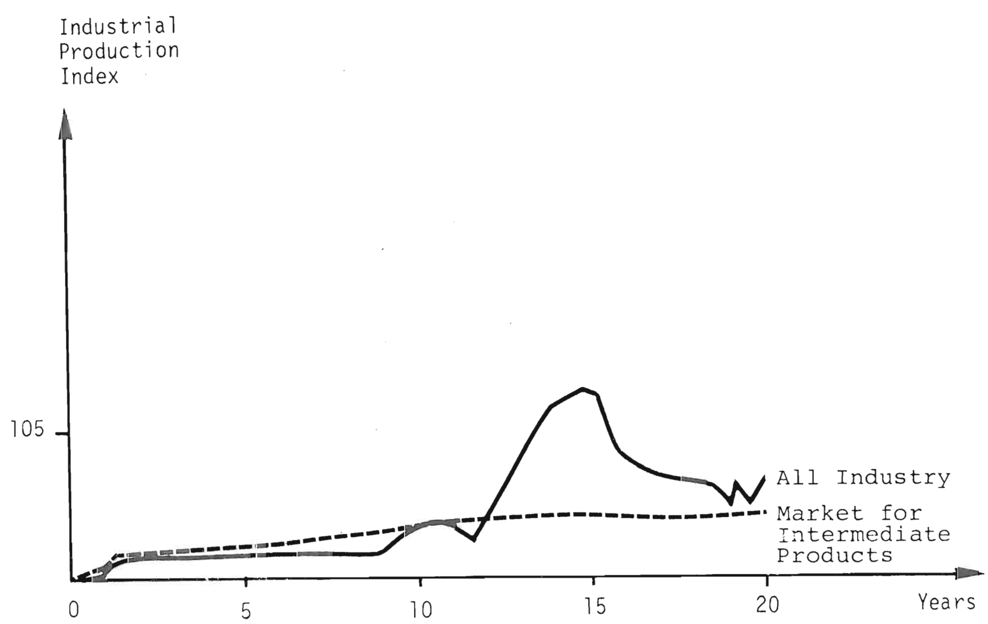


Figure 6E finally pictures the industrial production effect of the new (average, this case) entrants. Both output curves are compared on index form with a reference case. As one can see, the output effect is positive and slowly growing as expected. One interesting thing happens in year 13 when new capacity added for intermediate goods production suddenly releases a bottleneck, that allows a strong, temporary increase in total industrial output. Furthermore, when new, above average firms enter the market for intermediate products there is a slight lowering of the rate of increase of prices in the same market as below average performers are forced to slow down growth or to contract output. Average profit margins for the same market are left roughly unaffected.

4. A FORMAL REPRESENTATION OF THE MODEL

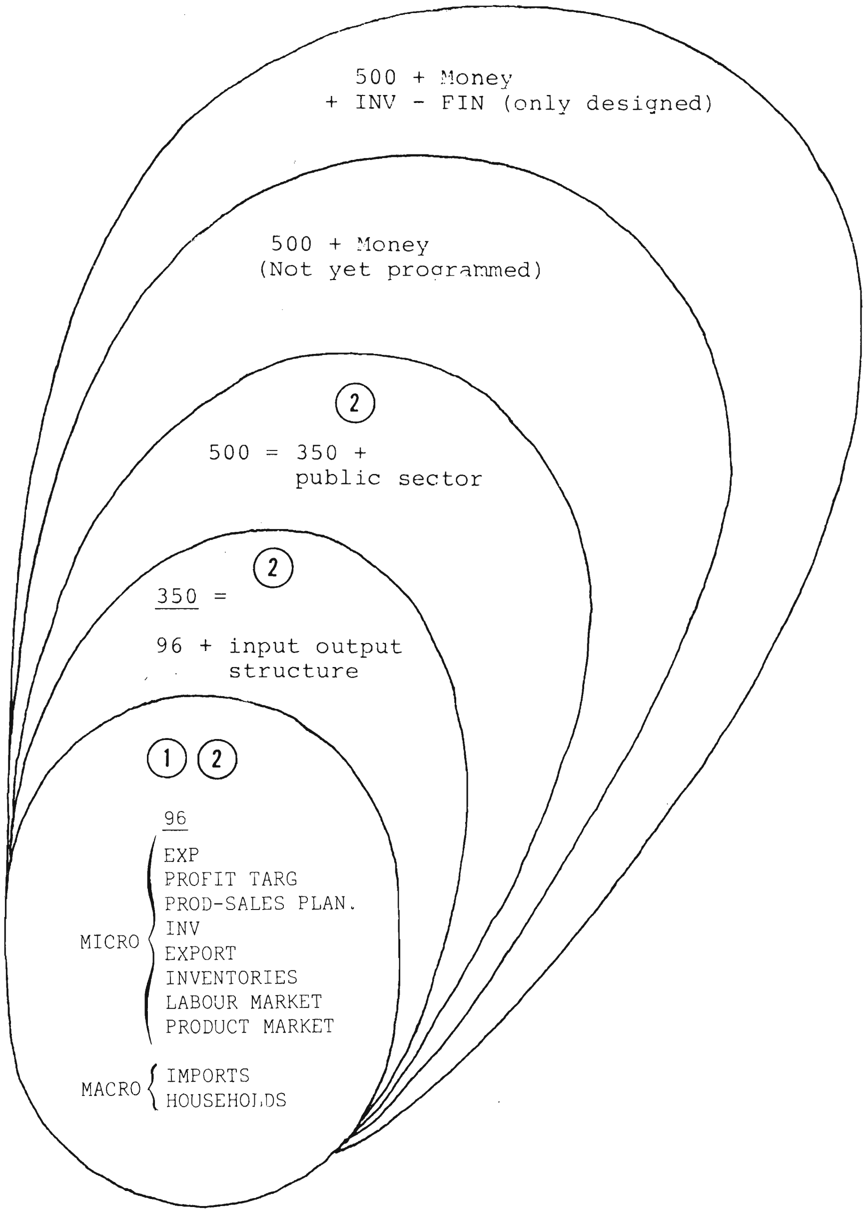
This section highlights some "analytical" features of the so called 96-version of the Swedish micro-to-macro model. A full and quite extensive presentation is found in Eliasson (1976 b, chapters 2 through 8). This presentation does not include more than the most important behavioral and market specifications that constitute the model. A complete technical specification is put together by myself, Gösta Olavi and Mats Heiman, (see Eliasson-Heiman-Olavi (1978), that in turn relates one-to-one to the APL programme. We have found it useful to give a full presentation of the 96-version here since we have managed to fit it into the largest (64 K) version of the IBM 5100 desk computer, and someone might be interested in giving this version a try of his own. In this version of the model there is no input output structure (firms are producing value added only) and no public and money sectors.

Figure 7 tells how the 96-version relates to the various stages of the extended versions that have now been implemented.

4.1 Targeting sector

Central to the macro properties of the model system is the business objective function. At the corporate headquarter level, that we are modelling, and even more so at the macro level, we see no reason to vest other ambitions with corporate headquarter management than being an efficient profit making machine (see Eliasson 1976 a, p. 250). That is, however, by no means synonymous to being a profit maximizing entity. Profit maximization is practically without meaning at the "firm macro level" at which headquarter management operates. Since we are

Figure 7. Vintages of Swedish micro-to-macro model*



(1) Installed in the IBM 5100 Desk Computer

(2) Installed in IBM Computing Center, Stockholm

* As of April 1978 the complete model 2 with a fully integrated money system has been programmed and is being calibrated. The data base now holds 30 real firms and 30 synthetic firms. On a consolidated basis they add up to the corresponding sector totals in the Swedish national accounts system.

modelling their behaviour, so be it also here. And both the convenience of and reason for this approach becomes clear from this break-down of the value growth of an individual firm (proof follows at the end).[1)]

A separable, additive targeting function

$$DNW + \theta = \underbrace{M * \alpha}_{A} - \underbrace{\rho * \beta}_{B} + \underbrace{DP(DUR) * \beta}_{C} + \underbrace{(RRN-RI) * \Psi}_{D} \qquad (1a)$$

$$\text{Headquarter GOAL Variable} = DNW + \theta - DCPI \qquad (1b)$$

$$M = 1 - \frac{L}{Q} * \frac{W}{P} \qquad (1c)$$

The variables are defined verbally and in operational terms as follows:

DX will always mean the relative change in X (i.e. $\Delta X/X$) during a certain period of time.

CH will always represent the absolute change,

i.e. $\Delta X \approx \frac{dX}{dt} \cdot \Delta t$

A = total assets valued at replacement costs

BW = total outstanding debt

NW = Net worth defined as the difference between total assets (A) and debt (BW) i.e. NW = A-BW

θ = the rate of dividend (DIV) payout of NW = DIV/NW

α = S/A

S = sales expressed in current prices

β = Kl/A

1) See also Eliasson (1976 a, p. 291 ff.).

K1 = production equipment, valued at replacement cost

ρ = rate of depreciation of equipment[1] of type K1

W = wage cost index

P = product price index

CPI = consumer price index

M = gross profit margin in terms of sales (=S)

$K2 \equiv A-K1$ = other assets (inventories, given trade credits, cash etc)[2]

Ψ = BW/NW = the debt (BW) net worth (NW) or gearing ratio

RI = rate of interest

$$RRN = \frac{M*S - K1*(\rho - DP)}{A}$$ = nominal rate of return on total capital

$$RRNW = \frac{M*S - K1*(\rho - DP) - RI*BW}{NW}$$ = nominal rate of return on net worth

We assume here that all stock entities are valued at replacement costs. This means that firm net worth (NW) has been obtained by a consistent (residual) valuation method.[3] It is an entirely-empirical matter whether the decision criteria derived from such valuation principles are relevant, a circumstance that we will discuss later.

---

1) This requires that the following identity holds:

$$INV = \frac{dK1}{dt}\Delta t + \rho * K1 - \frac{K1}{P} * \frac{dP}{dt}\Delta t$$ where INV is gross investment.

2) Note that K2 is broken down into several components in the next chapter.

3) The balance sheet of the firm looks:

Assets	Debt
A	BW NW (Residual)
Total assets	Total debt

(1a) states that the relative change in firm net worth (DNW) plus the period's dividend payout in percent of the same net worth (θ) is the sum of four components:

(A) The profit margin (M) times the ratio between sales and total assets (α).

(B) Calculated economic depreciation (subtracted)

(C) Inflationary (capital) gains on assets[1)]

(D) The leverage contribution defined as the difference between the nominal return to total assets and the (average) interest rate on debt (BW) times the debt to net worth ratio ($BW/NW=\varphi$).

It is easily demonstrated that:

$$RRN = A + B + C \qquad (1d)$$

It can furthermore be proved that:

$$DNW+\theta = (\text{nominal return to NW}) = RRNW \qquad (1e)$$

One may say that (1a) corresponds well with a targeting-delegation scheme often found in large business organizations (Eliasson 1976 a). B, C and D represent typical corporate headquarter considerations that we will make use of when the long term investment financing decision has been modeled (Eliasson 1976 b, p. 52 ff). A refers directly to operational cost control matters and can be broken down consistently into a whole spectrum of profit margins and cost shares at the level of individual production lines to be used for targeting and control purposes.[2)] The value growth component A in (1a) is the one that we will be concerned with in what follows. It defines the prime targeting variable for short term operational planning which constitutes the core of the so called 96 model version.

1) There is a problem here. If realized inflationary gains are listed under (C) the costing principle used to obtain M has to be based on a replacement valuation of raw materials and intermediate products. This is a problem we have to face when the model is fed with real firm data.

2) Eliasson (1976a).

We believe to be well supported by empirical evidence, when assuming the following feed back targeting scheme for short term operational decision making:[1]

$$MHIST := \lambda * MHIST + (1-\lambda) * M \qquad (1.1a)$$

$$TARG(M) := (1-R) * MHIST * (1+\varepsilon) + R * TARGX(M) \qquad (1.1b)^{2)}$$

$$0 \leq [\lambda, R] \leq 1, \; \varepsilon \geq 0 \text{ but small}$$

$$TARG(M) := MAX[MHIST(1+\varepsilon), TARGX(M)] \qquad (1.1c)$$

The profit margin history of a firm (MHIST) is currently updated by (1.1a). It is fed into current targets, perhaps upgraded by (1+ε) according to "maintain or improve" (MIP) standards very often met with in firms[3], after (perhaps) having been weighted together with some external reference target like profit performance in a competing firm. Targets are not always 100 percent enforced ex ante (see below). Ex post non satisfaction of targets can easily occur because of mistaken expectations. (Also see p.245).

---

1) Note the Algol notation (:=) "make equal to" that we use throughout to be able to delete indices of lagged variables.

2) TARGX(M) has not been programmed into the 96-version of the model that is fully described in the technical specifications supplement. Thus the used specification of the 96-version presumes R=O.

3) Eliasson (1976 a, p. 159).

4.2 Expectations sector

We use a general learning feed back expectations function developed partly and discussed in Eliasson (1974 pp.79-83).

$$HIST(\tau) := \lambda_1 * HIST(\tau) + (1-\lambda_1) * \tau \quad (2a)$$
$$HIST(DEV) := \lambda_2 * HIST(DEV) + (1-\lambda_2) * [\tau - EXP(\tau)] \quad (2b)$$
$$HIST(DEV2) := \lambda_3 * HIST(DEV2) + (1-\lambda_3) * [\tau - EXP(\tau)]^2 \quad (2c)$$
$$EXPI(\tau) := HIST(\tau) + \alpha * HIST(DEV) + \beta * \sqrt{HIST(DEV2)} \quad (2d)$$
$$EXP(\tau) := (1-R) * EXPI(\tau) + R * EXPX(\tau) \quad (2e)$$

where $0 \leq \lambda_i, R \leq 1$

$DEV = [\tau - EXP(\tau)]$

$DEV2 = [\tau - EXP(\tau)]^2$

Internal expectations on τ are generated out of the firms' own experience as determined by the conventional smoothing formulae combined with a quadratic learning function as entered in (2a-d).

α * HIST(DEV) ; is a correction factor for systematic mistakes in the past. $\alpha \geq 0$.

β * HIST(DEV2) ; defines the effect of variations in expectational hits whichever way they go. Even though HIST(DEV) may average out over time the very existence of variation is expected to make firms more cautious. Hence $\beta \leq 0$.

We do not believe that internal experience is enough to guide firms so we have made allowance for outside, external influences on expectations through (2e). A firm may watch a market price indicator or the CPI or forecasts by someone and form an outside EXPX(τ) to weigh together with its internal, interpreted τ-experience EXPI(τ) as in (2d).

These are what we call short-term expectations, that stretch from year to year. There is a quarterly updating function within the year as described in the Technical Code (3.1). These functions apply to firm prices (P), wage costs (W) and to sales (S), in the last case as a start up datum for production planning (see below). We plan to distinguish between long-term and short-term expectations by varying the time weights as described by λ in (2a-c). Long-term expectations are, however, not needed until the long-term investment financing sector is introduced. This has been described in Eliasson (1976 b, pp. 75-107). It is, however, not yet coded and programmed. Hence we do not discuss it here.

4.3 Production Sector

4.3.1 The Production Frontier

The production system consists mainly of the search algoritms aimed at finding a TARG satisfying solution somewhere within a feasible production frontier. This is too complex to describe in satisfactory detail here. A fairly complete description is found in Eliasson (1976 b, pp. 108-148) and an exhaustive description in Eliasson-Heiman-Olavi (1978); (see item (4.3)).

We begin here by defining the production possibility frontier. In order to make this presentation reasonably condensed we delete certain features like slack formation etc. We should note, however, that search leading to a TARG satisfactory output solution is a quite novel specification and gives the entire model system unique and quite realistic properties.[1] The production possibility frontier is defined each moment in time for each firm by:

$$QFR(L) = QTOP*(1-e^{-\gamma L}) \qquad (3a)$$

L stands for labour input in production and QTOP is the maximum possible output at the application of an infinite amount of labour input (see diagram 3).

---

1) This is also one of the designs of the model that makes an analytical representation hopelessly entangled and hence numerical methods the only practicable approach.

Capital stock is not explicit. However, investment shifts the function QFR(L) outwards and depreciation (measured in terms of potential output) shifts it inward, so it enters indirectly (see below).

A firm is always located somewhere within its QFR(L). Determining next period's production plan means starting from the point A each quarter calculated from EXP(S) and searching outward along several alternative paths until TARG(M) is satisfied. Thereafter QFR(L) is solved for L and the firm begins to look for new labour in the market, or lays off people as the solution advices.

QFR(L) has certain convenient properties that we make use of. First, the planning survey of the Federation of Swedish Industries has been designed to allow a simple estimation of QFR (see Virin (1976), Albrecht (1978)). Once A and the L-coordinate of D has been obtained, QFR can be approximated (Albrecht (1978)). From a series of consecutive investment data we should then be able to determine how QFR shifts because of investment.

Second,

$$\frac{dQFR}{dL} = QTOP * \gamma * e^{-\gamma * L} \qquad (3b)$$

clearly $\frac{d^2}{dL^2} < 0$

and $$\frac{dQFR(L=0)}{dL} = QTOP * \gamma = TEC \qquad (3c)$$

If we define

$$TEC = \gamma * QTOP \qquad (3d)$$

TEC determines labour productivity of the last piece of equipment to be closed down. Labour productivity is

$$OPTPROD = \frac{QTOP(1-e^{-\gamma L})}{L} \qquad (3e)$$

OUTPROD signifies productivity when the firm is performing on the frontier QFR. It is furthermore, monotonously declining as more L is applied within each period (read: for each given QFR).

Actual labour productivity (=PROD) can, however, be increased by leaps and bounds when the firm reduces its redundant labour by moving vertically between A and B (see diagram 3) or horisontally to the frontier (leftwards) by laying off people. The first kind is what takes place predominantly in the early upswing phase of a business cycle, the second in the late stages of the recession.

4.3.2 The Technology Constraint

TEC is updated exogenously through DMTEC that defines the annual increase in feasible labour productivity on a piece of new equipment invested. Together with investment, that brings in new technology, the time development of DMTEC defines the technology constraint or the upper limit of feasible growth in industry.

New investment increases QTOP as described below. New MTEC is integrated with the production system of each firm and stirred well to produce a new TEC feature of the frontier as described by the harmonic average:[1)]

$$TEC: = \frac{QTOP + CHQTOP}{\frac{QTOP}{TEC} + \frac{CHQTOP}{MTEC}} \qquad (3f)$$

1) This can also be written:

$$\frac{QTOP + CHQTOP}{NEWTEC} = \frac{QTOP}{TEC} + \frac{CHQTOP}{MTEC}$$

The left hand side of this expression tells how much people that would have been needed to produce QTOP+CHQTOP if the production would have been a straight tangent to QFR in the origin after investment. The right hand side tells the same before the change (QTOP/TEC) plus the same value for the marginal addition to capacity (CHQTOP/MTEC). One could also say that investment creates a new, marginal production frontier [$= CHQTOP * (1 - \exp(-\frac{MTEC * L}{CHQTOP}))$] that via (3f) blends with (3a) into a new QFR(L).

4.4 Investment function

In the model now in operation investment decisions feed on the current profit inflow. This simple "plow back" or "capital budgeting" explanation of investment is adjusted in three ways:

a) build-ups of current assets associated with sales growth (RW*CHS) and interest payments (RI*BW) represent a mandatory claim on financial resources. RW is a coefficient.

b) residual funds available for investment after (a) are augmented or reduced by the current net borrowing rate. This depends on the current nominal rate of return of the individual firm and the nominal interest rate (RI);

$$DBW = \frac{CHBW}{BW} = \alpha + \beta * (RR + DP - RI)$$

c) this modified cash inflow marked for spending on capital account is in turn adjusted downwards for unused machinery capacity. If borrowing is negative this means that debt is being paid off.

Thus we come out with the following formulation of the investment function[1]:

$$INVMAX := MxS - RW*CHS - RI*BW + [\alpha + \beta (RR+DP-RI] BW \quad (4a)$$

$$INV := A*KORR*INVMAX \quad (4b)$$

KORR stands for the rate of capacity utilization[2] and A is a scale factor.

if (1-A*KORR)*INVMAX < CHBW

reduce CHBW to equality with left hand expression.

---

1) This formulation is very much based on a capital budgeting model of investment planning derived and estimated on macro data in Eliasson (1969).

2) Distance AB+CD in Figure 3 measures the amount of unused capacity.

<u>else</u> make CHBW:= 0

and distribute

(1-A*KORR)*INVMAX > 0

as dividends to households.[1)]

Note that the investment function (4a) is based more or less directly on the separable additive targeting function (1a). (4a) implies that the inclination of the firm to increase its rate of growth in total assets (and even more so in net worth by borrowing and investing) increases with the difference between the nominal return to total assets (RRN=RR+DP) and the rate of interest (RI).

Real capital stock in <u>volume</u> terms is not explicit in the model and we prefer to have it that way. The concept of capital, however, cannot be avoided for obvious reasons. It enters indirectly when investment shifts the production frontier QFR(L) every quarter.

<u>First</u>, the decision to spend on INV by a firm results in INV after a quarter. The additional delay between INV and the corresponding capacity increase can be varied between firms and subindustries. For the time being we are using a 2 quarter delay between spending on investment account and the resulting capacity increase, which is too short for many of the firms.

<u>Second</u>, depreciation is defined in terms of QTOP and takes place at a predetermined rate:

$$QTOP: = QTOP*(1-\rho) \qquad (4c)$$

where ρ is the exogenously given rate of depreciation.

---

1) In the 96-version as described in Eliasson-Heiman-Olavi (1978) A*KORR: = 0.

Third, and simplifying somewhat, QTOP shifts outwards according to:

$$\text{CHQTOP} := \frac{\text{INV*INVEFF}}{\text{P(DUR)}} \qquad (4d)$$

P(DUR) is the endogenously determined investment goods price index.[1)]

INVEFF is a predetermined coefficient for each firm that relates one deflated unit of investment to QTOP. For the time being it is treated as a constant. We can, however, allow it to be updated endogenously via a current endogenous upvaluation of production capital in the balance sheet of the firm using P(DUR). This would mean bringing in the value of capital stock explicitly, and that value would also embody the extra value brought in by DMTEC in new investment. We can deflate that capital (stock) value by P(DUR). Whether a stable production function Q = f(L,K,...), with K so defined, exists at the firm or the industry level, or not, is a matter that does not concern us here. In fact, the total model would be an ideal instrument for probing deeper into that controversial issue, if one so wishes.

4.5 Production solution search

We will here give a very condensed specification of the production solution search process. A complete coding is found in section 4.3 in Eliasson-Heiman-Olavi (1978). A verbal and formal presentation in Eliasson (1976b, pp. 123 ff) and partially also in Albrecht (1978, in this volume). QFR(L) and its inverse RFQ(Q) are used as described below. Four algorithms (START, SAT, CHECK, SOLVE) plus a predetermined set of SEARCH paths lead us to a production and recruitment PLAN:

1) Same as final price in sector 5 in the household chapter 4.8.

START

PLAN(Q): $= \frac{EXP(S)}{EXP(P)} + \frac{OPTSTO-STO}{CLOSE}$ (5a)

PLAN(L): = MAX [L; RFQ(PLAN(Q))]

OPTSTO = optimal finished goods inventory level

STO = actual

CLOSE = number of periods to close gap (OPTSTO-STO) by varying production level.

SAT

determines whether

$$1 - \frac{PLAN(L)*EXP(W)}{PLAN(Q)*EXP(P)} \geq TARG(M) \quad (5b)$$

is true or false for any trial combination of PLAN(Q) and PLAN(L).

CHECK (optional)
ascertains that no step in SEARCH leads to less expected profits in money terms than in position before. If decrease, step back to earlier position and EXIT with plan[1)].

SOLVE

is a technical device used on certain sections of the SEARCH path to find where on the QFR(L) curve that TARG(M) is satisfied. A straight line represents the points when planned profit margins M equal TARG(M) and we look for its intersection with QFR(L). The resulting function is transcedental and we have to use an iterative solution procedure. We use the Newton-Raphson method. See further section 4.3.12 in Eliasson-Heiman-Olavi (1978).

First QFR(L) is updated by investment and the labour force of the individual firm is corrected for retirement etc.

[1)] Not in 96-version of model as presented in Eliasson-Heiman-Olavi (1978).

The firm is then positioned somewhere on the vertical line AB (Alternative I) in Figure 1 or at some point on QFR(L) above B but below D (Alternative II) via START, which calculates the first trial step in the production planning sequence. SAT checks whether the first step taken leads to a satisfactory profit performance ex ante. If not, SEARCH continues until SAT, occasionally leading to the origin in Figure 3 and a close down of operations.

How exactly firms scan their interior for satisfactory solutions is an entirely empirical problem. The alternatives are so numerous that we can easily guide the firm to all kinds of odd behaviour. For the time being firms switch between two alternative SEARCH paths;

Alternative I, which begins at a point somewhere on AB in Figure 3 and means that redundant labour is sufficient.

Alternative II, which begins at a point on QFR(L) above B but below D and requires more people than currently employed to realize Plan (Q).

We think the production search procedure now to be described provides a rough representation of what is going on in a real firm and we believe we should abstain from further detailing of the paths until we know more.

SEARCH[1)]

Start as described above.

If PLAN(Q) > Q(B) ⇒
PLAN(L) > L (more people needed for PLAN(Q)) then go to 5

If PLAN(Q) ≤ Q(B) ⇒ PLAN(L) = L go to 1.

1) Alternative I: (redundant labour sufficient)

If SAT at starting point A. Exit with PLAN(L)=L.

---

1) This is described in more detail and with further diagrammatical help in section 4.3.1-12 in Eliasson-Heiman-Olavi (1978).

Else

2) Raise PLAN(Q): = MIN(QFR(L), Q) such that MAXSTO is not exceeded.[1)] This happens at Q2.
Stop (and exit) if SAT is reached with PLAN(Q)∈ (Q(B),Q2).

Else

3) At Q2, computed above, reduce L down to RFQ(Q2).
Stop (and exit) if SAT is reached.

Else

4) Reduce PLAN(Q) further down along QFR(L) until original PLAN(Q), as determined in START(5a), is reached, or stop (and exit) if SAT is reached (using SOLVE). Else go down to 7 below, which is common for I and II alternatives.

5) This is alternative II: PLAN(Q) = QFR(L);
If SAT at starting point ⇒ PLAN(Q) > Q(B)⇒ Exit.

Else

6) Reduce Q down along QFR(L) until Q(B) at point B or stop (and exit) if SAT is reached before (using SOLVE device).

Else

7) (Common for both I and II Alternatives)

Activate SLACK RESERVE

This device (described by (4.0.1), (4.1.3-4) and (4.3.7) in Eliasson-Heiman-Olavi (1978) diagrammatically means pivoting QFR(L) slightly outward to a NEW QFR(L). The size of the pivot is endogenously determined in two steps by investment and by a short term limit within a long term limit defined by the scale of operations.
Move PLAN(L) down at given Q(B) stop and exit if SAT is reached.

Else

---

1) MAXSTO is defined as a fixed multiple of past sales. In (2) above MAXSTO - STO defines how much above Q(B) production can be raised.

8) Reduce Q down along NEW QFR(L) until zero.
Stop (and exit) if SAT is reached (using SOLVE device).

9) If the origin (0,0) is reached and the firm has not found a Q/L combination satisfying TARG(M), it is eliminated from the model, and its L is added to the pool of unemployed.

10) At any step 1-8 above, "exit" means that search is terminated, and that the current Q/L combination (giving target satisfaction) is fixed as the production/recruitment plan for the period in question.

In general one may say that search is geared towards the maintenance of long term rate of return requirements (cf. proof of targeting formula pp.256 ff). Firms strive to maintain past output levels, if compatible with targets and to make the best use of the existing labor force. Certain short term "floors", e.g. lay-off restrictions (see next footnote below) slow down contractions in firm size in the short run.

The pivoting of QFR(L) at (7) above has been entered to handle the case when difficulties to meet profit targets are encountered. A number of solutions are always available to raise productivity at the shopfloor level, although Corporate Headquarter management will not normally be aware of exactly how (see Eliasson 1976 a, p, 210 and pp. 234 ff). One well known solution that does not require new investment is to shut-down some low productive operations and allocate some labour to high productive areas. Another is simply to identify and eliminate some labour "functions" that do not affect output in the short run. There are always plenty of such "functions" in a large company.

One may ask why this was not done before the difficulties were encountered. And the answer is, there was no need since profit targets were satisfied. This may perhaps be called an instance of non-optimal behaviour. There is much evidence that it exists in a form specified in this model and described above (see e.g. Eliasson (1976 b), which can be seen as a preparatory study for this modelling project). We could of course save the concept of rational behaviour in terms of optimal behaviour by introducing very steep cost functions for new information or, fast adjustments and some of the model results might remain. This would mean changing our language and specification from something that is easy to understand for those who represent our decision makers in the model and our data, to something that is very unfamiliar.

It would mean unnecessary extra mathematical exercises and, possibly, quite erroneous properties of the model system at some places. Finally, behaviour in our model as specified is as rational as it can ever be. To take drastic action to ride through a crisis situation is a very unpleasant thing for employees and management alike, but normally accepted if the crisis is there. Not otherwise, however, and this is a very good reason for not doing the utmost at every point in time.

Summing up so far, production SEARCH steps lead to a desired reduction in the labour force or a planned expansion. If a reduction, let us assume here that all labour not needed is laid off.[1] If an expansion the firm enters the labour market with

PLAN(Q,L)

and the offering wage

$$\text{OFFER}(W) := W + \text{IOTA} * [\text{EXP}(W) - W]$$

$$\text{PLAN}(Q) \geq 0$$

PLAN(Q,L) can only be realized to the extent that the firm gets all people needed or can keep the labour it has, after Labour market search.

4.6 Labour market search (wage determination)

The labour market process is characterised by firms in active search for passively waiting labour of homogeneous quality.

1) Eliasson (1977a) presents an experiment on what happens when the new Swedish advance notice requirements before lay-off are introduced into the model system.

Search follows a predetermined market sequence, firms being ordered by the degree of expansion exhibited in their plans.

The probability of one firm raiding another firm is proportional to the size (labour force) of the firm being raided.

The probability that search leads to the pool of unemployed is proportional to its size augmented by an exogenously determined factor SKREPA ≥ 1.

SEARCH is characterized by

(A) the <u>intensity of search</u> measured by the number of search loops allowed each firm (NITER) and

(B) the <u>intensity of response</u>. This intensity, represented by the $\{\xi\}$ factors (see below), is the core or the wage setting process. It can be formally represented as:

(C) FIRM I is raiding, wanting a quantity of labour determined in the production planning sequence (above) CHL(I) at an offering wage OFFER [W(I)]

This is the way labour market search is organized:

(1) SEARCH $\Rightarrow$ pool of unemployed $\Rightarrow$ [PLAN(L)-L] = realized employment increase at OFFER(W)

(2) <u>else</u>[1)]

$$\text{OFFER}[W(I)] \geq \text{OFFER}[W(II)] * (1+\gamma), \gamma \in [0,1]$$

$$\begin{cases} CHL(I) := MIN[\theta * L(II), CHL(I)], \theta \in [0,1] \\ W(II) := W(II) + \xi_1 * [W(I) - W(II)], \xi_1 \in [0,1] \end{cases}$$

(3) <u>else</u>

$$CHL(I) := 0$$

$$W(I) := W(I) + \xi_2 * [W(II)(1+\gamma) - W(I)], \xi_2 \in [0,1]$$

1) Note that firms immediately upgrade their wage level to the OFFER level once it has been determined. We thus delete the prefix OFFER in what follows.

This is all there is needed to describe the market principles at work here. For updating algoritms etc the reader is referred to Eliasson-Heiman-Olavi (1978).

4.7 Foreign sector

Foreign connections of the economy are determined at the micro firm level on the export side and at the market level on the import side.

The export ratio (X) of the individual firm is determined as

$$CHX = f\{\frac{PFOR-PDOM}{PFOR}\} \qquad (7a)$$

The import ratio (IMP) of the market is determined accordingly as

$$CHIMP = f\{\frac{PDOM-PFOR}{PFOR}\} \qquad (7b)$$

The functions, as they are now specified in the program, are differentiable at all points except when PDOM=PFOR. In principle a high or low price elasticity of foreign trade refers to the rate of change of the X and IMP ratios in response to the {PFOR-PDOM} differential. We are, however, not dealing with constant elasticity functions. Rather, a high elasticity means that goods are diverted to or from domestic markets very fast, causing a drop (or an increase) in volume supplies that forces the price to adjust (closes the (PFOR-PDOM) differential) through volume changes and hence curbs the volume adjustment just started. A low price elasticity on the other hand works more slowly on volumes (through X and IMP) and hence closes the gap volumes (through X and IMP) and hence closes the gap (PFOR-PDOM) more slowly. This more complex machinery makes the use of the term elasticity give rise to somewhat misleading associations. Sometimes we use the term faster or slower, X-IMP times (TMX in (6.1.1) and TMIMP in (7.3.1) in Eliasson-Heiman-Olavi (1978). TMX and TMIMP measure the number of years (roughly) it takes for X (or IMP) to change with as many percentage points as (PDOM-PFOR)/PFOR.

It would in fact be much more relevant to view the drift in export ratios over time as a result of the relative profitability of exports and domestic sales. This would at least be much more in keeping with the business manager's way of phrasing himself than using conventional demand functions. Since production costs (fixed and variable) can be said to be roughly the same irrespective of where the goods are sold the major discriminating variable (besides prices on imported input goods) are the relative prices on exports and domestic sales. Hence (7a) and (7b) can be said to approximate the alternative formulation that CHX and CHIMP depend on relative profit margins.[1)] As we will take clear note of in my applications paper below (How does inflation affect growth?) the X and IMP functions are the prime transmitters of foreign inflation to our model economy. We do think that these clean, profitability oriented export and import share function catch the decision machinery better at our quarter period specification than would the conventional approach to add a foreign demand component like GNP of the industrialized world. However, by abstaining from relying on proxies to impose the business cycle on the Swedish economy we are certainly making things more difficult for ourselves.

4.8 Household sector

Household demand is determined by a nonlinear expenditure system where all households are assumed to be identical. In practice this is a macro specification.

---

1) For proof and further discussion, see Eliasson (1976b, pp. 150 ff.).

The novel features here are that:

(a) expenditure shares are determined in the long run by the growth in real income (β_3 in (8a)).[1)]

(b) durable consumption is out of a stock of durable goods, that varies with the household purchase decision, the price and the (fixed) rate of consumption (ρ) out of the stock.[2)]

(c) During iterations in product markets durable spending can be SWAPped for saving, and vice versa depending on the relative development of the interest rate (RI), CPI and the rate of unemployment (RU).

(d) Desired saving is aimed at maintaining a long run, stable relationship between household financial wealth and disposable income (8d) but

(e) this desire and SWAPPING only guides households in their spending decisions restricted by (8a). Final household saving is determined residually as (8g).

---

1) No growth in real income D(DI/CPI)=0 means that residual income is divided up in fixed proportions over time (β_{23} = constant for all i). In this case the marginal propensity to spend out of residual income is also β_{23}. If real income moves over time and if the consumer price index is not independent of nominal disposable income (which is reasonable) the analytical expression of the marginal propensity to spend becomes much more cumbersome.

2) According to the formula:

STO: = (1-ρ)*(SPE(DUR)+(1+DP)*STO)

STO stands for the stock of durable goods in the household sector.

Household spending function

$$SP(i): = \beta_1(i)*SPE(i)+\underbrace{[\beta_2(i)+\frac{\beta 3(i)}{DI/CPI}]}_{\beta_{23}}*[DI-\Sigma_i(\beta_1(i)*SPE(i)]$$

all β_j i=1,2,3 ≥ 0 (8a)

$\overset{i}{\Sigma}\beta_2(i)=1$

$\Sigma\beta_3(i)=0$

Nondurable consumption (i=2,3,4)

$$SPE(i): = P(i)*[\alpha_1(i)+\alpha_2(i) \sum_{-T}^{-1}\omega * \frac{SP(i)}{P(i)}] \quad (8b)$$

when not otherwise indicated summation is always over historic time [-T, -1]

ω = weight for each year [-T, -1]

i = 4 is service consumption

Note the distinction between SPE ex ante, desired spending, before iterations are completed each period, and

SP = actual spending as in (8a).

Durable consumption[1)] (i=5)

$$SPE=\frac{P*[\alpha_1+\alpha_2\Sigma\omega * \frac{SP}{P}]}{\rho} - (1+DP)*STO-DI*SWAP \quad (8c)$$

STO = stock of durables (current replacement value) that is consumed at the rate ρ per year.

---

1) Since consumption and spending are different things in the case of durables, formulation (8c) is not entirely correct. We use it here for simplicity. For details see Eliasson-Heiman-Olavi (1978).

Household saving (i=6)

$$SAVH = SPE(i) = (WHRA*DI-WH)+DI*SWAP \qquad (8d)$$

$$WHRA = \gamma *WHRA+(1-\gamma)*\frac{WH}{DI}, \qquad \gamma \in (0,1)$$

WH = household wealth

SWAP-function

$$SWAP = \alpha_3*CH(RI-DCPI)+\alpha_4*CHRU \qquad (8e)$$

RI = nominal rate of interest
CPI = consumer price index
RU = unemployment rate

Adjustment mechanism

1) Firms {EXP[P(i)]} $\Rightarrow$ informs market
2) Households {SPE(i) $\overset{cond.}{\Leftarrow}$ EXP[P(i)]} $\Rightarrow$ informs market
3) Firms {EXP[P(i)] $\overset{cond.}{\Leftarrow}$ SP(i)} $\Rightarrow$ informs market

cond. stands for conditional upon.

Market process: If SP intentions above provisional supplies, firms supply out of their inventories down to min levels. If below, firms try to maintain prices at "expected" levels and reduce offering prices only gradually at a predetermined rate.

4) Repeat MARKETITER times (8f)
5) THEN {P(i) $\Leftrightarrow$ SP(i)}, $i \neq 6$
calculate:
6) $SP(6)=SAVH \equiv DI- \underset{(1,5)}{SUM}[SP(i)]$ (8g)

Consumer price index

$$CPI = \frac{\Sigma\, SP(i)*P(i)}{\Sigma\, SP(i)} \qquad i = 1, \ldots 5 \qquad (8h)$$

SUPPLEMENT: PROOF OF SEPARABLE ADDITIVE TARGETING FUNCTION

Assume no taxes.[1)]

Cash flow identity

$$\Pi - RI*BW - DIV + \frac{dBW}{dt} \equiv INV + \frac{dK_2}{dt} \qquad (A)$$

Definition of gross investment spending:

$$INV \equiv \frac{dK_1}{dt} - \frac{dP}{dt} * \bar{K}_1 + \rho * K_1 \qquad (B)$$

Π = Operating profits (gross), inclusive of depreciation
RI = Average rate of interest on net debt (=BW)

K_1 = Replacement value of production equipment on which the depreciation rate (ρ) is applied to obtain depreciation ($=\rho * K_1$)
$\bar{K}_1$ = The corresponding volume measure, obtained by deflating K_1 with the investment goods deflator P
K_2 = All other assets, same valuation
NW = Net worth residually determined from:
$A \equiv K_1 + K_2 \equiv BW + NW$

Now reshuffle terms in (A) and insert in (B):

$$\Pi - \rho * K_1 - RI*BW + \frac{dP}{dt} * \bar{K}_1 \equiv DIV - \frac{dBW}{dt} + \underbrace{\frac{dK_1}{dt} + \frac{dK_2}{dt}}_{\frac{dA}{dt}}$$

From the definition of the nominal rate of return to net worth:

$$RRNW = \frac{\Pi - \rho * K_1 - RI*BW + \frac{dP}{dt} * \bar{K}_1}{NW} = \underbrace{\frac{DIV}{NW}}_{\theta} + \frac{\frac{dNW}{dt}}{NW}$$

(θ is dividend pay out rate.)

Furthermore follows:

$$RRNW = \underbrace{\frac{\Pi - \rho * K_1 - \frac{\frac{dP}{dt}}{P} * K_2}{A}}_{RR} * \frac{A}{NW} - RI * \frac{BW}{NW} + \frac{\frac{dP}{dt}}{P} * \frac{P * \bar{K}_1}{NW} + \frac{\frac{dP}{dt}}{P} * \frac{K_2}{NW} = \theta + \frac{\frac{dNW}{dt}}{NW}$$

---

1) For an extension of the separable, additive targeting formula (1) on p. 234 with taxes included see Eliasson: Business Economic Planning, (Wiley) 1976, pp. 293 ff. See also Eliasson: Two Papers on Planning and Efficiency, Economic Research Report B 13, Federation of Swedish Industries, Stockholm, October 1976, pp. 30-31.

and

$$RRNW = RR * (1 + \frac{BW}{NW}) - RI * \frac{BW}{NW} + \frac{\frac{dP}{dt}}{P} * (1 + \frac{BW}{NW}) = \theta + \frac{\frac{dNW}{dt}}{NW}$$

since $\frac{A}{NW} = 1 + \frac{BW}{NW} = 1 + \psi$

(ψ = leverage factor)

Thus:

$$RRNW = \frac{\frac{dNW}{dt}}{NW} + \theta = RR + (\underbrace{RR + \frac{\frac{dP}{dt}}{P}}_{RRN} - RI) * \psi + \frac{\frac{dP}{dt}}{P}$$

But:

$$RR = \underbrace{\frac{\Pi}{S}}_{M} * \frac{S}{A} - \rho * \frac{K_1}{A} - \frac{\frac{dP}{dt}}{P} * \frac{K_2}{A}$$

$$\therefore \frac{\frac{dNW}{dt}}{NW} + \theta = M * \frac{S}{A} - \rho * \frac{K_1}{A} + \frac{\frac{dP}{dt}}{P} * \frac{K_1}{A} + (RRN - RI) * \psi$$

Q.E.D.

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ON ESTIMATION AND OTHER PROBLEMS OF STATISTICAL INFERENCE IN THE MICRO SIMULATION APPROACH

Anders Klevmarken

The micro simulation approach to economic analysis is still in the beginning of its development. Although "numbers" are involved in the simulations much work is largely of a theoretical character one step away from empirical applications. This is so partly because of data shortage but also because there is a need to use the simulation approach to learn about the properties of ones theoretical constructs. The ultimate goal must, however, be to make an inference to the economy, whether on a macro or a micro level. To do this adequate micro data are needed as well as a basis for the inference.

The general principles of statistical inference apply to the micro simulation approach as well as to other research in econometrics. As a matter of fact, it is hard to find any useful alternative. This does not exclude, however, that there are methodological problems which are more or less specific to this approach. In the following I will first give a few comments on the analysis of micro data in general and then turn to some problems more specific to the micro simulation approach.

Analysis of micro data, some common problems

Micro data, and in particular longitudinal micro data, certainly offer new possibilities to obtain a better understanding of micro and macro behaviour, but nothing is for free. The use of micro data makes it necessary to solve problems we tend to neglect at the macro level.

1. There is usually a large individual variability in micro data which show up in low R^2:s. To explain this variability we will probably have to use models which involve more parameters than is typically the case at an aggregate level. For instance, an analysis of household consumption would not only involve household income and lagged consumption but also measures of household characteristics.

2. Partly because of the large range of variability micro relations are frequently non-linear which makes the statistical inference difficult.

3. Measurement errors become relatively important. Sometimes we will work with proxy or indicator variables which "suggest" models with latent structures, (c.f. Aigner & Goldberger (1977), Wold (1973, 1974, 1975)).

4. There are selectivity problems in micro data which may be difficult to handle. In panel data in particular self-selectivity may demand a separate treatment. One promising approach is to incorporate the selection mechanism into the basic model and estimate both at the same time, (c.f. Heckman (1976), Maddala (1977)).

5. Although micro data are expected to be a rich source of information there will most certainly remain unmeasurable individual characteristics. In panel data these have sometimes been taken care of by a variance-components approach.

6. The relationships between cross-section, cohort and time series data deserve more attention. We do not only need to know how macro activities influence micro units and how micro units should be aggregated to macro. Because the increasing demand for personal integrity will limit our possibilities to obtain micro data, and in particular panel data, we will often also have to investigate if cross-sectional data could be used for an inference about longitudinal behaviour.

We already have statistical methods which can be used to treat some of these problems, but the new emphasis on micro data will have to "generate" new methods. To indicate the nature of these methods I would like to give a few key words:

a) Although macro theory usually has a micro theoretical foundation it is not always good enough for empirical studies of micro behaviour. Our methods will thus have to be exploratory.

b) Because the sample size will be relatively large it is possible to emphasise consistency rather than efficiency. In traditional macro econometrics consistency is a completely uninteresting property because of the short time-series usually available. Frequently, however, we only know the asymptotic properties of our estimators. For this reason I agree with those who claim that one should not give much credence to confidence intervals computed in macro econometric models. On the other hand, from this does not follow that statistical inference is useless.

c) One should also emphasize robustness of methods. There is usually a conflict between our desire to have robust and efficient methods. With large samples of micro data, however, we will not have to be overly concerned about the loss in efficiency.

d) In traditional econometrics we concentrate on mean relationships, while with micro data the distributional aspects will be more emphasized. For this purpose we will probably have to develop better statistical methods than those available now.

e) There will be a need for methods which require neither linearity nor assumptions of particular non-linear forms, but rather admit data to determine the functional form of the relationships estimated.

Problems in the micro simulation approach

Next I would like to comment on a few problems which are more specific to the micro simulation method. The size of the models contributes to many of the practical difficulties. It is important to know the properties of an estimated model and the predictions produced by this model. It has been suggested that these properties could be explored by tracing out "reaction surfaces" by alternative assumptions about model structure and parameter values (sensitivity analysis). This is a good idea for small or medium sized models or for exploring particular features but cannot be used to evaluate a large micro simulation model. The sources of uncertainty in the predictions are the same as in most other econometric predictions. There will be genuine residual variation as well as measurement errors. Parameters will be unknown but estimated. Exogenous variables are not known but predicted. There will be specification errors, etc. The multiple of these errors cannot be explored in "reaction surfaces" because it would be unmanageable to analyse the large amount of computer printout required. With these large models it is not feasible to simulate all possible implications of a model and discover unrealistic features. Also, such an approach would not give the probability of the occurance of a simulated event. For these reasons it is very important that each detail (assumption) in the model be tested by statistical methods. It is also important to test the model carefully to balance what I would like to call the "size law", namely that the vested interest in our own model is proportional to its size.

Large size models also make simulations expensive. Methods have to be found which quickly trace out the distributions for strategic variables. Although the simulation methods will depend on the model structure there are general, efficient Monte Carlo methods and there are also powerful computer languages for simulations like for instance SIMULA. Experts on numerical methods and computer simulations could undoubtedly contribute to a more efficient use of the computer.

Another major problem in micro simulation studies is the lack of data. A typical feature of some micro analytic studies is that the objective function which is maximized (or minimized) to obtain estimates of the micro parameters is formulated in macro variables because micro data are not available. For instance, with respect to the micro parameters one might attempt to minimize some quadratic function of the residuals between observed and predicted GNP, consumption expenditures, investment expenditures, rate of unemployment, rate of increase in consumer prices etc. This procedure might easily lead into identification problems. To illustrate by a simple example, if we only know the sum of two variables each of which are linearly related to two other variables, it is not possible to identify the two intercepts. In a more complex model it might be difficult to see if the model is identified or not. If not, the search for a maximum (minimum) may go on for ever. Even if the model is formally identified there may be cases analogous to multicollinearity in ordinary linear models, i.e. the surface of the objective function in the neighbourhood of the extremum is flat. It might then be possible to change some parameter values with but a very small change in the value of the objective function.

Gunnar Eliasson in his paper "How does inflation affect growth - Experiments on the Swedish Model"[1) presented a slightly different data problem. He wanted to investigate if the "over shooting" response of his model to an external shock is a realistic feature. The problem is that so far we have not observed such an "over shooting" in the economy which makes it difficult to put this property of the model to a direct test.

First we would like to know if this particular property is the result of the general model structure or the particular parameter estimates obtained. Suppose we can write the model

$$M1: F(y, \theta) = 0; \theta \varepsilon S$$

where y is a vector of variables and θ a vector of unknown parameters which belong to the set S. These relations define our maintained hypothesis. If F has the over shooting property for every θ in S no sample would be able to reject this property, i.e. no test is possible. In this case there is no support for the property and one would like to consider a more general model which would include M1.

Even if there are θ:s in S which do not imply "over shooting" one might think of cases when this property is "almost" untestable. Suppose our data are generated by another (stochastic) model M2 which does not have the "over shooting" property and that the distribution of y is such that we with a probability close to 1 will obtain estimates of θ in M1 which give over shooting, then the probability to reject this

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1) See pp. 277 ff in this conference volume.

property will be close to 0. To obtain some protection against this possibility one would like to investigate if theoretically plausible models different from M1 with about the same fit would also give the over shooting property. If they do, some support for overshooting is obtained.

In general I can see no other way to solve the testing problem than to test each part of the model against micro data by statistical methods. If micro data are unavailable we will most certainly encounter difficulties in discriminating between model structures. Suppose our data are generated by M1 but there are many parameter vectors $\hat{\theta}$ which give almost the same fit to the observed (macro) data and some give "over shooting" while others do not. This result neither give support to the over shooting property, nor rejects it. Equivalently, if one estimate $\hat{\theta}$ implies overshooting but it is possible to find another $\hat{\theta}$ which gives almost the same fit but no overshooting, then there is no support.

Eliasson discovered the over shooting property of his model by deterministic simulation. But assigning the value zero to the random errors does not always give unbiased predictions, c.f. the case of log-normally distributed errors. Depending on the structure of the model it might also generate random shocks which would counteract the over shooting. If the random errors implicit in the behavioural relations are taken into account by stochastic simulations one might thus obtain different results vis à vis over shooting.

Finally I would like to comment on what is called "the dynamic approach" to estimation. Let us take the following simple example:

$$y_t = \alpha + \beta y_{t-1} + \varepsilon_t \ ; \ \varepsilon_t \text{ is NID}(0,\sigma^2_\varepsilon)$$

Minimization of

$$\sum_1^T (y_t - \hat{y}|y_{t-1})^2 = \sum_1^T (y_t - \alpha - \beta y_{t-1})^2 ,$$

gives the Ordinary Least Squares estimates which are maximum likelihood estimates and they are consistent, asymptotically unbiased and asymptotically efficient. In the dynamic approach the following residual sum of squares is minimized

$$\sum_{1}^{T} (y_t - \hat{y}_t | \hat{y}_{t-1})^2 = \sum_{t=1}^{T} (y_t - \alpha \sum_{i=1}^{t} \beta^{i-2} - \beta^{t-1} y_1)^2 ,$$

where y_1 is the first y-observation. It remains to be shown that the estimates obtained have any desirable properties.

If the OLS estimates are used for "dynamic predictions", i.e. only the first y-observation is used to start the forecasting, and if all ε_t are set equal to zero, one would probably obtain a sequence of y-predictions which deviates from the observed series in a seemingly non-random way. Is this result an indication of a bad model? Not necessarily! In a mean-square sense the prediction was the best possible given that we only knew the first y-value. The random number generator which we call the economy will generate a y-series with all ε set equal to zero only with a probability close to zero. The probability that our random number generator would be able to generate the same series of ε values as generated by the economy is also almost zero. To simulate only one future y-path thus is almost useless. What is of interest is to simulate the whole distribution of y-paths. Our interest must then be concentrated on building models which yield distributions with small variances.

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STEPWISE PARAMETER ESTIMATION OF A MICRO SIMULATION MODEL

Gunnar Eliasson and Gösta Olavi

An intuitive stepwise calibration method has been used so far on the Swedish Micro-Macro Model. This paper codifies this procedure described in the paper on the model already presented[1] at this conference as a first step towards a more systematic, computer based estimation procedure.

Being recursively specified through-out, the model cannot be solved as simultaneous equations, but is forwarded in time via a simulation scheme. Since a complete set of real micro data has not yet been made ready, we apply fully dynamic simulations and calibrate all blocks simultaneously. It has not yet been possible to fit endogenously simulated micro data to its "correct" values, or to do the same thing partially block by block keeping all other blocks exogenous each time. Exogenization of blocks and partial block by block calibration in fact contradict the essential idea of the whole model. There is so much linkage across blocks, especially in the micro based market processes that exogenization of most blocks involves redesigning the model. Hence exogenization itself should be expected to affect macro behaviour in a not negligible way. Consequently it will not be very helpful in a calibration context.

Once we get a complete set of micro firm data we will also use simulated cross sectional patterns over time to calibrate the model further[2]. We want to emphasize, however, that

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1) G Eliasson: A Micro Simulation Model of a National Economy: The case of Sweden, pp 179 ff.

2) Some such work can be said to have been done already. For instance, we know roughly the rate at which the correlation between past and current rates of return of individual firms decreases with time. We have checked that model simulations do not contradict this evidence. It should be noted here that there is no randomizing device in the model that sees to it that such results are obtained. In this context the model is deterministic.

the most important empirical test of the model has to do with getting the micro assumptions numerically right. (Cf the discussion on pp. 32-51.) Here we are concerned with "estimating" a very limited number of parameters indirectly where access to direct micro observation has not been possible. This estimation also serves as a complementary check at the macro level that this "other" numerical information, that has gone into the model, is consistent with reality.

It will be obvious from what follows, that this paper is concerned with one side of the estimation procedure only, namely with the practical problem of how to obtain the "best fit" within reasonable computer resource limits. We do not discuss here the important problem of the stochastical properties of the estimates we eventually reach.

The general idea is to first calibrate the model to produce trends for critical endogenous macro variables over the simulation period that are consistent with Swedish post-war development, and then to calibrate the year-to-year historical development. The approach in each of these two phases is to move a selected subset of model parameters within a predetermined range, to get successively better values of an objective function, measuring the closeness of fit. This two-step scheme is made possible by the fact, noted from initial experimentation with the model, that most model parameters can be classified into one of two groups; one largely operating on model trends and the other mostly on short term cyclical behavior.

For each of the two steps, the objective function has been chosen so as to

a) economize on computer time

b) allow the inclusion of as much a priori knowledge as possible

c) lead to an improved numerical specification from the chosen starting point.

The philosophy behind this two-step method is that the complexity of micro simulation models of the Swedish kind

(1) allows for a multitude of solutions that satisfy the goodness of fit criterion if scanning is unrestricted but

(2) that a priori considerations (knowledge) allow us to limit the number of choices considerably. We also believe

(3) that our own intuitive capabilities are superior to mechanical, unlimited scanning when it comes to avoiding non-global optima, but that the mechanical approach is superior when we reach the stage of fine tuning with little risk of going in the wrong direction.

First we define a set of goal variables G_i and find out by way of sensitivity analysis which parameters work on G mostly in the long run (Trend = GTR_i) and on short run cyclical variations (= GCL_i).

Then we define a goodness of fit criterion.

To make the presentation more concrete we introduce the chosen set of goal variables directly from the model version described in Eliasson-Heiman-Olavi (1976)[1]. There is no practical way whatsoever to perform this estimation on all macro variables and the variables thus have had to be chosen so as to minimize the risk that other variables stray off in undesired directions. We do not, however, explain this choice here.

Step one: TRENDS

Goal variables = GTR_i = Trends for the following macro entities:

Q	= (i = 1)	=	industrial production
L (TOT)	= (i = 2)	=	total employment
W	= (i = 3)	=	wage costs in industry
P	= (i = 4)	=	wholesale price index
CPI	= (i = 5)	=	consumer price index
SAVH	= (i = 6)	=	household saving

Trend criterion

(A) Minimize $\underset{i}{MAX} \left| GTR_i^{model} - GTR_i^{actual} \right.$

subject to:

(A1) M, RU, SUM $\in$ {low, high} through simulation

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1) See Eliasson-Heiman-Olavi (1978).

(A2) by varying

KSI	$\in\{0.1, 1.0\}$
NITER	$\in\{5, 15\}$ (integer)
IOTA	$\in\{0.5, 1\}$
ALFABW	≥ 0
BETABW	≥ 0
DMTEC	≥ 0.1
MARKET-ITER	≥ 1 (integer)
MAXDP	≥ 0
GAMMA	≥ 0
THETA	$\in\{0.1\}$

Note that we consider correct evolution of firms' profit margins (M), rate of unemployment (RU), and industrial capacity utilization (SUM) to be so important for calibrating the model, that we have chosen to enter them as restrictions rather than to include them in the objective function.

KSI — is a parameter that tells to what extent a firm, having performed an unsuccessful raid for new labour on another firm, closes the observed wage difference by increasing its own wage level. Also see p.220 in this conference volume.

NITER — gives the number of interactions (searches) a firm is allowed in the labour market each period (quarter).

IOTA — is the fraction of the expected wage increase that a firm chooses to offer directly when entering the labour market in search for people.

ALFABW and BETABW — the rate of increase in firm (net) borrowing is assumed to depend linearly on the difference between the nominal return to total assets and the borrowing rate. ALFABW is the intercept and BETABW the coefficient.

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1) Numbers refer to algorithms where this parameter appears in Eliasson-Heiman-Olavi (1978).

DMTEC — is the (exogenous) rate of increase in productivity of new equipment invested.

MARKET-ITER — tells the number of producer-household price-volume iterations in the product market.

MAXDP — maximum fraction by which one year's price increases can differ from expected values, as a consequence of excess supply or demand in the product market.

GAMMA — the relative wage improvement a worker demands to move to a new job.

THETA — maximum fraction of a firm's labour force that can be lost in one raid.

The optimum value of the objective function is of course zero; that is, it should be feasible to track the six trends exactly under the restrictions indicated. However, limited resources (time and money) for the calibration will force us to terminate the iterative process at some point which does not produce the optimum, but a closeness of fit which we have prespecified as satisfactory.

Step two: CYCLES

Use the same goal variables G_i as in step one. Let GCL_{ij} indicate the value of variable G_i in year j of the simulation.

The objective function to be minimized is now, (with an appropriate set (w_i) of weights):

(B) $$\sum_i w_i * \sum_j (GCL_{ij}^{model} - GCL_{ij}^{actual})^2$$

Restrictions are

(B1) M, RU, SUM as in (A1)

(B2) Don't let achieved trends suffer more than $\pm\ \varepsilon$ compared with step 1. Stipulate for each GTR_i that:

$$|GTR_i^{model}-GTR_i^{actual}|_{step\ 2} \leq |GTR_i^{model}-GTR_i^{actual}|_{step\ 1}+\varepsilon$$

In step 2, the following model parameters are varied:

SMS	$\in\{0,1\}$
SMP	$\in\{0,1\}$
SMW	$\in\{0,1\}$
SMT	$\in\{0,1\}$
FI	$\in\{0,1\}$
TMSTO	≥ 0
TMIMSTO	≥ 0
TMX	≥ 0
TMIMP	≥ 0
SKREPA	$\in\{1,50\}$

SMS,SMP,SMW,SMT	smoothing parameters, used by firms to make each year's trade-off between old and current experiences when forming expectations for sales, prices, wages, and profit targets, respectively.
FI	a smoothing parameter, used by firms to make quarterly adjustments of expectations.
TMSTO	a time reaction parameter, used by firms as the time planned for to adjust a deviation of their finished-goods inventories from their optimum level.
TMIMSTO	same as TMSTO, but applied to input-goods inventories.
TMX,TMIMP	time reaction parameters, controlling the rate of change of export/import ratios as a response to foreign-domestic price differentials.
SKREPA	a parameter regulating the probability that a recruiting firm will turn to the pool of unemployed (instead of trying to raid other firms), and thus affecting the time pattern of a net increase in total employment.

To be able to calibrate a year-to-year fit, we have been careful to choose, in this step, a parameter set that mainly affects the time response patterns of the model. Compare this with the trend-calibrating step, where we selected parameters that have a relatively stronger impact on the long-run profitability and growth development of simulated firms, and thus on the long-run behaviour of the entire model.

Further considerations

The above is a formalization of our ad-hoc intuitive procedure for estimating critical model parameters. We have also told why we prefer a user-model interaction scheme in a first phase, instead of applying an outright, automatic optimization procedure. In a later phase of the project, when calibrations like this have resulted in reasonable interval estimates of the parameters and the risk of approaching a non-global optimum is smaller, a computer-based algorithm should be appropriate. With any such algorithm, our own interactive scheme would be mechanized into an iterative search process, evaluating for each new step to be taken what changes in the parameter set as we judge them, give the fastest improvement in the closeness-of-fit objective function. However, instead of directly computing the derivatives by way of explicit formula, the algorithm will use trial model simulations at each point, requiring a well-defined algorithm/model interface.

Note that with a computer-based optimization algorithm, the problem formulations in the two steps above might have to be modified to suit the characteristics of the algorithm in question. Integer-restrictions, like NITER and MARKETITER, are awkward to all opimization schemes; and MINMAX formulations often make optimizations very time-consuming. The exact formulations will have to be worked out in concordance with the performance of the chosen algorithm.

Note also, that with the objective function and the restrictions on the allowed parameter combinations, as we have them, we cannot guarantee the convexity of either. This might give rise to problems of finding the correct (global) optimum. Usually this problem is accomodated by running several optimizations, selecting different starting points. That would probably be too resource-consuming in practice in our case. Instead we chose to base our confidence on having found a good starting point for search - from the beginning - namely the parameter set that gave the best fit in the initial, intuitive search procedure.

HOW DOES INFLATION AFFECT GROWTH? – EXPERIMENTS ON THE SWEDISH MICRO-TO-MACRO MODEL

Gunnar Eliasson

INFLATION AND GROWTH

1. Introduction

The absolute price level can change for various reasons. We often tend to associate a higher growth rate with more inflation due to excess demand phenomena internal to the economy. There has been very little written or said on the characteristics of the reverse relationship. How does an exogenous change ("shock") in the general price level affect the rate of economic activity? This is a very relevant possibility for any economy engaged in extensive foreign trade. In fact it would be quite odd to assume a one to one correspondence between the rate of economic growth on the one hand and the rate of change in the general price level on the other, irrespective of the origin of growth and of inflation.

The same comment is in fact equally applicable to the relationship between price change and unemployment since so many and so different factors are at work on the two variables. The complexity of the originating and transmitting machinery certainly would generate an assymetrical price-volume response pattern.

We may say that this study is an essay on estimation. We have been through a series of frustrations when trying to load an extended version of the Swedish micro-macro model with numbers that resemble Swedish conditions. Some inconsistent pieces of empirical evidence still remain to sort out. The very fact that we can give an exact definition of what empirical information we do not possess in terms of the model should be interesting enough and conductive to further empirical research.

The model system operates on a market price signalling-interpretation-decision making mode among individual firms. At some critical inflation rate such a market based system tends to break down, if the inflation process is irregular enough and the interpretative learning mechanisms are not allowed time to adjust. Break down characteristics depend on certain market impulse time coefficients and (NB) the magnitude of the impulses being transmitted. We can study the behavior of the total system under alternative conditions and specifications and we can check some details although empirical evidence is distressingly scanty. The problem is that evidence on the speed of price transmission so far is not wholly consistent with a model specification that can withstand external price shocks of the same magnitude as those witnessed during the Korean boom and the recent oil crisis.

Preliminary experiments on an extended version suggest, however, that these instability properties will be satisfactorily reduced when we have introduced a full public sector and a complete taxation system. Sometimes an exogenous price increase in the foreign markets operates as a deflationary policy measure on the economy by reducing real incomes (as indeed the oil price hike did to the OECD countries); sometimes not, for instance the Korean boom where price hikes were concentrated to typical Swedish raw material exports. This series of experiments will however be structured so that we obtain the same aggregate price change on the import and export sides.

We have allowed some of the simulations to run for 20 years to study the convergence properties of the model system. For such a long time the ceteris paribus clause is of course utterly absurd and we expect the reader not to draw any empirical conclusions from this. The idea of this paper is to study the properties of the model economy of Sweden under somewhat refined and unrealistic conditions.

After we have formulated our problem more clearly we will first study how fast exogenous price changes are transmitted through the model economy described already in an earlier paper of mine to this seminar and in Eliasson (1976). We will then procede to investigate the secondary effects on economic activity levels caused by the market disequilibria occasioned by the price transmission process, and finally we will tell in more easy language what is in fact happening during the model simulations.

2. The problem

This paper combines three observations and asks one question.

First, never before in statistically registered time has such an intensive shock wave of endurable inflation encompassed so many countries and such a large total volume of economic activity as has been witnessed since 1968.

Second, we have found that one macro economic property of the Swedish micro-macro economic model is that exogenous step changes (shocks) in the economic environment of business firms, even if conventionally considered conductive to growth, if large enough in fact, are strongly detrimental to long run growth - if no counter-measures can be found.

One such exogenous step change that we have investigated at length is inflation in two forms;

a) a once and for all (sustained) change in the international market price of all Swedish export goods and

b) a temporary inflation pulse.

The results we are about to report on have been systematically maintained through several extensions of the model. If they can be shown to be reflections of real life phenomena and be substantiated by more empirical evidence, they have to mean a radical revision of our way of looking upon inflation and what it means for a market based industrial economy. Since we believe there is evidence to support the existence of the effects to be reported on but that their magnitude has as yet to be ascertained we should caution the reader to regard the results as theoretical for the time being and to be subject to further testing.[1] I should also add that the numerical results reported on in this paper are based on a model specification that we are gradually improving.

A price step impulse is transmitted through the model economy quite slowly and at different rates depending upon both the size of the initial step and the rate with which individual

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1) I am currently carrying out some of this testing work jointly with professor Hans Genberg, Institute of International Studies, Geneva.

export firms reallocate their supplies between foreign and domestic markets as a result of the new price differentials. The initial price impulse eventually overshoots in the sense that the ensuing consumer price increase becomes a multiple of the original step impulse, before a contractive process sets in. In those cases we have followed the process long enough - the consumer price effect tends to converge towards a price-price multiplier somewhere around unity in domestic markets for industrial goods (wholesale price index) and somewhere between zero and two in the consumer price end.

The overshooting mechanism feeds on the market price signalling system. When large, absolute and relative price changes are transmitted through the business sector interpretation-decision rules of individual firms become temporarily faulty and generate disorderly production, employment and investment decisions. Since market price arbitrage is faster than volume adjustments the net result is less growth in the long run if the price step is large enough and positive, negative or reversed back after a while; and the more so the more the economy swings off from a steady state growth path.

Very much so this paper is concerned with the stability properties of an open industrialized economy when the market pricing-interpretation-decision making system that holds it together is jolted by disturbances.

Third, the existence of a "price overshooting" property of our economy, in this case Sweden, is an hypothesis almost intractable to direct testing. If the overshooting lags are as long and as unstable as indicated in model simulations we do not have enough time series data to ascertain them properly. As the mechanics is a price-volume-price interaction, a conventional application of a stable lag to describe the price transmission with volumes kept constant will give biased results. We need a complete macro economic model. This we have, but to be relevant this model brings us far beyond the capabilities of conventional econometric techniques. We can, however, note the following. The overshooting property systematically remains after several extensions of the model. The model has also been quite successful in tracing the post-war growth patterns of Swedish industry.

Furthermore, the overshooting property means that a simple distributed lag regression of the consumer price change on the exogenous input change of foreign exogenous prices of an open economy like Sweden should display first positive and then negative time weights, the sum of the positive weights exceeding unity. Some support for such a lag profile was reported on in Genberg (1974). The lag length used by Genberg was, however, arbitrarily cut off at 2 1/2 years and the properties of a polynominal lag estimator are very sensitive to such a priori restrictions. Later experimentation with different and longer lags by Genberg and myself, however, preserve this property. Even though we cannot say that we have empirical control of the transmission rate time profile we believe that the overshooting property as such is empirically established.

The question to be posed finally is peripheral to the paper but central to the current economic debate in Sweden. If domestic prices and wages overshoot export firms can counter this only by cutting into profit margins and/or raising productivity. In the model productivity increases come by way of new investment reductions in output and employment and of slack. Depending upon the character of the disturbance firms respond differently. But the back side of the price overshooting mechanism normally is that firms are pricing themselves out of foreign markets in an economy subjected to international import and export competition, in a vain attempt to maintain profit targets. The more price- (or rather profit) sensitive foreign trade the faster exports and imports respond. Volumes shrink, profits plunge and the ensuing impact on investment spending brings the economy down onto a lower growth trend for a long time if everything else is the same. To many observers this seems to be exactly what has now been going on for some years in Sweden, beginning with the extreme profit boom of 1973/74 and threatening to break an almost uninterrupted 55 year steady state growth record of industrial production of close to 5 per cent. And we think that we can observe price overshooting going on around us.

The original export price steps associated with the 1973/74 profit boom (and with oil) have already been transmitted to the CPI index more than in full. The causal relationships in fact seem to have been turned upside down compared to what we were taught in the 60ies, when exogenous excess demand was thought to generate first more growth and then - as a consequence - more inflation.

Let us see what sort of evidence a sensitivity analysis[1)] of the Swedish micro-macro model, described already in an earlier paper, can shed on this peculiar issue.

3. The rate of price transmission

Figures 1 picture the rate of transmission of an exogenous (a) step change in foreign prices and (b) a pulse wave through several production stages to the consumer price. All "price" diagrams shown in this paper exhibit the cumulative domestic (wholesale or CPI) inflation effect either in per cent of the original price step or on index form with the reference case with no price step as the base. All activity diagrams in the next section are of the second index type. Five things can immediately be observed.

First, the larger the step increase the larger (each period) the response in the consumer price index but the longer it takes for the full effect to work itself through.

Second, transmission is somewhat faster to the wholesale price index than to the consumer price index and also in markets with relatively high foreign trade that are immediately affected by the first transitory growth impulse from inflation (intermediate and investment goods (not shown)). The speed of transmission also depends positively on the speed by which export firms and importers adjust their supplies in foreign and Swedish markets in response to foreign domestic price differentials. This can be seen from a comparison of Figures 1A and 1B. We may say that the high price elasticity case of Figure 1A represents a more open economy than the low elasticity case of Figure 1B.[2)]

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1) This experiment series has been run on what we call the 350 version of the model. It includes an elaborate interindustry market and inventory system but no tax and money systems. The government can only figure as an exogenously imposed surplus or deficit. See Figure 6 in my description of the Swedish model in this conference volume.

2) In the high elasticity case exports increase by half the quarterly foreign-domestic percentage price differential the next quarter and in the low elasticity case with 20 per cent. Part of the story is that the higher the elasticity the faster the price difference closes through volume responses. However, also see Albrecht's somewhat different way of distinguishing between an open and a closed economy in this same model in his paper for this conference volume.

Third, some overshooting displays itself throughout and is more persistent the slower supply responses by exporters and importers. Since this response time defines the openness of an economy we may perhaps say that the difference between Figures 1A and 1B picture the extent to which a foreign inflationary impulse can spin off a domestic inflationary spiral.

Fourth, in the longer run convergence is not towards a one to one correspondence between initial step and final change in the consumer price level as is often conventionally assumed. Some of the price effect may be absorbed or reinforced by profit margins. The equilibrium conditions (cyclical, etc.) characterizing the point in time when the price step hits the economy strongly affects the relative sizes of step inputs and whole sale and consumer price effects. The ensuing investment and relative sector growth effects may modify the transmission further.

Fifth, there is no necessary symmetry in time response patterns between step increases and decreases of equal magnitude. The reason is of course that firms do not respond symmetrically to plus and minus changes in their prices.

In Figure 1A the shaded area is the cumulated lag estimated on Swedish data by Genberg and myself using a polynominal lag, 12 years long assumed to add up to unity. It is one of a few trial estimates from a project initiated by the controversial findings of the model study reported on in this paper. The estimated lag represents the average lag response of all the ups and downs in the Swedish export price index since 1950. We will return to it in the next section, but we note in passing that if supportive at all it lends support to the faster supply reactions on the part of exporters and importers or for a more open economy. The econometric results furthermore are consistent with overshooting as well as the faster transmission to the wholesale price index.

Figure 1C finally pictures the transmission to the consumer price index of a 10 and 20 per cent step increase in the export price index respectively in year 2 that is reversed back to its beginning position in year 4 in the low elasticity case. We notice that the long run CPI effect is pracically zero.

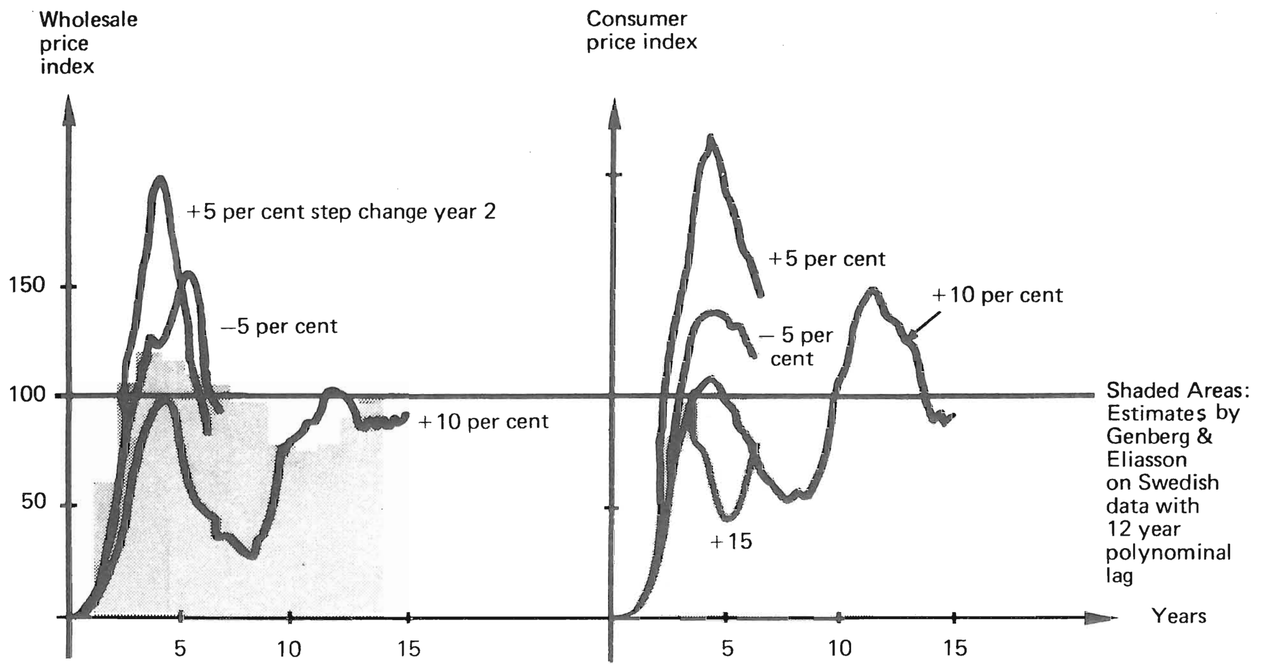
4. Asymmetric activity responses

Figures 3 picture the volume (output and employment) and Figure 2 the profit margin responses of a Swedish-like economy to the same series of step changes and pulses in the export price level the second year. Index 100 is the chosen reference case that traces the Swedish post war growth history quite well. We have allowed one simulation (the one with +10 per cent) to run for 30 years to ascertain the long run convergence of repercussions generated by the exogenous step change.

The initial profit margin effect of a foreign price increase is upward in all cases. However, over a 5 year period (whether up or down) the exogenous change spins off profit margin oscillations around a downward trend in the case with faster export and import volume reactions, seemingly supported by empirical evidence. After a few years the oscillation is replaced by a smoother development that eventually reverses into an upward tendency with the profit margin deviation converging towards zero in the 30 year run. However, for price step changes above +20 per cent market disorder gets out of hand and the economy shrinks substantially. This property was not there in the simpler, earlier versions of the model with no inter-industry markets and inventories. In this more extended version we have to slow down foreign trade price elasticities to make the economy stable enough to withstand extreme rates of export price change during the postwar period. In the low elasticity case the profit margin (Figure 2A) effect is first up from a positive price step, then down normally, until negative. Over the longer run total economy responses seem to cancel the profit effect altogether.

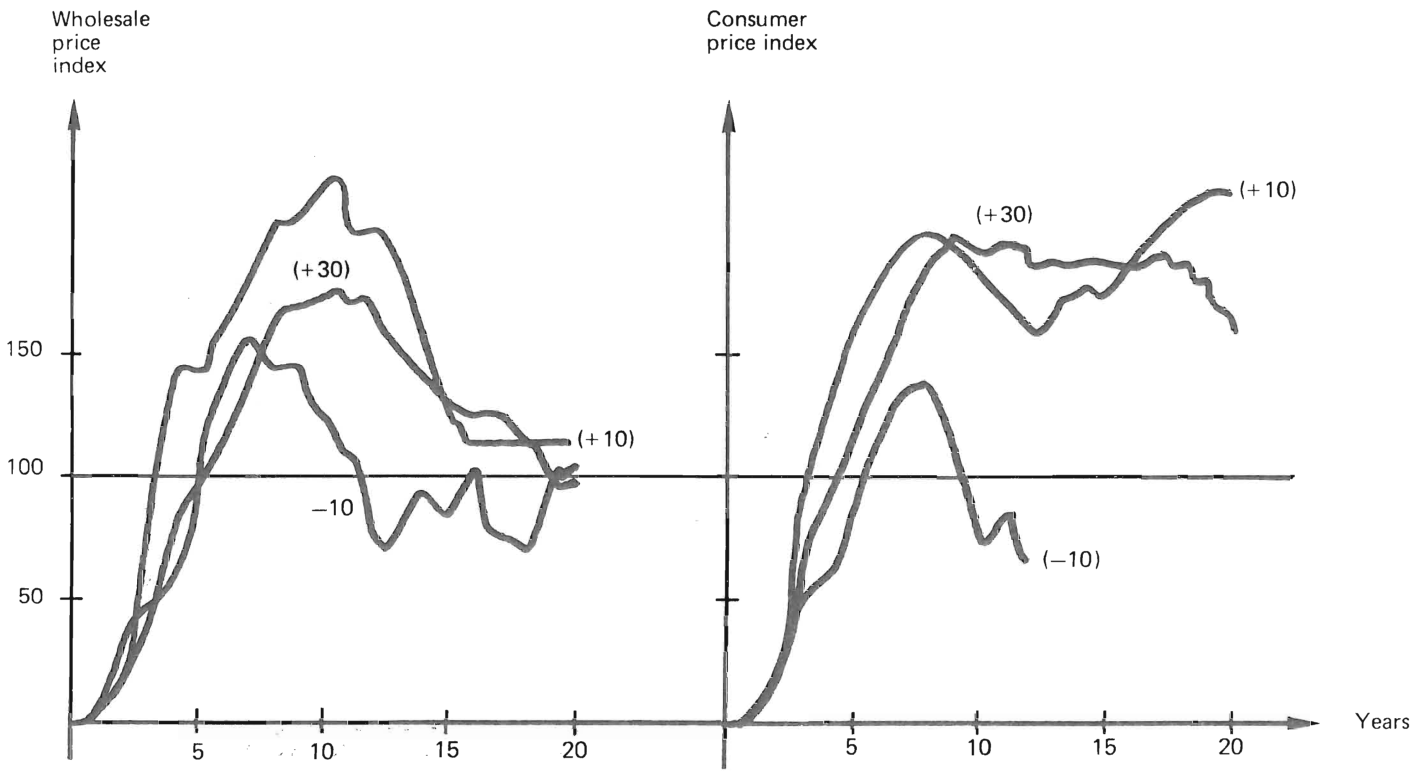
With lower foreign trade price elasticities the properties of the entire model economy changes. The positive activity (industrial growth) effect persists at least for some years even for large positive price steps in the case with smaller export and import price elasticities. On this point, when this paper is being written, we are at a loss exactly which case or which compromise to favour. Even though we need more evidence to decide, the high elasticity case seems to be the one to be preferred to allow a sufficiently fast transmission of foreign price impulses through the economy. However, we do not yet know

Figure 1A. Export-Domestic price transmission, with high foreign trade price elasticity



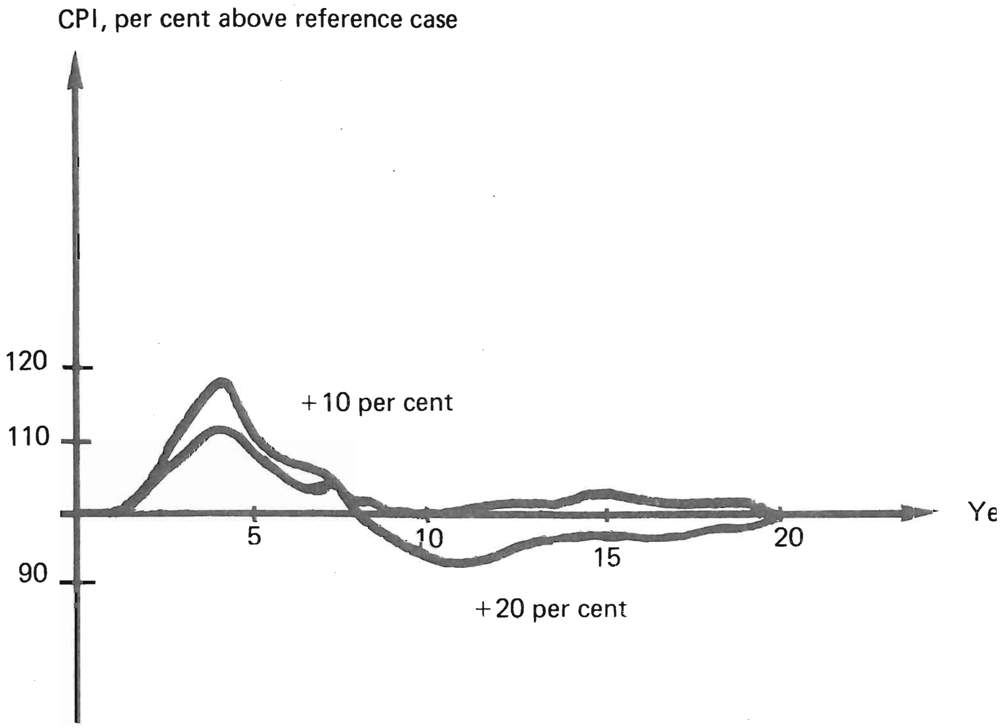
Note: *Index = 100 means that an initial step change in the export price index year 2 of x per cent has resulted in an x per cent change in the whole sale price index or the CPI above a reference case with no such change in the export price.*

Figure 1B, **Export-Domestic price transmission, with low foreign trade price elasticities**



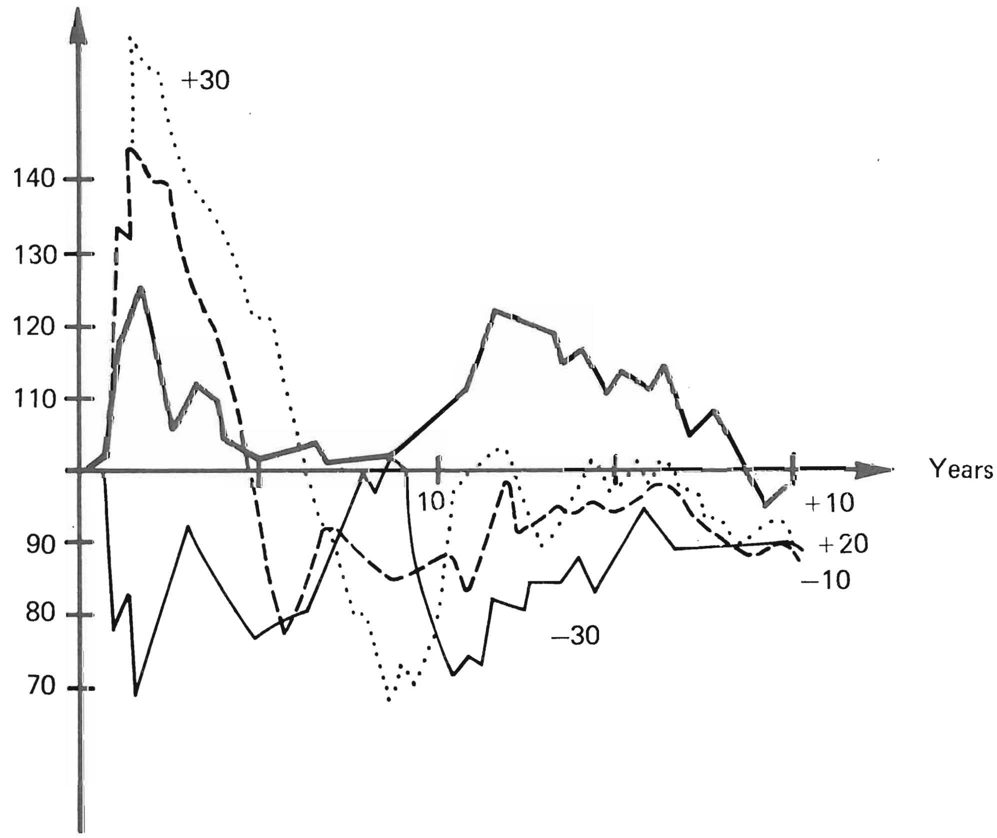
Note: Index = 100 means that an initial change of x per cent in the export price index has resulted in an x per cent change in the wholesale or consumer price index

Figure 1C. Export-Domestic price transmission with temporary price step



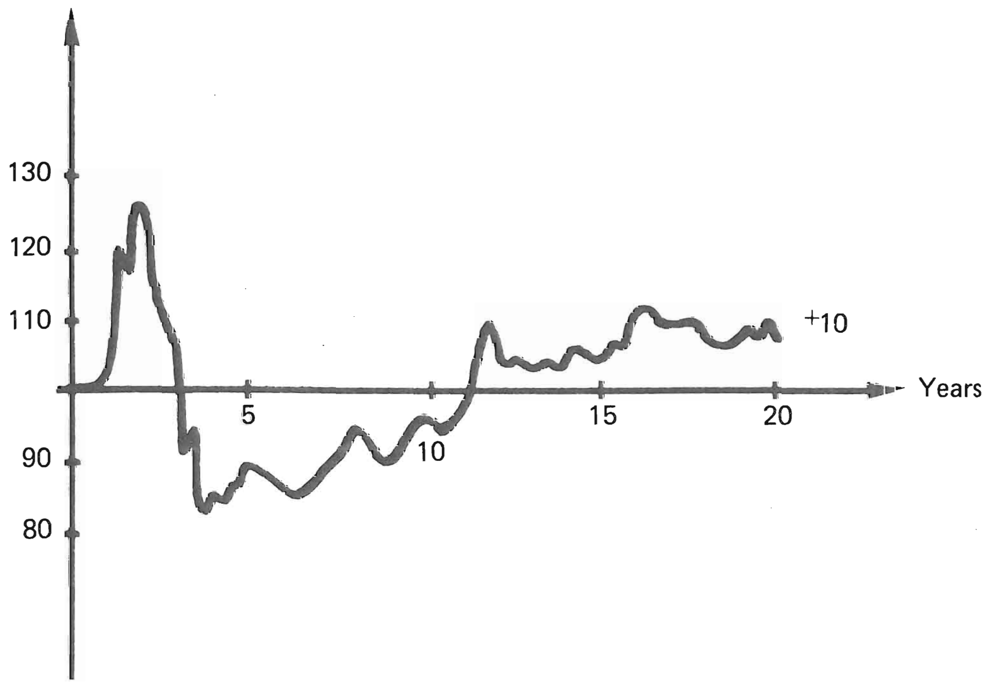
Note: *The export price rises with 10 and 20 per cent respectively the second year. In the fourth year it then drops back to its original time path in the reference case.*

Figure 2A. Effects on profit margins with low foreign trade price elasticity



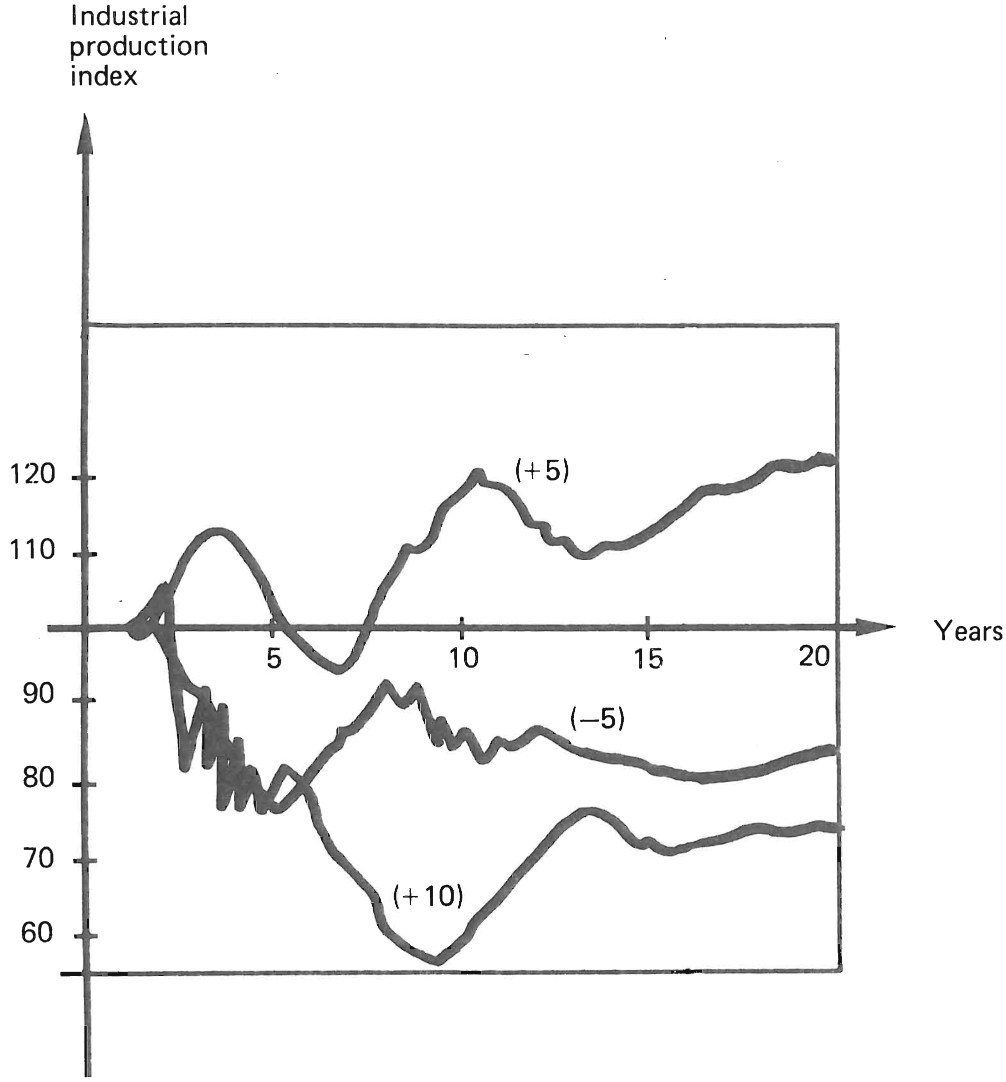
Note: Index 100 = profit margin in reference run.

Figure 2B. Effects on profit margins, temporary foreign price step between 2nd and 4th year



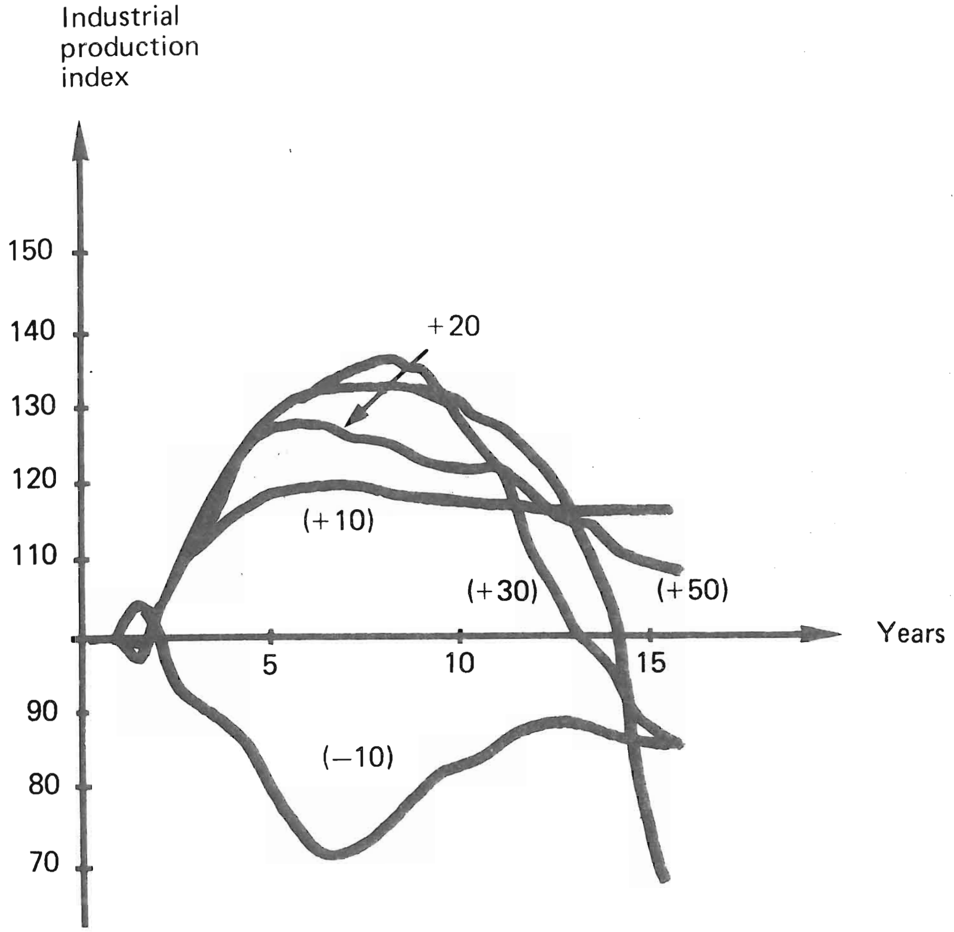
Note: Index 100 = profit margin in reference run.

Figure 3A. Effects on industrial production with high foreign trade price elasticity



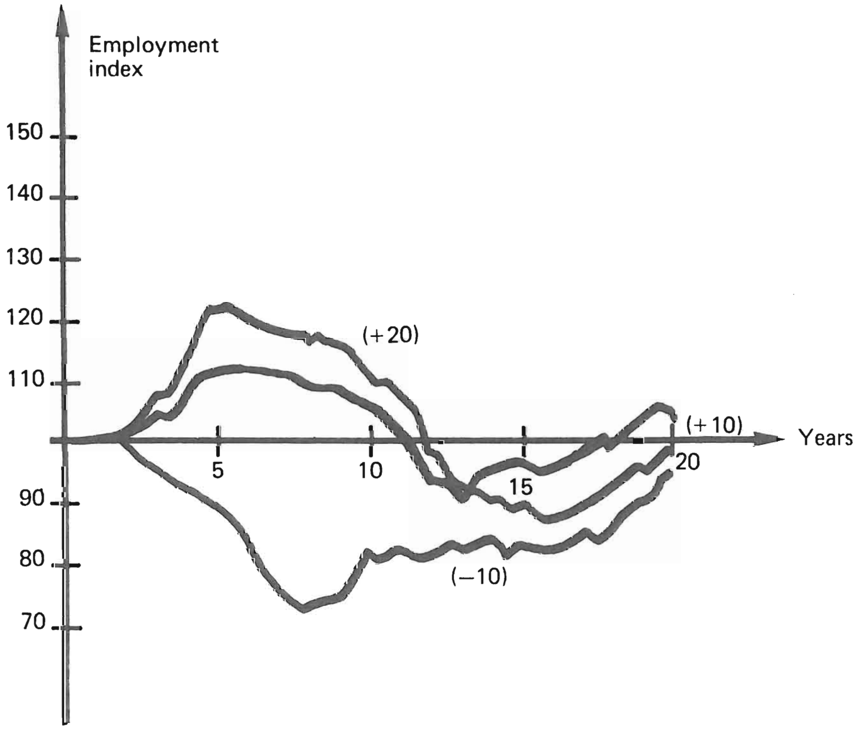
Note: The Index shows the deviation of the simulation with a price step from the reference case. Index 100 = Reference run

Figure 3B. Effects on industrial production with low foreign trade price elasticities



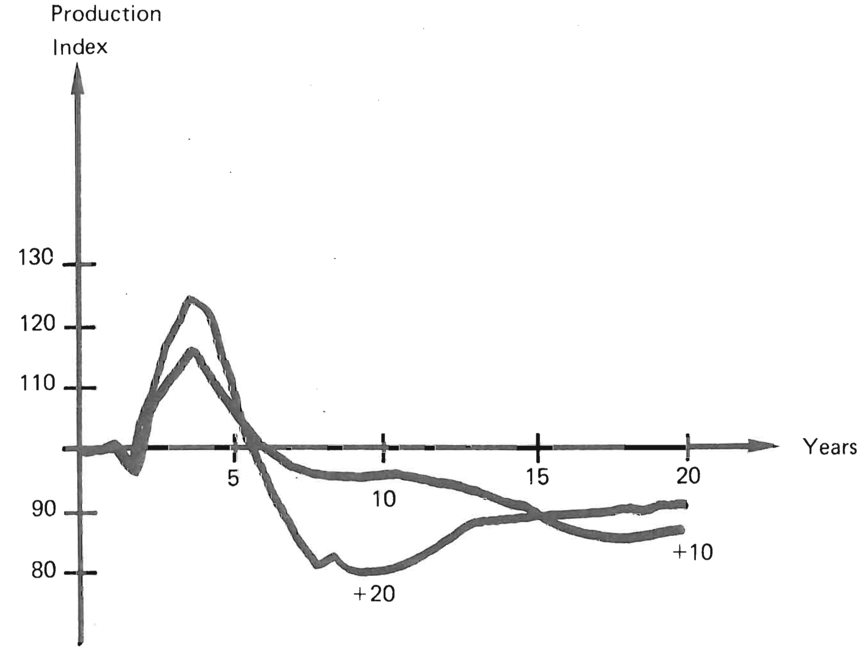
Note: Index Scaling, see Figure 3A.

Figure 3C. Effects on industrial employment, low foreign trade price elasticities



Note: Index scaling see Figure 3A.

Figure 3D. Effects on industrial production from temporary foreign price step between years 2 and 4



Note: Index scaling, see Figure 3A.

how exactly to adjust the market response parameters to obtain realistic stability of the entire economic system. Can domestic inflationary expectations of an overshooting nature alone generate such disorder? Not really if we consult Albrecht's simulation experiments on the Swedish model reported on later in this conference volume. To what extent can inflation of domestic origin, say of a wage cost-push nature, not caused by shocks external to the system retard economic growth? Is there a difference if the cost-push is of a steady state type or irregular? We know that a set of not particularly unrealistic, fast labour market - wage change - job change time parameters in combination with excessive expectations is capable of creating labour market disorder that affects growth negatively. Since fast price (wage) responses in the labour market favour short term allocative efficiency we have obviously identified an interesting conflict between short term efficiency and economic stability. This we will have to probe deeper into. If relevant as an empirical phenomenon a number of policy implications will follow. Similarly, such a conflict between efficiency and stability bears directly on the relevance on much steady state theorizing in growth economics.

Figure 3D, however, only partially supports the conclusion that the higher foreign trade elasticities are to be preferred. It pictures the activity effects of a temporary foreign price step in year 2 that is reverted back again in year 4. This assumption is more like the Korean price experience while the permanent price step is similar to what we believe will be the consequence of the present inflation experience. This simulation operates on the lower foreign trade price elasticity model. For year 1 through 3 the response is identical to that pictured in Figure 3C. As soon as the foreign price drops back again, however, bad experience is recorded. The output and employment effects are negative in the long run. So is also the profit experience of firms for more than 10 years after the first transitory two year period of exhilaration. The only comfort one can derive is that this temporary foreign inflation leaves no permanent domestic inflation effect (Figure 1C).

5. The micro process

This is what happens in the model:

The initial profit improvement from the positive price step spins off erroneous overexpansion in capacity and also output. Even though the overly optimistic expectations and initial expansion generate wage drift and more demand the final outcome proves detrimental when the domestic price level, after overshooting and reinforced by the reversal in foreign prices, begins to wind down again.

Firms respond by cutting back on output growth and investment to restore profit margins. Such measures increase productivity. However, labour is laid off, demand growth slackens and a backward multiplier gets going. In the long run industrial output growth seems to stabilize on a trend lower than that of the reference case even though the initial profit, investment and growth effects were positive.

We can compare these results with the effects of a permanent foreign price increase in Figure 3A (high elasticity case). In the +5 per cent case recovery is fast and strong. In the +10 per cent case the net impact of inflation is still negative but recovery is on its way after 30 years.

As it seems, however, the economy is in an even healthier condition after some 15 years after a moderate reflation than in the case with a somewhat larger inflationary shock and it is just about to move onto a faster growth path towards the end of the 20 year period.

In conclusion I would like to say that for smaller disturbances the model responds in a well behaved way. However, for larger disturbances it overreacts and much more so in the extended version that we are now experimenting with (with an elaborate interindustry delivery and inventory system) than in the earlier, simpler versions.

6. Summary

What can we learn from this? How reasonable are these results that are not forthcoming out of conventional Keynesian or neoclassical models?

The new properties of our (model) economic system originate in the misinterpretation of market signals by business firms in particular when they bounce outside well-known boundaries. The initial positive effects on business profits amplify this misinterpretation and spread the response pattern over a longer period.

In the tougher price decrease case firms are forced to do something about profits directly and the situation therefore improves sooner than in the more easygoing case with effortless price induced profit hikes that create problems in the longer run. The special, individual firm, feed back, profit targeting device that gears firms' future ambitions to past performance plays an important rôle here. We think this device is very realistic.

The high and low foreign trade elasticity alternatives may be said to picture the degree of openness of the economy. We have not been successful in "estimating" these elasticities but we have seen that the more closed the economy the stronger the tendency for the consumer price to run off on its own and higher than the initial foreign price impulse.[1)]

If the foreign price impulse is small enough this might even be conductive to growth. However, the results warn us that our market based economies may not be such stable systems as all of us no doubt thought during the steady state, non inflationary 50ies and the 60ies. For large foreign price shocks only the closed (low elasticity) model alternative responds with a stable future time path. I am very unhappy that we are not yet ready to allow the Government to enter the model together with business firms, also to misinterpret the situation and to policy the economy accordingly.

Perhaps we can also learn that the profession has more or less forgotten (or not observed) the experience from the inflationary Korean boom in the early 50ies. At that time the initial export price hike was even larger than during the "oil crisis" (+61 per cent 1951 in Sweden). After this price hike followed a prolonged period of relatively slow growth, in Sweden at least. The impact was not as hard as during the recent so-called oil crisis and the reason - in terms of the model - may be that the wage cost escalation from "overoptimistic" price expectations on the part of business firms was not as strong, probably due to a substantial rebound downward of export prices almost immediately after 1951.

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1) Also cf. Albrecht's experiments on the Swedish model and a parallel version loaded with US data reported on in this conference volume.

Perhaps the results also tell us something about the advisability of devaluating a currency to solve an immediate problem rather than stubbornly living on with a somewhat overvalued currency. It perhaps does if we are not overly concerned with the immediate employment effects.

LITERATURE

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TECHNICAL CHANGE AND LONGEVITY OF CAPITAL IN SWEDISH SIMULATION MODEL

Bo Carlsson and Gösta Olavi

The Model

The purpose of this paper is to explore the effects of varying assumptions on technical change and the longevity of capital on the performance of a microbased simulation model of the Swedish economy. This model has been described in several papers[1]. We shall be concerned here only with the block within the larger model where the output, employment and investment of firms are determined.

Like in all growth models, the assumptions regarding the way technological change enters in are crucial. In the particular model investigated here, the production function for each firm is of the form

$$Q(t) = QTOP(t)\cdot\left\{1 - e^{\frac{-TEC(t)\cdot L(t)}{QTOP(t)}}\right\} \qquad (1)$$

where Q(t) = potential output (value added)
QTOP(t) = the maximum level of output which is approached asymptotically when infinite amounts of labor are used, given a certain level of capital stock.
TEC(t) = state of technology
L(t) = firm employment and
t refers to the time period.

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1) E.g. Gunnar Eliasson in collaboration with Gösta Olavi and Mats Heiman; A Micro Macro Interactive Simulation Model of the Swedish Economy. Preliminary Model Specification. IUI, Working Paper No. 7, 1976.

The production function is illustrated in figure 1. The only factor of production which is explicit in this function is labor. However, the potential output, and hence the productivity of labor, is determined by the state of technology TEC(t). The state of technology at time t is determined by the previous period's state of technology and the amounts and level of productivity of new capital:

$$TEC(t) = \frac{TEC(t-1) \cdot QTOP(t-1) + MTEC(t) \cdot \Delta QTOP(t)}{QTOP(t-1) + \Delta QTOP(t)} \quad (2)$$

where

$$MTEC(t) = MTEC(t-1) \cdot \{1 + DMTEC(j)\}; \quad (3)$$

$$QTOP(t) = QTOP(t-1) \cdot \{1 - RHO(j)\} + \Delta QTOP(t); \quad (4)$$

$$\Delta QTOP(t) = INV(t) \cdot INVEFF(t); \quad (5)$$

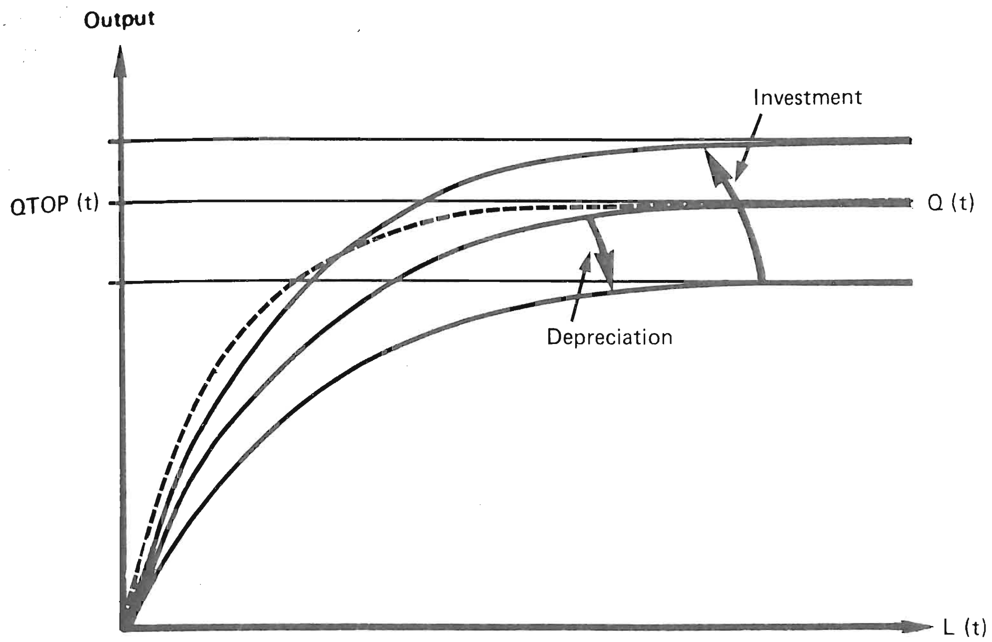
INV(t) = the level of investment in the firm in period t;
INVEFF(t) = the efficiency of newly installed capital (obtained from another part of the model and therefore treated here as exogenous);
MTEC(t) = the level of labor productivity associated with new capital;
DMTEC(j) = the rate of change of MTEC(t) in sector j; exogenous;

RHO(j) = the rate of capital depreciation in sector j, j=1,...,4

1 = raw material processing sector
2 = intermediate goods manufacturing sector
3 = investment goods manufacturing sector
4 = consumer goods manufacturing sector.

Hence, capital enters into the production function indirectly via its effects on labor productivity, and technological change can therefore be regarded as embodied in new capital. Note that QTOP(t), the maximum output attained asymptotically when infinite amounts of labor are used, is not affected by TEC(t). However, with a better state of technology, the curvature of the production function is increased so that the asymptote is approached more quickly (cf. broken curve in figure 1). QTOP(t) is lowered due to the depreciation of capital and raised due to gross investment.

Figure 1. Production Function.



Note: Figure from Eliasson; A Micro-Macro Interactive Simulation Model of the Swedish Economy, p. 133. IUI Working Paper No. 7, 1976.

It can be seen that there are three factors which are essential to the growth of potential output, namely the level of investment INV(t), the productivity of new capital MTEC(t), and the rate of depreciation of capital RHO(j). The level of investment is determined endogenously in another block of the model; however, in the present paper it is treated as an exogenous variable. We will be concerned, therefore, with only two "growth factors", the rate of change of labor productivity associated with new capital and the rate of depreciation of capital. Both of these variables are regarded here as branch specific rather than firm specific. This is an assumption which can be changed when the synthetic firm data which are currently used in the model are replaced by real firm data. It will then be possible also to let both DMTEC(j) and RHO(j) vary over time as well as between firms.

In order to limit the system further and focus the analysis, we also treated household demand for industrial goods by sector as exogenous, even though this set of variables is determined endogenously in the full version of the model. The version used here has interindustry markets and a full input/output system but no public and monetary sectors.[1)] The time period studied is 1955-75, and each simulation run covers 20 years.

Experiments with the Rates of Depreciation and Technological Change

Two sets of experiments were carried out. In the first set, the assumption in the original model regarding the longevity of capital DEPR(j) = 1/RHO(j) and the rate of growth of productivity of new investments DMTEC(j) were changed. The purpose of this experiment was to investigate the sensitivity of some key results in the model to changes of this sort.

In the second set of experiments, the idea was to apply empirical data from other sources regarding the rate of growth of labor productivity, i.e. the growth rate of TEC(t), in such a way that it was possible (1) to differentiate among the four industrial sectors in the model and (2) to determine what rate of change in the productivity of new capital, DMTEC(j), would be compatible with the observed differences in TEC(t), given the investments in each sector.

In the original model, the depreciation period of capital was assumed to be 10 years for all firms. In the first set of experiments the depreciation period was lengthened to 20 years and 30 years. At the same time, the assumed rate of growth of productivity of new investments, DMTEC, was allowed to vary from 3.0 percent per annum in the original model.

The combinations of assumptions made are shown in figure 2 and the results are summarized in figures 3-5, together with empirically observed trends. It can be seen that the rates of growth of labor productivity and production increase and the rate of decline of the industrial labor force slow down as the depreciation period is increased. The growth effect may seem surprising at first sight but it indicates that there is a capacity constraint depending on the longevity of capital which keeps down output and employment. A longer life of equipment, ceteris paribus, simply means that there will be more capital per employee to work with.

It is hardly surprising that production and labor productivity increase faster when the rate of growth of productivity of new capital rises. It is less obvious, however, that the rate of decline of the industrial labor force should not be correlated with the changes in

1) See Figures 1 and 6 in Eliasson's presentation of The Swedish Micro-to-Macro Model, pp. 179 ff.

the productivity of new capital. Note that industrial employment has declined in the last 20 years and that this is reflected in all the experiments reported here. As can be seen in figure 5, the rate of decline in industrial employment becomes somewhat slower as DMTEC rises from zero to 1.5%. Then the rate of decline increases as DMTEC continues to increase. Our interpretation is that, on the one hand, higher productivity of new capital yields a higher profit to firms, thus supporting investment and growth in output and hence more expansive labor recruitment plans. But, on the other hand, as the productivity of new capital reaches beyond a certain point, the labor requirement is reduced and hence industrial employment decreases. This result depends on the fact that economic growth is fully endogenized in the model within the capacity constraint set by the rate at which new technology (MTEC) enters in.

The conclusion from these experiments is that the results in the model are fairly sensitive to the changes in assumptions made here. Generally speaking, the results seem to improve relative to those of the original version of the model as the depreciation period is lengthened from 10 years to 30 years, although they still leave a good deal to be desired. The results as far as technological change goes are much less clear. Therefore, we will turn now to a sensitivity analysis using various numerical specifications of DMTEC.

Figure 2. Assumptions

		DEPR=10 DMTEC=0.03	
DEPR=20 DMTEC=0.00	DEPR=20 DMTEC=0.015	DEPR=20 DMTEC=0.03	DEPR=20 DMTEC=0.06
		DEPR=30 DMTEC=0.03	

Figure 3. Rate of Growth of Labor Productivity
% anually

		3.98	
3.78	3.88	4.14	4.41
		4.27	

Empirically observed value: 6.1%.

Figure 4. Rate of Growth of Production
% anually

		2.64	
2.35	2.90	3.06	3.14
		3.32	

Empirically observed value: 4.6 %/year

Figure 5. Rate of Growth of Employment in Industrial Sector
% annually

		-1.28	
-1.38	-0.94	-1.04	-1.22
		-0.90	

Empirically observed value: -0.9 %/year

Technological Change Broken Down by Sector

In a study published recently by the Industrial Institute for Economic and Social Research (IUI)[1], an attempt was made to estimate "total producitivity" growth after allowance has been made for the increase in labor and capital inputs (the so-called residual). This concept is very closely related to the rate of change of TEC(t) in our model. TEC(t) is normally determined endogenously in the model, based on assumptions on DMTEC(j) as shown above. In the original model, DMTEC(j) is set to 3.0 percent per year in all four industrial sectors. The basic idea behind the second set of experiments was to try to "estimate" DMTEC(j) in each sector, given TEC(t) as obtained from the study just mentioned, and given exogenous values on investment. In this sense, the procedure used here is the reverse of that normally used in the model.

An iterative approach was used. As a starting point, DMTEC(j) was set equal to the empirically observed trend for TEC(t) in each sector. The depreciation period was assumed to be 20 years. The results are shown in the upper part of figure 6. Under these assumptions, the resulting trend for TEC(t) turns out to be higher than that observed in all four sectors (cf. bottom line in the figure). This is true especially for the consumer goods sector.

In another iteration, the same assumptions were made except for a longer depreciation period, namely 35 years instead of 20 years. The results are very similar to those of the first iteration, as shown in the middle section of figure 6, i.e. the length of the depreciation period beyond 20 years does not seem to make much difference.

The assumption of a 35-year depreciation period is based on empirical studies[2] which estimate the depreciation time at 35-40 years (an average for machine and building investments) depending on the sector in question. The assumption of a 35-year depreciation period was retained throughout the rest of the iterations.

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1) G Eriksson, U Jakobsson and L Jansson, "Produktionsfunktioner och strukturomvandlingsanalys" (Production Functions and Analysis of Structural Change), in IUI:s långtidsbedömning 1976. Bilagor (IUI, Stockholm 1977).

2) E.g. C O Cederbladh,"Realkapital och avskrivning" (Real Capital and Depreciation), Urval, no 4, National Central Bureau of Statistics. Stockholm 1971.

In the lower section of figure 6, the results of the final iteration are shown. It turns out that the growth rates of the labor productivity associated with new capital which are compatible with the observed trends for TEC(t) are the following: 5.6% per year in the raw materials processing sector, 3.0% in the intermediate goods sector, 2.6% in the investment goods sector, and only 0.4% in the consumer goods sector. Thus, there seems to be a substantial reduction in the rate of growth of the labor productivity associated with new capital as we go from the heavy process industries to the light consumer goods industries, i.e., the rate of technological change seems to be reduced considerably. This is quite plausible, given the fact that technological change can be expected to be more embodied in highly capital intensive industries than in industries where capital plays a relatively insignificant rôle.

This result might indicate that the hypothesis that technological change is embodied attributes too much to capital, especially in the consumer goods industries. It appears reasonable that technological change is more disembodied in relatively labor and skill intensive industries than in capital intensive industries. This type of interpretation would explain why the difference between DMTEC(j) and the trend for TEC(t) is large in these industries and small in capital intensive industries. However, even if this should be true, the fact that the rate of growth of TEC(t) is relatively small in the consumer goods industries would indicate that the disembodied technological change has been slow, even if all technological change were attributed to this factor.

It can be demonstrated that if

DMTEC > (RHO + Net Capacity Growth),

i.e. if the rate of growth of marginal labor productivity is higher than the sum of the rate of depreciation and the net capacity growth, the growth of average productivity of firms would not be able to keep up with DMTEC but would lag more and more behind. With RHO = 2.9% per year (35-year depreciation), and as long as net capacity expands, such an increasing gap would arise only at rates of growth of MTEC substantially exceeding 2.9%. As is shown in the lower part of figure 6, this would be most likely to occur in the raw materials processing sector, since that is the only sector where

Figure 6. Results of Experiments with Varying Assumptions on Technological Change and the Longevity of Capital

	Raw Materials Processing	Inter-mediate Goods	Invest-ment Goods	Consumer Goods
DMTEC =	5.9%	3.9%	3.6%	1.5%
Resulting trend for TEC DEPR = 20 years	6,1%	4.8%	4.5%	2.7%
DMTEC =	5.9%	3.9%	3.6%	1.5%
Resulting trend for TEC DEPR = 35 years	5.8%	5.0%	4.5%	2.7%
DMTEC =	5.6%	3.0%	2.6%	0.4%
Resulting trend for TEC DEPR = 35 years	5.9%	3.9%	3.6%	1.5%
ACTUAL trend for TEC	5.9%	3.9%	3.6%	1.5%

DMTEC > 3%/year. However, even in this sector, like in the others, the "estimated" DMTEC is lower than the trend for TEC in all four sectors but especially in the consumer goods sector. This implies that investment must have taken place at such a high rate that the average labor productivity has risen faster than that of new capital, i.e. that the gap between average and best practice technology has diminished. This finding, if it is borne out in further analysis, is directly opposite to results obtained in some other IUI studies[1)] which have indicated an increasing gap.

The question thus arises whether the results in the studies cited here hold only for the relatively homogeneous sectors for which they were obtained or if they have more general application. This is being analyzed in a research project currently going on at the IUI. Another issue which is also the object of further study within the same project is whether it is true, as indicated above, that technological change has been more rapid in capital intensive than in labor and skill intensive industries and how such differences could be explained at both industry and firm level. The simulation model used in the current paper will provide a means of analyzing the impact at the macro (economy-wide) level of technological and productivity changes at the micro level.

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1) L Hjalmarsson and F Førsund, "Technical Progress and Structural Efficiency in Swedish Milk Processing", paper presented at the international colloquium on Capital in the Production Function at Paris-Nanterre, November 18-20, 1976; Hjalmarsson and Førsund, "Production Functions in Swedish Particle Board Industry", paper presented at the same conference; A Grufman, "Technical Change in the Swedish Hydro Power Sector 1900-1975", paper presented at the IUI Conference on Production, Technology and Structural Change, in Stockholm July 1977.

EXPECTATIONS, CYCLICAL FLUCTUATIONS AND GROWTH – EXPERIMENTS ON THE SWEDISH MODEL

Jim Albrecht

This paper presents results from simulation runs on the "micro-macro interactive simulation model of the Swedish economy" (MOSES for short) that is being developed by Gunnar Eliasson at IUI. These results are based on what we call Version 96 of MOSES. As compared with the model presented in this conference volume by Eliasson, the 96 Version lacks an explicit treatment of intermediate goods (i.e., no inter-industry markets and no input-output matrix for each firm) and does not have a block for an active government sector. Yet to come in any version of the model (as of September, 1977) are blocks for a monetary sector and for long-term investment financing decisions. On the other hand, the 96 Version has been more completely calibrated and is more thoroughly documented (in Eliasson, Heiman and Olavi(1976) -- which I will refer to as the "documentation").

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1) This paper is based on simulation of the "Swedish" model which was described in Eliassons's paper presented at the conference. An alternative description of the model, one which is both more extensive and which describes a model more like the one I have simulated, is given in Eliasson, Heiman and Olavi (1976). A capsule version of the model may be found in Eliasson (1977). These bibliographic notes are for the reader who is not familiar with the model; a self-contained paper would necessarily be much lengthier.

Thanks to several of the conference participants for comments on the first draft and to Gunnar Eliasson and Gösta Olavi for originally explaining the model to me. Financial support was received through the Columbia Council for Research in the Social Sciences and Industriens Utredningsinstitut.

The purpose of these runs is to gain some insight into the role of business expectations in the cyclical fluctuation and growth of economies. Most economists regard the view of the future held by individual firms to be an important determinant of the course of the macro-economy, but our theoretical understanding of how this determination operates is rudimentary. As is so often the case in linking the micro- and macro-economies, we are in the position of having an intuitive, imprecise notion that a micro-phenomenom has a significant influence on the macro-economy without knowing how to model that influence in a precise, abstract way.

One motivation for developing and using micro-simulation models (and this is the primary motivation behind MOSES) is the desire to construct better theory. This can work in two ways. First, the discipline imposed during model construction by the requirement of internal consistency and by the need to pare away inessentials forces the model-builder to organize his thinking. Second, the generation of simulation results provides a sort of synthetic experience to be used as a basis for induction. Reality does not often provide us with *ceteris paribus* experience -- too many factors are changing simultaneously. One point of simulation is to generate a synthetic reality in which the phenomena of interest are isolated one at a time.

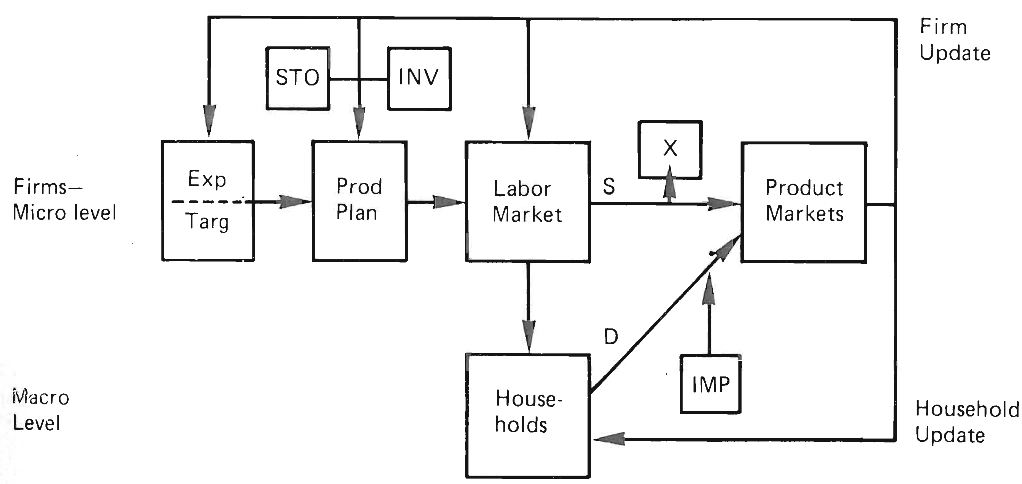
An obvious problem with this technique of creating synthetic experience is that it is difficult for the reader to judge the extent to which the simulation results represent a valid distillation of reality as opposed to idiosyncracies of model construction. It is necessary for the reader to have some feeling for how the model works, or else the simulation results are impossible to judge. Therefore, the first half of this paper gives an explanation of the basic operation of MOSES emphasizing the transmission of business expectations through the model.

The second half of the paper describes the simulation experiments and interprets their results. These experiments consist of modifications in the mechanisms generating price, sales and wage expectations in both an open (Sweden-like) and a closed (US-oid) economy and to some extent produce results contrary to what one might have expected. So, we are forced to trace back through the model and to try to decide to what extent these results suggest changes in the model and to what extent they suggest a re-thinking of our views about the role of expectations.

The MOSES economy

The operation of the MOSES economy is represented by the execution of a sequence of modules, and the completion of one sequence corresponds to one calendar quarter. The organization of these modules is pictured in Figure 1.

Figure 1



The micro aspect of MOSES is its business sector which is divided into a number of synthetic firm-like entities. The internal process of making decisions about production, employment, etc within these firms is modeled in detail (based on Eliasson(1976)), and the interactions between these firms, both in the labour market as demanders of labour, and in the product markets as suppliers of goods, are also specified in detail. In their internal planning processes and in their confrontations with one another these firms must start with some expectations about the options they face and they must have some performance criteria to guide their actions; thus, the forming of expectations and setting of targets come first in the module sequence.

Version 96 starts with 36 firms divided into 4 sectors, and each of these is assigned single-valued expectations -- expressed as percent changes -- about sales, prices and wages. For example, the expected percent change in sales on an annual basis for a given firm is computed as

$$EXPIDS_t = \lambda EXPIDS_{t-1} + (1-\lambda)\cdot\{DS_{t-1}+\alpha(DS_{t-1}-EXPDS_{t-1})\}$$

$$EXPDS_t = \gamma EXPXDS_t + (1-\gamma)EXPIDS_t,$$

where $EXPDS_t$ = expected annual %Δ in sales in year t,

DS_t = actual annual %Δ in sales in year t,

$EXPIDS_t$ = "internally generated" expected annual %Δ in sales in year t,

$EXPXDS_t$ = "externally generated" expected annual %Δ in sales in year t.

If $EXPXDS_t$ is constant for all t, then this formulation sets $EXPDS_t$ equal to a constant plus a sum of past actual annual percentage changes in sales with weights declining asymptotically to zero.

Expected percent changes in wages and prices are computed in an analogous way. Thus, explicit 1-year histories for sales, prices and wages are required to start up the model, and longer histories are implicit in the lagged internally generated expectations. (The routine that initializes the internally generated expectations is based on 5-year histories.)

This formulation gives a simple representation of several expectational phenomena. The parameter λ ($0 \leq \lambda \leq 1$) defines how quickly the firm reacts to changes in the economic environment; thus, λ is close to zero for firms that place almost all weight on their experiences in year t-1 and almost no weight on their experiences in years t-2, t-3,....etc. The parameter α ($\alpha \geq 0$) characterizes the firm's learning response -- how fast are expectations adjusted to eliminate systematic biases?[2] The parameter γ ($0 \leq \gamma \leq 1$) indicates the relative weight placed on external information (i.e., indicators other than, say, lagged sales) or, alternatively, on pure unexplainable intuition of the animal spirits variety. Of course, any effects that can be generated via variations in γ can just as well be generated by varying the "externally generated" expectations themselves; and since the latter technique is more easily interpreted, that is the one I have used.

This expectational sequence is computed at the start of each year. However, MOSES runs on a quarterly basis, so it is necessary to convert expected percent changes on an annual basis into a quarterly basis and to make allowance for the ability of firms to change their forecasts over the course of the year. This is done in a simple way. In the first quarter, before any contrary experience has occurred, the expected percent change in (say) sales for the quarter is computed simply as

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2) The expectations functions in MOSES also include a variance term to pick up business managers attitude to risk taking. (See Eliasson's model presentation in this conference volume, section 4.2 in chapter 2, p.p.238 ff). Due to a misspecification I am unable to report on simulation results using this factor in this paper. Notice that the absence of the variance term makes the parameter α redundant.

$QEXPDS_t$ = EXPDS/4, and in quarters 2-4 as

$QEXPDS_t = QEXPDS_{t-1} + \delta_s[QDS_{t-1} - (EXPDS/4)]$.

Here $QEXPDS_t$ = expected %Δ in sales in quarter t,

EXPDS = expected %Δ in sales on an annual basis,

QDS_{t-1} = actual %Δ in sales in quarter t-1

δ_s = sales adjustment parameter.

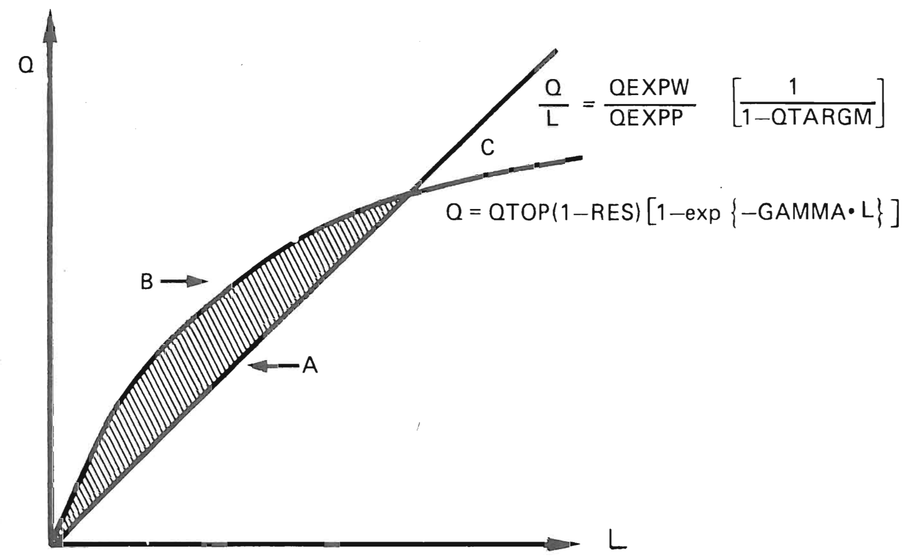
Quarterly expected percent changes in wages (QEXPDW) and in prices (QEXPDP) are computed analogously. Given QEXPDS, QEXPDW and QEXPDP, it is straightforward to compute the corresponding levels, QEXPS, QEXPW and QEXPP.

Once computed, these forecasted levels are used in the 3 micro segments of MOSES -- internal production planning, the labour market confrontation and the product market confrontation. These segments combine each firm's expectations and profit targets with the constraints of technology and with the actions of other firms to produce a final quarterly outcome.

Production planning is carried out individually by each firm in the block PRODPLAN. Within this block each firm chooses a preliminary planned output, labour combination (Q,L). The algorithm by which a (Q,L) plan is chosen is complicated, but the essentials can be seen in Figure 2.

In each quarter there is a set of feasible (Q,L) combinations (a short-run production possibilities set) open to a given firm that is defined by $Q \leq QTOP(1-RES)\{1-\exp(-GAMMA \cdot L)\}$. This feasible set is determined by the firm's past investments as these are embodied in QTOP, RES and GAMMA, and investment between quarters acts to enlarge this set. In addition to the set of feasible (Q,L) combinations, the firm has a set of satisfactory (Q,L) combinations. The satisficing criterion is given by a quarterly profit margin target (QTARGM), and this target is set in much the same manner as are expectations; i.e., the basic targeting is done on a yearly basis with quarterly adjustments, and profit margin targets adapt to experience. Given QTARGM

Figure 2



and price and wage expectations, a planned (Q,L) combination is satisfactory if the expected profit margin meets the profit margin target; i.e, if

$$QTARGM \leq (QEXPP \cdot Q - QEXPW \cdot L) / QEXPP \cdot Q$$

This is expressed in Figure 2 as

$\frac{Q}{L} \geq \frac{QEXPW}{QEXPP}\left[\frac{1}{1-QTARGM}\right]$. A shorthand expression for the satisfaction of this inequality is to say that SAT(Q,L) holds.

The problem for the firm is thus to choose a (Q,L) plan that is both feasible and satisfactory, i.e., to choose a point within the lens area of Figure 2. The choice algorithm consists of a rule to specify an initial set of (Q,L) trial points and of rules to adjust these initial points if they are not simultaneously feasible and satisfactory.

The firm reaches an initial trial plan in the following way. It has inherited a labour force, net of retirements, from the preceding quarter; and this is taken as the initial trial level, L. The firm then computes expected sales in "physical units" as QEXPS÷QEXPP, and these expected physical sales are adjusted to allow for a range of inventory change, thus producting a trial interval of output plans.

For a given L this interval either consists of at least some points which are both feasible and satisfactory (i.e., in the lens), consists of points which are feasible but not satisfactory (Region A), consists of points which are satisfactory but not feasible (Region B), or consists of points which are neither feasible nor satisfactory (Region C). Overlapping is, of course, possible.

Should the interval contain a feasible and satisfactory (Q,L) point, then the firm's preliminary plan is set at the minimum Q such that SAT(Q,L) holds. If not, the adjustment algorithms come into play. In Region A the firm adjusts by planning to lay off labour, and if it can find a simultaneously feasible and satisfactory (Q,L) point by doing so, then the firm's preliminary plan is set at the minimum Q and the maximum L such that SAT(Q,L) holds. In Region B the firm adjusts by planning to hire more labour, and if it can find a simultaneously feasible and satisfactory (Q,L) point by doing so, then the firm's preliminary plan is set at the minimum feasible Q and L. These are simple adjustments in the sense that the firm adheres to its initial trial output interval.

The complexities in the adjustment algorithm arise when there is no Q in the initial interval that is both feasible and satisfactory at any L. This must occur in Region C and can occur in Regions A and B. The firm must either reduce its planned output or shift its production possibilities set by the activation of "reserve slack" (in the form of a reduction in RES). The mechanisms by which these adjustments are carried out are intricate, but they are not directly relevant to this paper.

This completes the production planning sequence. To summarize, expectational variables influence firms' plans in two ways. First, the ratio of wage and price expectations, together with QTARGM, is used to define the set of satisfactory (Q,L) plans. The intersection of the set of satisfactory (Q,L) plans with the set of feasible (Q,L) plans is the set of allowable (Q,L) plans. Second, the actual plan chosen within the set of allowable plans depends upon the initial trial (Q,L) plan, and the initial trial/output interval is computed by adjusting QEXPS÷QEXPP for a range of inventory changes.

After completing its PRODPLAN sequence, each firm has a planned labour force and a planned output level, but these plans may be infeasible in the aggregate. Firms must confront one another and interact with the consuming public to resolve any inconsistencies.

Each firm enters the labour market with a planned and an actual labour force; call the discrepancy CHL. If CHL ≤ 0 for a given firm, then that firm begins the process of laying off CHL workers. The mechanics of doing this are complicated by Sweden's Åman laws from the seventies, which require up to a 2-quarter lag between a layoff notification and the layoff itself, but the essential thing is that these firms do not desire additional labour. On the other hand, there may be firms for whom CHL ≥ 0, and these firms will be forced to "raid" either another firm or the pool of unemployed. A raid is "successful" (labour is shifted to the raiding firm) if the wage offer of the raiding firm sufficiently exceeds that of the raided firm. This is where expectations enter directly into the labour market confrontation -- the wage offer of a firm depends upon the wage level it expects will prevail, i.e., upon QEXPW.

Firms first bid against each other in a stylized labour market to produce final wage levels and employments for each firm.

To be more specific, let W be the wage paid by a firm in the preceding quarter. Then its wage offer is computed as $WW = W + \eta_1(QEXPW-W)$.

After computing a wage offer for all firms, the firms are ranked by their relative desire for additional labour, i.e., by CHL/L. The first firm in this ordering chooses to raid either the pool of unemployed or another firm, and the choice of a raiding target is determined by a random device in which the probability of being raided is related to the size of a potential target's labour force.

Let i index the raider and let j index the target. An attack is successful if $WW_i \geq (1+\eta_2)WW_j$, and labour in the amount of $\min(\eta_3 L_j, CHL_i)$ is transferred from j to i. If j indexes the pool of unemployed (which is of size LU), then the attack is always successful and $\min(\eta_3 LU, CHL_i)$ workers become employed in firm i. When an attack succeeds, CHL_i, CHL_j, L_i and L_j are adjusted in the obvious way, and the raided firm adjusts its wage offer upwards by $\Delta WW_j = \eta_4(WW_i - WW_j)$.

On the other hand, if the attack fails, then it **is the attacking firm that ad**justs by setting

$$\Delta WW_i = \eta_5 (WW_j (1+\eta_2) - WW_i)^3.$$

This describes the attacking procedure for the first firm, and the same scenario is repeated for firm 2, firm 3, etc. When all firms (for whom CHL > 0) have undertaken an attack, one market iteration is completed. The process is then continued through a pre-determined number of iterations. The result is a wage and an employment level for each firm, and thus a total wage bill for the economy. Given the initial vector of CHL that began the labour market process, the aggregate wage bill is thus determined by firms' wage expectations as manifested through their wage offers.

The final interaction takes place in the product
The final interaction takes place in the product
market between firms as suppliers and households and firms as demanders. The process is specified at the market level, i.e., price and quantity adjustments are computed on a sectoral average basis, rather than firm by firm. Also, it is quantity demanded rather than quantity supplied that responds to price within each quarter. Consumers are the active agents in the product markets, and supplies are predetermined except for possible inventory adjustments. From period to period, however, supplies respond to prices both in domestic and foreign markets. Thus, firms' expectations directly affect the final product market outcomes only through the initial prices and quantities offered. Of course, firms' expectations also indirectly affect the operation of the product markets through the total amount of income that consumers have available for expenditure.

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3) The parameters $\eta_1, \ldots, \eta_5$ $(0 \leq \eta_k \leq 1)$ determine the speed of reaction to wage discrepancies in the labour market. In addition, the randomizer can be altered. In particular, it can be regulated in such a way that the unemployment rate generated by the MOSES economy is close to the observed level. The realism of the labour market process thus ought not be judged by the unemployment rate it produces.

How are starting prices and quantities set by firms on the product markets? At the end of the labour market sequence, firms may have found themselves unable to satisfy their desires for additional labour; consequently, output plans may need revision. Planned output (Q) is then specified for each firm as the smaller of the originally planned output (specified in PRODPLAN) and the maximum output attainable with the firm's post-labour market employment level. To move from Q to the initial offering of quantities on the domestic market, it is necessary to subtract off desired inventory changes (ΔSTO) and production for export markets. Let S = desired domestic market sales, and let x = the fraction of production for export. Then S = $(1-x)\cdot Q\cdot\{QEXPS/(QEXPS + QEXPP\cdot\Delta STO)\}$. The sum of S across all firms in a particular market determines the initial quantity offered in that sector.[4] The determination of initial market prices is also straightforward. Let j index the firms in this market so that these firms offer $\{S_j\}$ and expect prices $\{QEXPP_j\}$ in the current quarter. Then the initial offering price in this market is computed (approximately) as P = $\sum_j S_j QEXPP_j / \sum_j S_j$, i.e., as a weighted sum of price expectations.

Given an initial supply (ΣS_j) and supply price (P) on each market, it remains to be seen whether demand will correspond. Consumers express their willingness to allocate their income to each of the 4 sectors, to service goods and to savings. A modified linear expenditure system with habit formation is used as a demand system, with estimates of price and income elasticities from Dahlman and Klevmarken (1971). In addition, there is a demand for

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4) An export fraction is specified individually for each firm, but the change in these fractions depends upon the relative movement of domestic and foreign prices in the previous quarter on a market basis.

durables as investment goods by firms that is predetermined from the previous quarter. This constitutes the demand for firms' products, except that it is necessary to specify the fraction of demand that will be satisfied by imports (IMP). This fraction is determined in much the same way as the export fractions are determined; i.e., IMP is determined by the relative movement of domestic and foreign prices in the previous quarter on a market basis.

An adjustment by (1-IMP) gives desired purchases from domestic sources on each market (D), and a price adjustment mechanism is specified that tends toward the equation of demand and supply. Letting N denote the iteration number, the price adjusts by

$$\Delta P = (\lambda/N)\left[D-\sum_j S_j\right].$$

This is done on each market, leading to new market prices and new demands. The process is then allowed to run for a fixed number of iterations.

Upon completion of the product market sequence, the output of each firm has been specified and divided into domestic sales, foreign sales and inventory change (computed as a residual, but constrained to lie within certain bounds). A final (but not necessarily equilibrium) price has been computed for each market, implying an average rate of change which can then be spread across that market's firms. Employments and wage levels have been computed for each firm in the labour market. Thus, profits can be computed for each firm, and since (in the 96 Version) investment is financed out of profits, the link between quarters is made. Each firm's production possibilities set is updated according to its investments, and the entire process begins anew.

The Simulations

The simulations were designed to address two general types of questions. First, suppose that some "extraneous" events cause a short term change in business expectations; e.g., suppose a change in government induces a "wave of pessimism" among businessmen. Could this have any effect on the economy, and if so, would the effects persist over a long period of time?

Second, suppose the mechanism by which expectations are generated changes in some fundamental way. Will this change have any effect on economic performance? If so, can this change in the expectational mechanism be given a real-world interpretation?

These questions correspond roughly to two themes in the US business press -- that the economy is faltering either because businessmen "lack confidence", or because the "climate is too uncertain" for investment. One might view the simulations reported on below as an attempt to make some sense of these notions, but, of course, it is risky to use a model of the Swedish economy as a tool for reading US newspapers. One particular hazard is the extreme openness of the Swedish economy relative to that of the US economy. Holding all else constant, it seems much more likely that expectations would be capable of self-fulfillment in an economy that is close to being "self-contained"; i.e., there is an _a priori_ reason to expect expectational phenomena to be more important in the US than in Sweden.

To check on this, we have constructed a "US-oid" economy to supplement the basic Swedish version of MOSES. This supplementary economy is based _very_ roughly on the US national accounts, and it should be understood that this version of the model does not purport to represent the US. The US figures have been used only to provide a consistent basis for creating a relatively closed economy. Thus, two sets of simulations were run -- simulations on the model of the Swedish economy and simulations on a more closed, US-oid version of the model.

Questions about short term alterations in business expectations were addressed via changes in the "externally generated" expectations. In the reference cases these are set at EXPXDS = 0.07, EXPXDP = 0.03 and EXPXDW = 0.03 for all years. To model a short term burst of "bullish optimism," I have doubled EXPXDS, EXPXDP and EXPXDW in each of the first three years; thereafter they are reset to the reference case values. To model a short term period of "bearish pessimism," I have set EXPXDS = EXPXDP = EXPXDW = 0 for years 1-3; thereafter they are reset to the reference case values. One might question the sense in which a temporary increase in EXPXDW represents business optimism (or the sense in which setting EXPXDW = 0 represents pessimism), so I have also run simulations in which EXPXDS and EXPXDP are modified as described above but EXPXDW = 0.03 is maintained throughout. The results of these latter simulations are not qualitatively different.

To examine changes in the expectational mechanism, I have tried the simple experiment of allowing λ to vary. As compared with the reference run value of $\lambda = 0.5$, simulations were run with $\lambda = 0.1$ and $\lambda = 0.9$. The smaller value of λ allows a firm to change its expectations quite radically from year to year, whereas the larger value of λ builds in greater stability. These two cases are the only changes in the expectational mechanism that were considered; in particular, α and γ are left at their reference run values of $\alpha = 0.1$ and $\gamma = 0.5$.

Thus, there are 5 basic simulations for both the Swedish economy and the US-oid economy -- a reference case, the case of short term optimism (EXPXDS = 0.14, EXPXDP = 0.06 and EXPXDW = 0.06 for each of the first 3 years), the case of short term pessimism (EXPXDS = EXPXDP = EXPXDW = 0 for years 1-3), the case of $\lambda = 0.1$ and the case of $\lambda = 0.9$. Results for 20 year simulations are presented below. Table 1 gives the 20 year trends for selected key macro variables for the Swedish economy, and Table 2 gives comparable figures for the US-oid economy. These trends are measured as geometric means of percentage increase; e.g., if Q_1 denotes output's initial value and Q_{20} its terminal value, then the trend figure for output is computed as $(Q_{20}/Q_1)^{1/20}-1$.

Looking first at the Swedish economy, one can see that the reference case produces the greatest long-run rate of growth in output and productivity. The cases of pessimism and $\lambda = 0.1$ produce rates of growth only slightly below those of the reference case; however, the cases of optimism (NB) and of $\lambda = 0.9$ produce rather disasterously sub-par rates of growth. In terms of inflation, the reference case produces a slightly higher rate than any of the other simulations, but in general the 20 year rates of price increase do not vary much between cases. Finally, with the

TABLE 1

Swedish economy - Key 20 year trends

	0	1	2	3	4
Q	4.6	3.1	4.2	2.5	3.9
PROD	7.2	5.6	7.1	6.2	6.7
P	4.8	4.6	4.8	4.5	4.8
W	11.8	10.5	12.2	7.7	12.0
S	9.5	7.8	9.0	7.1	8.8

TABLE 2

US-oid economy - Key 20 year trends

	0	1	2	3	4
Q	3.6	2.4	3.8	2.7	2.8
PROD	5.6	4.2	5.8	5.4	5.2
P	4.7	4.5	4.6	4.3	4.5
W	9.8	8.9	9.8	7.8	9.9
S	8.4	6.9	8.4	7.1	7.3

Key:

Cases --

0 = reference run
1 = increase in EXPXDS, EXPXDP in years 1-3
2 = decrease in EXPXDS, EXPXDP in years 1-3
3 = λ=0.9
4 = λ=0.1

Variables --

Q = real output
PROD = real Q per labor hour
P = price
W = wage
S = sales

exception of the case of $\lambda = 0.9$, rates of wage inflation do not differ dramatically between cases.

The performance of the US-oid economy is roughly similar, except that the case of pessimism produces better performance than the reference run and the case of $\lambda = 0.1$ produces a much inferior performance. Rates of inflation are again nearly identical in all simulations. This was to be expected in the Swedish economy since the sectoral inflation rates must be "imported" to some degree (i.e., determined by inflation rates in comparable foreign markets) and the model has been fed constant exogenous rates of foreign price increases. However, one might have expected more independence of foreign inflation rates in the more closed US-oid economy.

It is also useful to look at Figures 3-6. Figure 3 charts the course of the level of real output for each of the four cases (optimism, pessimism, $\lambda = 0.1$ and $\lambda = 0.9$) relative to the reference case level of output for the Swedish economy with the reference case level normalized to 100. Figure 4 does likewise for the US-oid economy. Figures 5 and 6 chart the course of the price level generated by each of the 4 cases relative to that of the reference case for the Swedish and US-oid economies, respectively. It should be understood that these are charts of <u>relative</u> levels. When, for example, Fig 3 shows a decline in the $\lambda = 0.9$ series, this need not mean that output has fallen. Rather, it may mean that output in the $\lambda = 0.9$ case is rising less rapidly than in the reference case.

Figures 3 and 4 tell similar relative output stories. In both the Swedish and US-oid economies the expectational changes have a minor short term effect. After 5 years the largest deviation from the reference case is only +1.9% (for pessimism) in the Swedish case and +2.5% (for $\lambda = 0.9$) in the US-oid case. However, after 7-8 years of simulation, some dramatic changes occur. The outputs of the pessimism and $\lambda = 0.1$ cases suddenly exhibit strong growth relative to the reference case, but the cases of optimism and $\lambda = 0.9$ exhibit strong declines relative to the reference case. Thereafter, the two economies

Figure 3. Swedish economy: Outputs relative to reference case

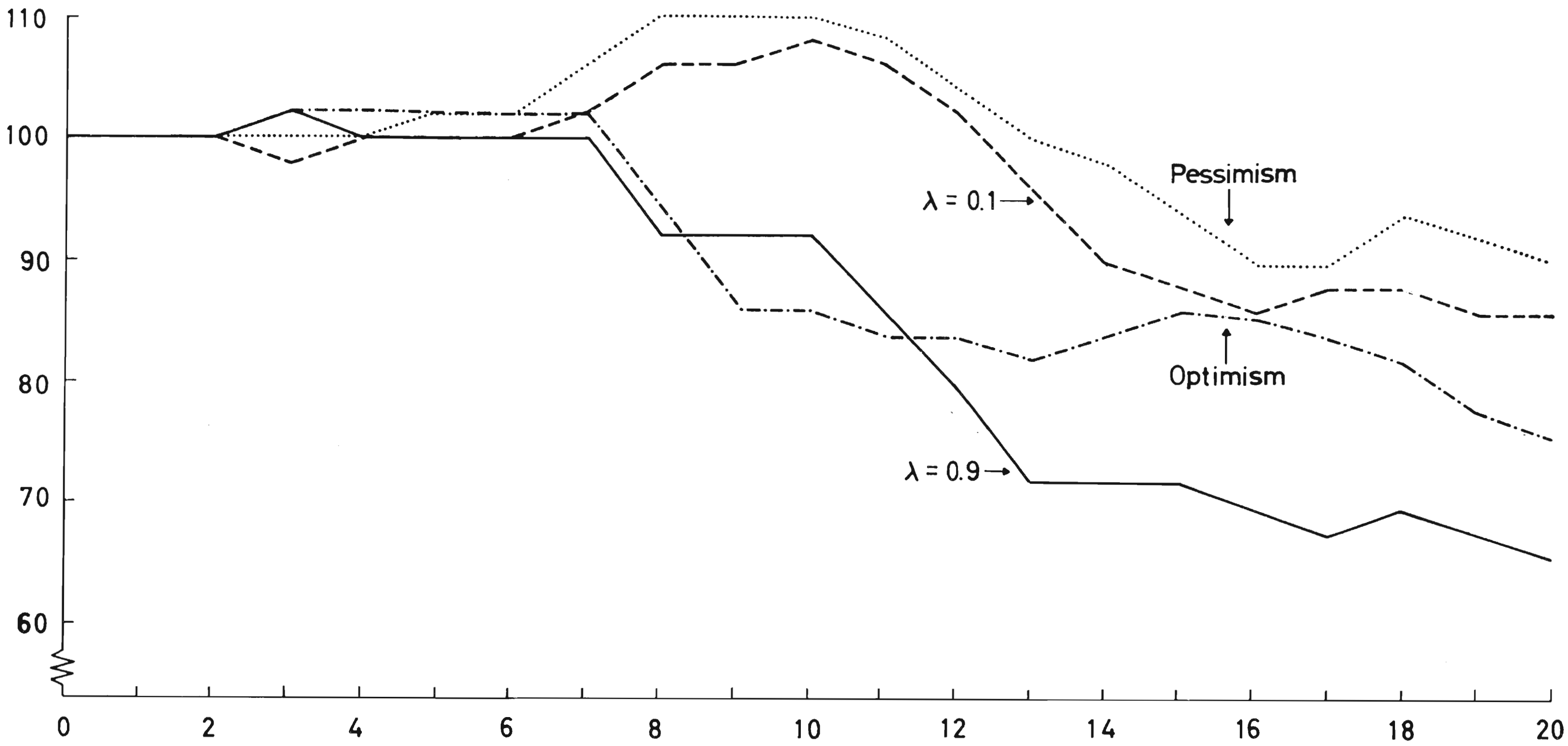


Figure 4. US-oid economy: Outputs relative to reference case

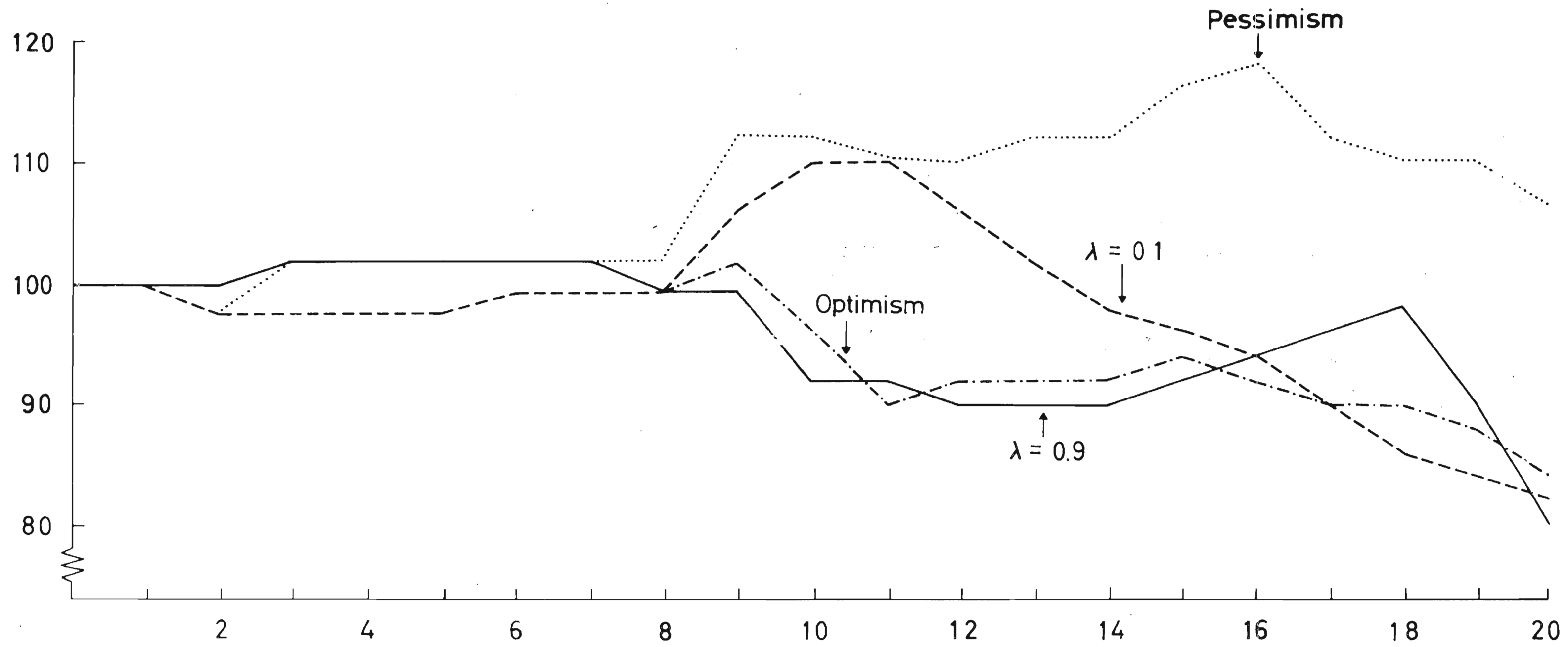


Figure 5. Swedish economy: Price level relative to reference case

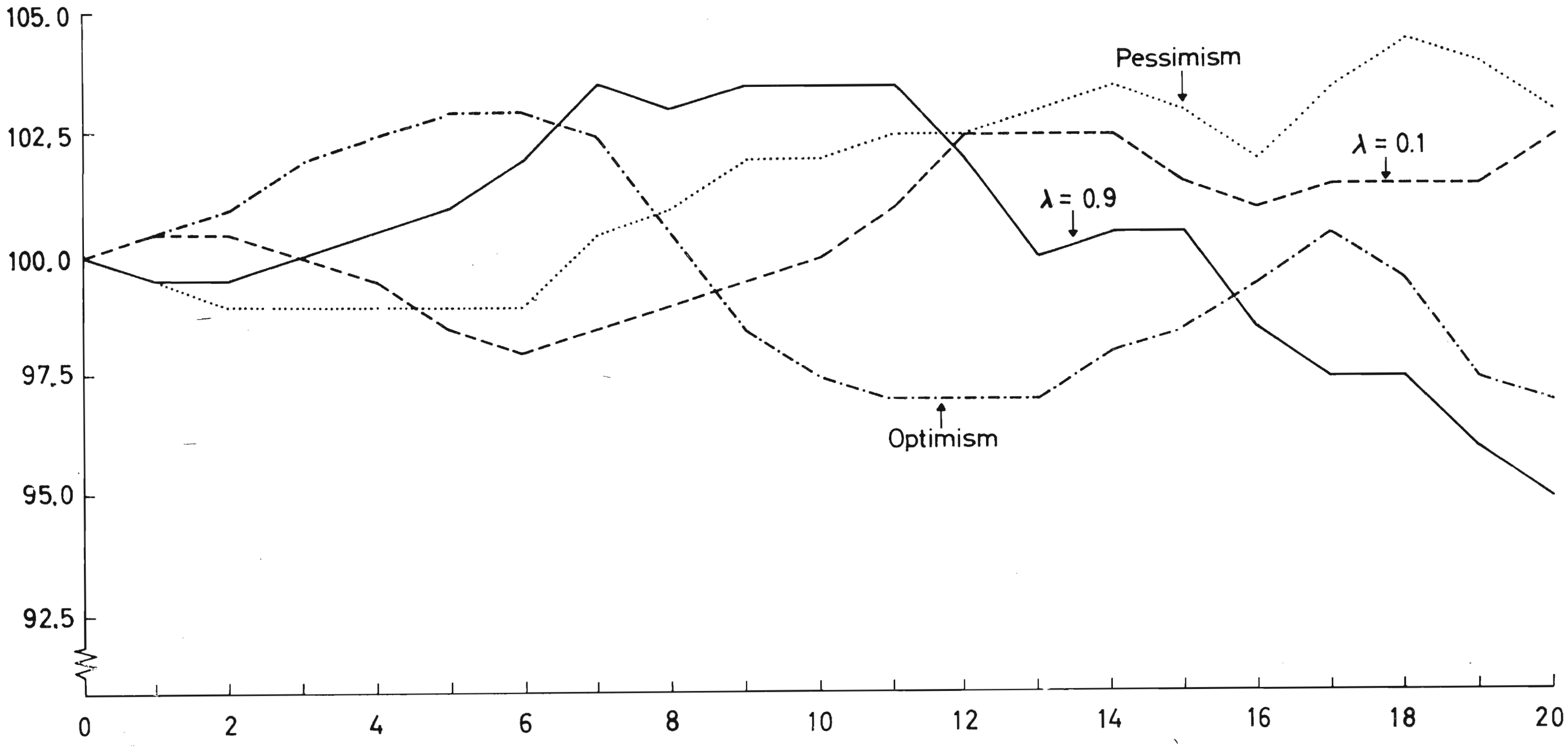
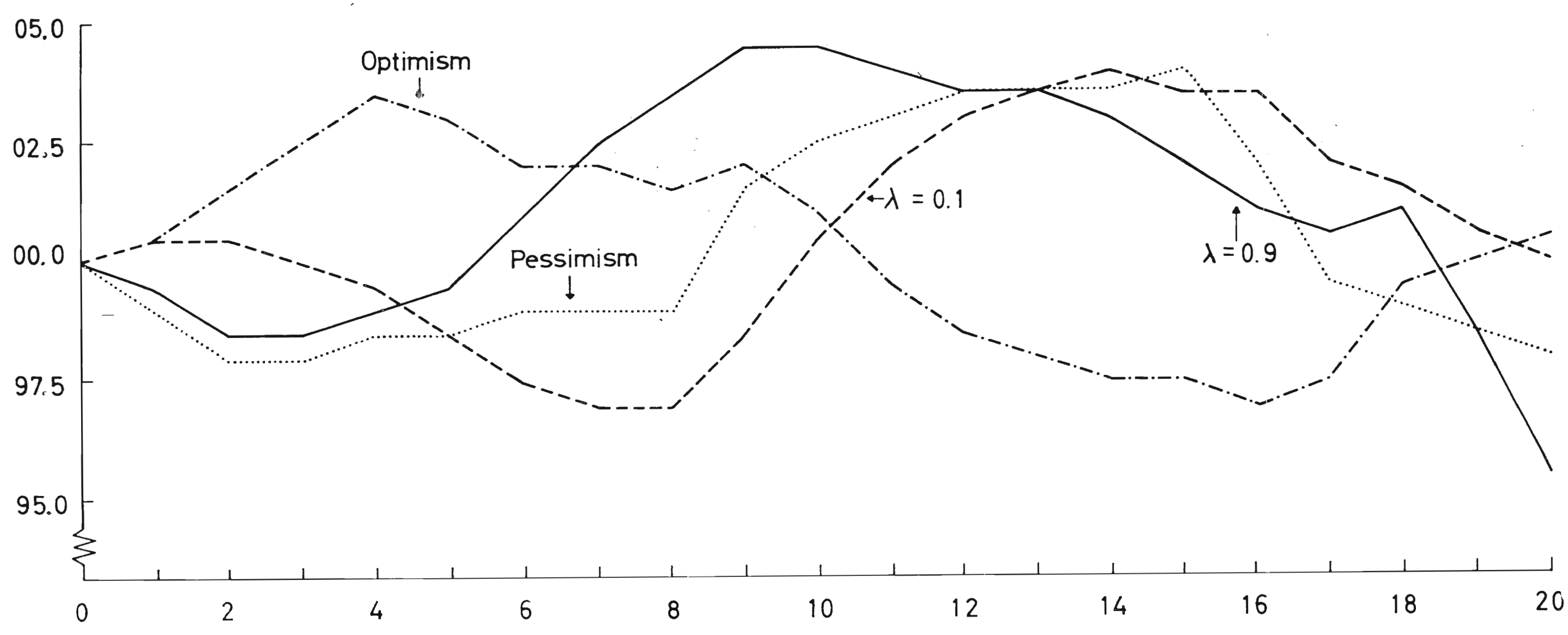


Figure 6. US-oid economy: Price level relative to reference case



differ slightly. In the Swedish economy all cases fall off gradually relative to the reference case, whereas in the US-oid economy the pessimism case maintains a rate of growth comparable to that of the reference case and the case of $\lambda = 0.1$ shows a serious decline.

Figures 5 and 6 show that the paths of relative prices over time fluctuate much less than do the paths of relative outputs. (Note the scales of Figs 3-4 relative to those of Figs 5-6). In contrast to output, price fluctuation relative to the reference case can be seen at a very early date. The optimism case exhibits strong price growth relative to the reference case in the first 4-5 years, then falls off for a long period (up to year 14 in the Swedish economy and up to year 16 in the US-oid economy) and finally begins to recover. The case of pessimism is close to a mirror image of optimism, and the cases of $\lambda = 0.1$ and 0.9 are also close to being mirror images of one another.

Interpretations

I examine the cases of $\lambda = 0.9$ and 0.1 first since the results of these simulations are probably least difficult to reconcile with one's intuition. The results for the cases of optimism and pessimism are perhaps more mysterious.

Recall that λ characterizes the speed at which firms react to changes in the economic environment. When $\lambda = 0.9$, firms do not change their expectations much from year to year, but rather rely on a longer historical perspective. One might say that firms are behaving very cautiously or acting as if they were very uncertain. Why does caution breed such poor economic performance in this model?

The problem is not one of caution making businessmen unwilling to invest, thereby eventually dragging down output. In fact, investment (and the profits from which investment is generated) are slightly larger in the case of $\lambda = 0.9$ than in the reference case. The problem is rather that the rate of capacity utilization is abysmally low. Firms are neither hiring enough labour to fully utilize their accumulated capacity nor are they utilizing the labour that they do hire very efficiently. What happens is that at some point firms' expectations "fall behind" reality. In setting their output plans firms start to think in terms of an output range that is too low. The aggregate *ex post* result of these plans is a high profit margin on a low volume of output. This result tends to reproduce itself in the sense that businessmen tend to get used to very small percentage increases in output each year while at the same time they come to expect ever-increasing profit margins since their profit margin targets adapt to past performance. With $\lambda = 0.9$ and with the rules of thumb for setting output/labour plans which have been ascribed to businessmen, firms in effect eventually behave like very satisfied monopolists. They are behaving this way, of course, not as optimizers, but rather because sluggish reactions on their parts happened to place them in a monopoly-like position. Once in such a position, the MOSES firms with adapting profit targets find the situation quite satisfactory.

The case of $\lambda = 0.1$ occupies the opposite end of the spectrum. When $\lambda = 0.1$, firms react very vigorously to short run changes. As a result they tend to operate at very high rates of capacity utilization but with relatively low profit margins. This produces a fairly strong economic performance for 8-10 years, but eventually a lack of profits and a concommitant lack of investment leads to a diminished capacity relative to that of the reference case. By the end of the 20 year simulation, "effective capacity" in the $\lambda = 0.1$ case is only 2/3 of what it is in the reference case.

What do these results tell us about the economy and what do they tell us about the model? If one believes that investments are generated primarily out of retained profits, then the suggestion is that in terms of aggregate economic growth there is a happy medium between firms having to compete vigorously for every dollar of profit on the one hand and having too easy a time of it on the other. If all firms live in a hyper-competitive environment (as generated by their quick adaptations), then too little profit will be generated to sustain investments; but, if profits come too easily, then firms will lack the incentive to make the most effective use of their capacities.

Of course, one could criticize the model for generating these results. The case of $\lambda = 0.9$ is bad for economic growth only because firms are able to settle into very lazy, albeit profitable, conditions. The classic economic remedy for this situation is simply to allow for the entry of new firms, and it is hard to believe that if profit margins were as large as they are in these simulations (and some are greater than 50%), new entrants would not be attracted. Conceptually, it is not difficult to modify MOSES to allow for the endogenous entry of new firms, and a simple experiment along these lines has in fact been undertaken. (See pp.228-229in Eliasson's paper on the total model in this conference volume). The results from the $\lambda = 0.1$ simulations might be criticized from another perspective. The reason that these simulations eventually show a slackening in growth is that firms are forced to finance all of their investments out of profits. If the model contained a functioning monetary sector (not yet ready), then this might not be such a serious problem; but it may be the case in reality (especially in Sweden) that financial markets are insufficiently developed to provide more than a partial remedy.

Finally, the cases of optimism and pessimism can be examined. The scenario that one might have envisioned in the optimism case is as follows. Firms start out with optimistic expectations and accordingly plan for a high level of output requiring substantial employment. They then bid aggressively for labour, thus fulfilling their wage expectations and creating a large total wage bill. This translates into a high level of disposable income, so firms' optimistic sales expectations are fulfilled. The pessimism case would be exactly the opposite -- pessimistic expectations feed upon themselves to produce unhappy results.

This is, of course, nothing but a simple multiplier story in which expectations provide the starting impulse. Although it is difficult to see in Figures 3-6, this story does have some merit during the first 5-8 years. Relative to the reference case, output, prices and wages all rise in the optimism case. The question is why the relative increase is so small. One answer is that the use of the LESH-type demand system makes it very difficult to get the multiplier going. Using a demand system with a heavy emphasis on habit formation makes consumption much less sensitive to aggregate income.

Instead, as income goes up, savings also go up; and in fact, savings are somewhat greater in the optimism case for the early years than in the reference case.

Another problem is that a significant fraction of the increase in disposable income gets spent on imports. Some of the multiplier effect leaks outside the country, something that is quite consistent with Sweden's experience.

The most serious jolt to the intuition is given by the performances of the optimism and pessimism cases after years 7 or 8. What explanation can be given for the collapse of the optimism economy? By the seventh year most of the effects of the initial changes in the "externally generated" expectations will have worked their way through the expectations mechanism; i.e., there is almost no "lingering" optimism or pessimism remaining through lagged expectations. There is, however, a counterbalancing effect in that the firms in the optimism case will have tended to err on the side of optimism for 7 years and the firms in the pessimism case will have tended to err on the opposite side. This creates some tendency at this point for the originally optimistic firms to begin to expect smaller percentage changes in output, and conversely for the originally pessimistic firms. Whatever the cause, firms in the optimistic case get trapped in a low output, low capacity and low profits syndrome. This is somewhat like the $\lambda = 0.9$ case except that firms are gloomy about price as well as output, so high profit margins do not develop. Not only is this state of affairs bad from the point of view of aggregate economic performance, but firms cannot be too happy either. It is the expression of the satisficing criterion in terms of profit margin targets that keeps firms from reacting to this situation.

Again, one can ask what changes in the model would produce more "realistic" results. One particular addition that has the potential to change the optimism/pessimism results is the long term investment financing block. In this block firms' "animal spirits" (or lack thereof) will be capable of being translated directly into a device for investment financing; i.e., firms will be allowed to indulge in a sort of optimism that is more likely to generate long term effects. This block has been designed but is not yet ready in the program. (See Eliasson-Heiman-Olavi (1976, chapter III).) Any of the other obvious devices for making the multiplier more potent, e.g., changing the demand system or lowering import flexibility, would seem to produce the "desired" results at the cost of sacrificing reality.

A final comment on the simulations is to note a recurrent pattern. In each simulation firms settle into an economic niche in the sense of falling into a pattern of behaviour that they lack sufficient incentive to change. In terms of Figure 2 firms tend to find themselves at approximately the same relative point in the lens area year after year. Thus, the model suggests that there are a number of potential output paths which are sustainable for a significant period of time, some of which are definitely superior to others. It should be understood that it is the behavioral rules ascribed to firms that allows the possibility of "multiple equilibria". Firms are satisficers in the sense that they lack the information to make "optimal" decisions and in the sense that their goals adapt to past experience. Were firms optimizers with perfect information, there could be only one possible sustainable path in this model. It is up to the reader to decide which picture of firm behaviour he finds most reasonable.

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THE MARKET ORIENTED INTER-INDUSTRY STOCK AND FLOW DATA AGGREGATION SCHEME USED IN THE SWEDISH MODEL

Louise Ahlström

The objectives of the Swedish Micro-to-Macro Model have been stated as

1. to formulate a micro explanation for inflation and

2. to study the relationships between inflation, profits, investment and growth.

The model thus places heavy emphasis on the market process and its importance for price and income determination and growth at the macro level. The chosen problems, however, also relate to typical dynamic processes and hence require that the time dimension and the cyclical features of simulations are quite well controlled empirically. For this reason an aggregation scheme that centers on markets and the use of industrial products rather than on the ordinary classification according to the production technique and raw material base has been necessary. We have chosen an aggregation level with four industrial production sectors:

Raw Material Processing Industries (RAW)
Intermediate Goods Industries (IMED)
Investment and Consumer Durable Goods Industries (DUR)
Non Durable Consumption Goods Industries (NDUR)

The reason for choosing such a small number of sectors is not only to keep the statistical work input within limits and to avoid getting bogged down in unnecessary detail. It can be shown that this particular aggregation principle emphasizes the variations in activity over the cycle as well as between industry sectors.[1] It can also be claimed that this aggregation has certain advantages over alternative ones, since the input-output matrix obtains an easily understood structure that has a tendency towards a one-way delivery pattern. This in turn facilitates a consistent projection of changes in the input-output coefficients.

Four industrial production sectors is a small number compared to what is normal in contemporary input-output models. However, in strong contrast to other model work - even of the microsimulation kind - each sector (market) in MOSES holds a large number of individual firms. The market processes in the model operate both between and within the above four sectors. The basic micro feature in MOSES in fact lies in the large number of firms within each sector and the aggregation scheme has been designed accordingly. This also means that the capacity utilization data from the Annual Planning Survey of the Federation of Swedish Industries can be used directly in the model.[2] On the other hand we run into difficulties when dealing with macro data. We have had to develop a market oriented classification scheme of our own in order to adapt the national accounts macro statistics to our micro based sector classification. Also lack of some firm data makes it necessary to use industrial macro data as substitutes.[3] The input-output matrix is one example where such simplifications have been necessary. Finally we have had to put in substantial effort to overcome inconsistencies in the data base that have crept in not only because of our new aggregation type but also because of inconsistencies between the various parts of the national accounts statistics themselves. We have found by experience that a consistent data base for the first period of a simulation is imperative for a proper tracking by the model of historic macro test data.

1) See Virin, O, "Industrins Utveckling 1974-76, enligt Industriförbundets planenkät 1975/76", Industrikonjunkturen, Våren 1976, Special Study D.

2) This planning survey covering all Swedish firms with more than 200 employees has in fact been designed on the format of MOSES.

3) For a description of how macro data are combined with real firm data see Eliasson, G, A Micro Simulation Model of a National Economy, chapter 3 on estimation methods, in this conference report.

In our efforts to obtain consistency in the data base it has been natural to use the input-output matrix as the reference base towards which adjustments are made. The input-output matrix for the total production system in MOSES consists of ten sectors:

1. Agriculture, Forestry and Fishing (A/F/F: 1.10 + 4.10)
2. Mining and Quarrying (ORE: 1.20 + 4.20)
3. Petroleum Products Imports (OIL: 5.11)
4. Raw Material Processing Industries (RAW: 2.10 + 5.10 excl 5.11)
5. Intermediate Goods Industries (IMED: 2.20 + 5.20)
6. Investment and Consumer Durable Goods Industries (DUR: 2.30 + 5.30, 2.51 + 5.51)
7. Construction (CONSTR: 2.40 + 5.40)
8. Non Durable Consumption Goods Industries (NDUR: 2.52 + 5.52, 2.53 + 5.53)
9. Electricity (EL: 3.10 + 6.10)
10. Other Services: (SERVICE: 3.20 + 6.20).

This aggregation corresponds to the general structure related to the input-output statistics (I/O) published by the Central Bureau of Statistics, that is described in Table 1. Of the four industrial production sectors that hold individual firms DUR and NDUR have a product content that differs somewhat from what is conventional as to the treatment of Capital Goods (2.51 + 5.51). In the input-output matrix we have included Consumer Capital Goods with Investment Goods, thus referring to this group as DURables and calling the remainder of Consumption Goods NonDURables. The six non-industry sectors (A/F/F, ORE, OIL, CONSTR, EL and SERVICE) are "external sectors" to the model appearing only as suppliers of certain goods in the conventional input-output fashion. Note here that the I-O sectors "Construction of Buildings" and "Letting of Dwellings and Use of Owner-Occupied Dwellings" - rents - both go into the CONSTRuction sector.

In order to obtain the general classification described in Table 1, we have constructed a weighting matrix, based on value added, by which the allocation is made. Since this allocation is based on macro data there is not necessarily a one-to-one correspondence between these data (allocated according to the market defined classification) and data based on industrial activities (SNI). Statistically the demand and output classification hence will be approximate when translated either way. When total value added for each market defined sector was compared to total value added, obtained by assigning specific companies to the market defined sectors, the correspondence was very good, however.

Table 1.1 Input

	ROW	I/O
I. Produced Commodities	1-11	1-34
1.00 Primary Production	1-2	1-4
1.10 Agriculture, Forestry and Fishing	1.	1-3
1.20 Mining and Quarrying	2.	4
2.00 Industrial Production	3-9	5-22[a]
2.10 Raw Material Processing	3.	
2.20 Intermediate Goods	4.	
2.30 Investment Goods	5.	
2.40 Construction incl Rents	6.	
2.50 Consumption Goods	7-9	
2.51 Capital Goods	7.	
2.52 Food and Beverage	8.	
2.53 Other Consumer Goods	9.	
3.00 Services	10-11	23-34[a]
3.10 Electricity	10.	24
3.20 Other Services excl Rents	11.	23-34 excl 24[a]

a) The sectors 25, 31 and 32 are included in Industrial Production and excluded from Services.

II.	Primary Commodities	12-30 excl 13, 16-18	36-42 45-48
4.00	Primary Production Imports	12+14	(1-4)[b]
4.10	Agricultural, Forestry and Fish Products	12	(1-3)
4.11	Agricultural Products	13	(1)
4.20	Mineral Products excl Crude Oil	14(excl Crude Oil)	(4)
5.00	Industrial Production Imports	15+(19-24)	(5-22)
5.10	Raw Material Processing Imports	15	
5.11	Petroleum Products Imports incl Crude Oil	16(incl Crude Oil)	
5.12	Ferrous Metal Imports	17	
5.13	Non Ferrous Metal Imports	18	
5.20	Intermediate Goods Imports	19	
5.30	Investment Goods Imports	20	
5.40	Construction Material Imports	21	
5.50	Consumption Goods Imports	22-24	
5.51	Capital Goods Imports	22	
5.52	Food and Beverage Imports	23	
5.53	Other Consumer Goods Imports	24	
6.00	Imports of Services	25-26	(23-34)[a]
6.10	Electricity Imports	25	(24)
6.20	Other Imports of Services	26	(23-34 excl 24)[a]
7.00	Duties, Taxes, Subsidies etc	27-28	37-42, 45-47
7.10	Commodity Taxes and Subsidies, Duties etc	27	37-42
7.20	Non Commodity Indirect Taxes and Subsidies	28	45-47
8.00	Value Added (SNR)	29-30	48
8.10	Wages	29	49
8.20	Profits and Depreciation	30	50
9.00	Total Input	1-30 excl 13, 16-18	51

a) The sectors 25, 31 and 32 are included in Industrial Production and excluded from Services.

b) Numbers within parenthesis refer to imports (table 5b in SCB Statistical Reports 1972:44).

Table 1.2 Output

		Column	I/O
I.	Use Within Prod. System	1-11	1-34
	1.00 Primary Production	1-2	1-4
	1.10 Agriculture, Forestry and Fishing	1.	1-3
	1.20 Mining and Quarrying	2.	4
	2.00 Industrial Production	3-9	5-22[a)]
	2.10 Raw Material Processing	3.	
	2.20 Intermediate Goods	4.	
	2.30 Investment Goods	5.	
	2.40 Construction Material	6.	
	2.50 Consumption Goods	7-9	
	2.51 Capital Goods	7.	
	2.52 Food and Beverage	8.	
	2.53 Other Consumer Goods	9.	
	3.00 Services	10-11	23-34[a)]
	3.10 Electricity	10.	24
	3.20 Other Services	11.	23-34 excl 24[a)]
II.	Final Consumption	12-16	37-41
	4.00 Public Consumption	12	37
	5.00 Private Consumption	13	38
	6.00 Gross Investments	14	39
	7.00 Change in Stocks	15	40
	8.00 Exports	16	41
	9.00 Total Output	1-16	43

a) The sectors 25, 31 and 32 are included in Industrial Production and excluded from Services.

Since the MOSES aggregation scheme centers on markets and the use of industrial products the input-output structure does not differentiate between imports and produced commodities. Instead import shares obtained from macro National Accounts time series data are varied over time for the four industrial production sectors. The same proportion of imports regardless of sector origin is assumed. The input-output structure is specified in basic values ("ungefärlig produktionskostnad") and thus makes use of available information on trade margins. Since our input-output matrix is specified in basic values it has been necessary to adjust all macro time series brought into the data base to this value level in order to obtain consistency in the "initialization" - the start-up of a simulation. A not insignificant amount of data are compiled from industrial statistics or other macro statistics which are not readily obtainable in basic values. This has created problems which have forced us to make a number of simplifying assumptions. On a number of occasions we have for instance assumed the same growth pattern for our variables specified in basic values as for time series valued at purchaser's prices. This implies that trade margins and commodity indirect taxes are growing proportionately. It is likewise assumed that margins and indirect taxes are identical for all inputs into each production system sector or final demand category regardless of sector origin. On the other hand we have managed to avoid problems with secondary production by using a commodity by commodity specification.[1)]

The input-output coefficients of one cell in the input-output matrix are allocated to each firm in that particular market. The coefficients of each firm are kept constant over time in the model (for the time being we use 1968 figures - see Table 2.1). Since individual firms within and between markets meet with success and failure very differently in the model they also grow at very different rates. Thus the macro input-output coefficients vary endogenously over time. Here we have had to assume, however, that price increases are the same for products from the four industrial production sectors regardless of which sector they are sold to as inputs or as final demand. The average spending shares for the five final demand categories - GOVernmenT, Household CONSumption, INVestments, Change in Stocks (ΔSTO) and EXports - are shown in Table 2.2.

The use of 1968 I/O coefficients each year clearly means introducing an inconsistency in the macro data basic system even though the macro coefficients will vary because of the way they are used in individual firms. This assumption will have to be relaxed in the future. Until we have got the necessary statistical information to allow time dependent I/O coefficients, however, we will have to be satisfied with the fixed coefficient assumption.

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1) For a detailed discussion of alternative methods in input-output analysis, see Höglund, B and Werin, L, The Production System of the Swedish Economy, An Input-Output Study, IUI, 1964.

Finally, it should be pointed out how the input-output structure is used in MOSES. The model is not solved by inverting the input-output matrix in the traditional way. For the four industrial production sectors the production volume is determined in the business system block while the corresponding input-output coefficients determine the amount of inputs needed to make this level of production possible. At both ends of these sectors, that is at both ends of each individual firm, there are buffer stocks to even out production flows. For the remaining six "external sectors" on the other hand the input-output matrix is operating as in a conventional macro input-output model complemented with a Keynesian demand system.

TABLE 2.1
INPUT OUTPUT COEFFICIENT MATRIX, 1968

	A/F/F	ORE	OIL	RAW	IMED	DUR	CONSTR	NDUR	EL	SERVICE	TOTAL
A/F/F	.02	.00	.00	.07	.06	.01	.01	.22	.00	.00	.04
ORE	.00	.07	.00	.06	.01	.00	.01	.00	.00	.00	.01
OIL	.01	.01	.00	.07	.01	.00	.00	.00	.03	.01	.01
RAW	.01	.02	.00	.18	.07	.10	.05	.02	.01	.01	.05
IMED	.03	.02	.00	.07	.14	.08	.03	.06	.00	.02	.05
DUR	.02	.04	.00	.04	.07	.18	.06	.02	.00	.02	.05
CONSTR	.07	.02	.00	.03	.03	.04	.11	.02	.09	.07	.06
NDUR	.09	.01	.00	.03	.08	.03	.02	.22	.01	.05	.07
EL	.01	.03	.00	.02	.02	.01	.01	.01	.03	.01	.01
SERVICE	.08	.05	.00	.09	.06	.06	.09	.06	.03	.16	.10
TAXES	.06	.09	.00	.03	.02	.03	.04	.00	.03	.01	.02
VA	.60	.64	.00	.32	.42	.46	.56	.37	.82	.66	.53
TOTAL	1.00	1.00	.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 2.2
AVERAGE SPENDING SHARES, 1968

	GOVT	CONS	INV	STO	EXP	TOTAL
A/F/F	.01	.03	.00	.19	.03	.06
ORE	.00	.00	.00	.01	.03	.01
OIL	.02	.01	.00	.00	.01	.01
RAW	.01	.01	.00	.21	.15	.07
IMED	.11	.03	.04	.03	.18	.09
DUR	.23	.04	.20	.24	.28	.14
CONSTR	.21	.19	.69	.08	.07	.25
NDUR	.17	.20	.01	.29	.09	.15
EL	.03	.01	.00	.00	.00	.02
SERVICE	.29	.33	.02	.02	.16	.25
TAXES	.08	.15	.03	.04	.01	.08
TOTAL	1.00	1.00	1.00	1.00	1.00	1.00

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OTHER MODELS

IS THERE AN EFFICIENT LEVEL OF UNEMPLOYMENT? SIMULATION EXPERIMENTS ON A LABOR MARKET MODEL

Donald A. Nichols

> "....the power of modern computing equipment may well restore the numerical example to a position of honor among tools of analysis in regard to problems too difficult for a more general solution."
>
> T.C. Koopmans

1. Introduction

Solow says "The art of successful theorising is to make the inevitable simplifying assumptions in such way that the final results are not very sensitive."[1] Unfortunately, for a variety of labor market problems, the results seem to be exceptionally sensitive to the kinds of assumptions economists usually make. Thus, at present, labor market economists are finding great difficulty in choosing a set of assumptions which will reduce their problems to a mathematically tractable level without affecting significantly the conclusions that can be drawn about several important phenomena. Specifications that are simple enough to yield results do not seem to be able to lend insight into many questions of great importance.

For many problems, this shortcoming of conventional theory may be no more than an annoyance. But for other problems, and in particular, for the explanation of unemployment, the use of supply and demand, or any other apparatus that treats laborers identically, merely side-steps the problem. Unfortunately, we cannot at this date model heterogeneity in a very tractable way.

The simulation model I report on in this paper is intended to shed light on this question. This model uses a very simple specification of hiring, firing, quit, and wage decisions that are applied to 1000 workers of differing abilities. These decisions constitute a labor market that has certain realistic characteristics not seen in previous models.

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[1] Solow (1956), p.65.

Specifically, in this paper I can answer the following questions: (1) Is there a non-zero rate of unemployment which maximizes steady state GNP? (2) Does an economy with cyclically fluctuating unemployment rate have a higher or lower GNP on average than one with the same average, but constant, unemployment rate? (3) How does the equilibrium unemployment rate depend on the structure of the labor market?

The model I will describe is a pilot model whose purpose is to explore in the abstract the relations between certain economic concepts which can be related only with great difficulty using analytic techniques. Therefore, the quantitative results I derive are of little interest; it is the qualitative dependencies that I wish to isolate.

The macro-economic issues were described in the volume by Phelps et al. (1970) which explored the link between inflation and unemployment. Various factors must be considered when describing that link, and a large literature now exists on each. Holt and David (1966), in a seminar paper, had first described the links between turnover and unemployment, thereby giving an empirical foundation to the dynamic concept of frictional unemployment. Recently, estimates of many aspects of these complex hypotheses have appeared in several issues of the Brookings Papers, most notably the work of Hall (1970, 1972), Gordon (1971, 1973), and Perry (1970, 1972). The emphasis in this literature has been macro-economic in the sense that its purpose has been to improve our understanding of the effect of macro-economic policy on inflation and unemployment.

Various institutional theories have also grown up to explain other labor market phenomena not easily described by neoclassical theory. These include the work of Thurow and Lucas (1972), Piore and Doeringer (1971), and the more radical market segmentation theories of Reich, Gordon and Edwards (1973). Feldstein (1973) also examined the effect of a group of institutional forces on the equilibrium unemployment rate.

The reader of this literature cannot fail to be impressed with the difficulty of the problems being considered, and the inadequacy of existing theory to give concise, satisfactory answers to the important questions being asked.

2. An overview of the model

There are 1000 workers in the simulation who differ from each other by a single normally distributed characteristic called talent. There are ten firms, each of which produces output according to a production function that uses ten different labor skills as inputs. Skills differ from each other only in the level of talent that they require. Different workers will be able to contribute different amounts of each skill with high talent workers being able to outproduce low talent workers in all skills. The functional dependency is nonlinear so that high talent individuals have a comparative advantage at high skill jobs. There is no skill-specific training that workers must have.

Thus there are 100 different jobs (firm-skill combinations) that a worker might acquire, each with its own wage rate. Workers attempt to get the best jobs they can -- those with the highest wage rates -- while firms attempt to hire the best workers they can -- those with the most talent. The heart of the simulation is the set of rules which governs the search processes that are carried out in each time period in order to match workers and jobs.

Each worker, if employed, decides whether or not to quit. He makes this decision after considering the unemployment rate, the wages available on his present job and elsewhere, and his own talent relative to that of his coworkers. If he quits, he determines an asking wage and becomes unemployed. He seeks work in the skill classification above the one he left. If unemployed at the outset of the period, he lowers his asking wage by five percent, and decides whether or not to lower his skill-classification and search for less desirable jobs.

Firms examine their employees and fire those workers whose production is less than eighty percent of the wage being paid at that level. The heterogeneity of the labor force implies that each worker will have a different marginal product at each job. It is marginal in the sense that the production is calculated taking as given the allocation of the other workers to their jobs within that firm.

Firms then search the unemployed for workers who have a level of talent that is high enough to make them productive at the job in question. The search is carried out for each job in order according to the wage rate being offered, with the high wage jobs getting the first crack. The unemployed are classified by skill, and only those classed one above, at, or one below the skill listing of the jobs are searched. An offer is made to any unemployed worker discovered through this process whose talent is sufficiently large that his marginal product will exceed the wage at the job in question. A worker accepts the first job offer which has a wage in excess of his asking wage. These hire, fire, and quit decisions determine a new allocation of workers to jobs which is maintained until the next period. The only behavior or importance that is not contained in this sequence is that which determines wage rates. Firms determine wage offers in a rather complex manner that is described more fully below. Here, we need only note that wages are increased when they are less than the marginal product of the worst worker on the job, and decreased when they are greater.

Aggregate demand can be simulated by changing the demand for the output of all firms. This demand is an important element of the demand for labor. These output demand functions can also be subjected to random shocks in order to create the need for labor turnover. This is the only stochastic force which I have used in this paper.

Labor characteristics

The single characteristic, TALENT, which distinguishes workers from each other is normally distributed with a mean of 1.0 and standard deviation of .15.[1] Specifically, each worker is assigned a level of talent according to the following implicit function

$$(1)\qquad \frac{K-1/2}{1000} = \int_{-\infty}^{\text{TALENT }(K)} \frac{1}{.15\sqrt{2\pi}}\, e^{1/2\left(\frac{x-1}{.15}\right)}\, dx,$$

where workers are indexed K = (1, 1000).

TALENT is transferred into the various labor SKILLS by a set of nonlinear functions. SKILLS are indexed by the letter I. The quantity of the I-th SKILL input that the K-th worker can produce is determined by (2).

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1 Initially, I intended to use the variable I.Q. instead of talent. I.Q:s initially had a mean of 100 and a standard deviation of 15. While my colleagues cautioned me that I.Q. and productive ability are not identical and therefore a different variable name was in order, I kept the original dimensions and occasionally made references to I.Q.

(2) SKILL(I,K) = LOC [TALENT(K) + .68 - .08*I]

Thus in the most demanding skill class, (I=10), it takes a level of talent greater than 1.12 for a worker to be productive while in the least demanding skill class, a level of talent greater than .4 is required.

Equation (2) guarantees diminishing returns to talent in any skill classification, and it guarantees high talent individuals a comparative advantage at high talent jobs. Since the functions for each skill classification differ from each other by a constant, it will be true that the ratio of the output of a specific skill of a high talent individual to that of a low talent individual will be higher the higher the skill classification. It is easily seen why the logarithmic form of these equations guarantees that high talent individuals will have a comparative advantage at high skill jobs. This should guarantee the existence of a unique optimal allocation of men to jobs in the absence of stochastic disturbances and market frictions.

The supply and demand system

Each of the ten different firms in the economy faces a separate demand curve for its output and must produce that output using a Cobb-Douglas production function defined over the ten labor skill classes.

Thus there are 100 different jobs that a worker might acquire. He can also be unemployed, and when he is, he remains attached to one of the ten different skill classifications. Because the production functions are Cobb-Doublas, each firm has a strong incentive to hire some labor at each skill classification.

Demand curves are assumed to be rectangular hyperbolae.

(3) OUTPUT(J) = B(J)/PRICE(J)

Random shocks when used, enter in the form of changes in the constants B(J). Changes in aggregate demand are simulated by increasing all the B(J) simultaneously.

These three equations complete the environment within which decisions are to be made. The environment is technically very simple, yet it leads to difficult decisions because of the problems introduced by heterogeneous labor.

Allocation of workers to the correct jobs

While the number of decisions to be made in this model are small, the environment within which these decisions are to be made is complex. Since each worker is different and since each firm has at any point in time a work force of differing composition, the marginal product of a particular worker may vary dramatically from firm to firm even at the same skill classification. A very lengthy search procedure for both workers and firms would be necessary if a state of perfect knowledge were to be attained in which each worker worked in that job at which his productivity was highest.

Some simple rules of behavior that are generally consistent with profit and utility maximization in the long run are now applied.

Each of the 100 firm-skill job classifications has an individually determined wage rate. Workers examine these rates and determine whether they feel they can improve their income by quitting their present job and looking for a different one. This calculation is made by comparing two numbers, one to represent the costs of search and possible unemployment, the other to represent the expected income gain to be attained once the job switch has been completed. Since all hiring is done from the pool of unemployed workers, it is necessary for a worker first to quit before he can attain a better job. However, it is possible for a worker to accept employment in the same time period in which he had quit.

The costs of unemployment are assumed by the worker to be his present wage rate, WAGE(I,J), multiplied by the present unemployment rate for workers in the skill class in question with a constant added to the unemployment rate and another constant multiplying the whole expression. These constants are to be varied to determine their effect on the labor market's adjustment to equilibrium. The expression denotes the cost of being unemployed for one time period (the present wage rate) multiplied by terms which represent the probability of being unemployed and the expected duration of that unemployment.

The benefits to be gained from switching jobs are estimated to be equal to the difference in wage rates between the present job and that paid on average at the next higher classification multiplied times the difference in talent between the worker in question and the average of his co-workers multiplied by a constant. The worker is assumed to feel underpaid only if he feels he is better than his co-workers. The constant in this expression serves two purposes. It converts talent into mantime periods, and it multiplies the resulting expression by the number of time periods the new job is expected to be held. The effect of the constant is to determine the talent differential necessary to make quitting profitable.

Once the worker quits, he seeks work in the job classification immediately above the one he just left. His asking wage is set equal to a weighted average of his old wage and the average wage paid at the new classification.

Fired workers must also determine an asking wage. It is a fixed percentage of the wage on the job they just left. Fired workers seek work in the job classification below the one they just left.

Each period, all those unemployed who do not find work lower their asking wages by five percent. When the asking wage falls to be equal to the average wage paid in the next lower skill classification, the worker drops to that classification. There is no other worker behavior.

The behavior of firms

The firms must determine employment and the wage rates at each skill classification. Each worker at a given firm in a given skill class earns the same wage. Thus the firm must determine how much to pay a diverse group of employees, and it must take account of several factors when making this decision.

- The firm realizes that workers' talents differ and that it can generally hire better workers by paying higher wage rates.

- The firm realizes that its best present workers will quit if wages are too low.

- The firm knows that it is easier to hire and retain workers when unemployment rates are high.

- For a given labor force, the firm obviously makes higher profits the lower are the wages it pays.

- The firm wishes to hire anyone whose marginal product exceeds the real wage.

At present, I determine wages in the following fashion. The worst worker employed in a particular skill class is the marginal worker. He is denoted $\underline{K}$(I,J). His marginal product is attributed to the skill class.

(4) MPL(I,J) = .1*PRICE(J)*OUTPUT(J)*SKILL

[I,$\underline{K}$(I,J)]/SKILLS(I,J)

Note that this marginal product is defined per worker while output is a function of skill units. Thus a term appears in (4) in addition to the marginal product of an additional unit of skill; this term converts skill units into workers. It is equal to the number of units of skill possessed by the worst worker in the relevant skill class currently employed by the firm.[1]

If the marginal product exceeds the wage being paid, the firm attempts to expand employment in that skill class while it attempts to contract in the opposite case. When the firm is expanding, wages are determined according to (5).

(5) WAGE(I,J) = (.2 + .6*U(I,J))*WAGE(I,J)

+ (.8 - .6*U(I,J))*MPL(I,J)

where U(I,J) is a measure of unemployment or the availability of labor relative to the size of the firm

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[1] Note also that the use of the Cobb-Douglas production function and the unitary elastic output demand curv simplify this formula a great deal.

U(I,J) = UNEMP(I)/[UNEMP(I) + N(I,J)]

There are some further constraints on the rate at which wages can go up which are merely designed to prevent awkward results during unusual periods of turmoil (such as the period of adjustment to the initial random allocation of workers). These constraints prevent real wage rates from going up more than 25 percent per period unless the firm's wage would still be below the average asking wage of the unemployed in that class.

For contraction, the wage equation is (6) which merely reverses the weights used in (5)

(6) WAGE(I,J) = (.2 + .6*U(I,J))*MPL(I,J)

+ (.8 - .6*U(I,J))*WAGE(I,J)

Once the firm has chosen a set of wage rates, the rest of its behavior is simple. Firms hire those unemployed workers whose marginal products exceed the real wage of the relevant labor classification, who are looking for work at that classification, and whose asking wage is less than the firm's offer. They search for these workers in the pool of unemployed, and, generally, offer work to the most talented workers first. As each worker is hired, he reduces the marginal product of a unit of labor at that classification.

A worker is fired if his marginal product is less than 80 percent of the real wage he is to be paid. This requirement is checked immediately before and after the firm searches for new workers in the given skill class.

Behavior is simulated in the following manner. At the beginning, workers are assigned job classifications according to a pseudo-random process.[1] The initial wage offers are supplied exogenously and various behavioral parameters are assigned.

The program then enters the basic loop which determines a complete time period of behavior.

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[1] Pseudo-random numbers are numbers that appear to be random for statistical purposes, but are in fact generated by a deterministic process. Since the process can be replicated, it is possible to use the same set of random numbers for successive experiments.

Then come the behavioral decisions which form the heart of the model. First, workers decide whether or not to quit, and once they become unemployed, they determine an asking wage. In subsequent time periods, those already unemployed determine whether or not to drop to a lower skill class. There now exists a pool of unemployed with fixed wage demands in each skill class, and a set of firms with a stock of employees and fixed wage offers. At this point, market clearing behavior occurs.

The 100 jobs, each denoting a firm and skill classification, are considered in order according to wage offers, highest first. The firm fires workers whose marginal products are less than 80 percent of the wage rate. These workers immediately join the unemployed of the next lowest skill class. The unemployed in the relevant skill classes are then searched to see if job offers should be made. These classes include the ones immediately above and below that of the job in question, as well as its own class. When an unemployed worker is found to have a marginal product in excess of the real wage, he is offered a job. He accepts if the wage offer equals or exceeds his asking wage. If any hiring is done, it reduces the marginal product of labor in the class in question, and it is again necessary to determine that the workers' marginal products are at least 80 percent of the real wage.

3. Behavior of the Model: A preliminary check

When presenting a theoretical model, one lists the assumptions that have been made in order to simplify the complex real world. These assumptions usually restrict the breadth of the model sufficiently that a complete description of its behavior is then possible. The difficult choices that must be made are those concerning the assumptions, and these are made prior to the analysis.

Simulations, however, yield an extensive and rich set of data output that are too numerous to report completely. In order to make any sense from this complex collection of numbers, it is necessary to use at this stage some of the conventions and assumptions that are usually made at the outset as part of the ordinary routine of the art of theorizing.

The first behavior I report on concerns the adjustment of the model to the initial random allocation of workers in the absence of any additional shocks. Can the model take this random allocation and sort them into a new allocation at which no turnover exists? How close is this final allocation to the optimum? By examining the behavior of the model when confronted with this problem, a rough idea of the efficiency of the search procedure and in indication of the stability of the equilibrium can be gained. This problem was also the one used while debugging the program. At the outset, turnover is very high as workers with high levels of talent quit the low skill jobs and workers with low levels of talent are fired from the high skill jobs. Fires in the first three periods alone are almost half the labor force, while quits are about one-fourth.

Unemployment averages more than a fourth of the labor force for the first nine time periods. But gradually, as the table shows, it declines steadily until it becomes less than one percent.

The allocation of workers that results is far more efficient than the random one that appeared at the outset. Real GNP is 13.016 in period 1 with one quarter of the labor force unemployed. In period 39, GNP is 20,892, which represents an increase of 21 percent per employed worker and 61 percent overall. This understates the increase since GNP even in period 1 has benefited from a great deal of turnover. The initial allocation would have produced a much lower level of GNP even with zero unemployment. This is due to the fact that many of the low talent workers have a negative effect on output when they are assigned to high skill jobs. This experiment does indicate that the model will approach an equilibrium even when it begins with a badly allocated labor force. The stability, however, is not very robust in the near neighborhood of the equilibrium. Even after 199 periods with no shocks, there is still some turnover in the model though it is very minor.

4. The effect of random shocks on unemployment

For all subsequent experiments, it was decided to use as the initial allocation, the one that resulted after 19 periods in the previous experiment. Much of the churning that occurs in those early periods gets replicated exactly for all other experiments, and it is so large that it swamps turnover due to other sources. Thus there is little to be learned from running these periods again

Table 1.

Period	Quits	Hires	Fires	Unemploy-ment	Real GNP
1	170	254	331	247	13.016
2	55	143	107	266	14.126
3	24	60	58	288	14.410
4	13	40	13	274	14.697
5	11	20	6	271	15.164
6	18	40	4	253	15.792
7	5	24	3	237	16.119
8	2	25	7	221	16.430
9	1	21	2	203	16.764
10	0	22	3	184	17.470
11	26	51	0	159	18.094
12	18	53	14	138	18.061
13	6	41	7	110	18.785
14	8	19	8	107	18.952
15	39	61	5	90	19.200
16	23	62	10	61	19.741
17	31	44	11	59	19.744
18	17	30	12	58	19.751
19	34	56	3	39	20.022
20					
21	35	63	14	25	20.472
22	45	64	14	20	20.473
23	17	25	7	19	20.551
24	8	10	2	19	20.557
25	7	11	0	15	20.678
26	10	13	0	12	20.762
27	17	19	1	11	20.801
28	22	17	2	18	20.530
29	11	20	2	11	20.792
30	14	18	4	11	20.802
31	16	13	2	16	20.699
32	12	20	2	10	20.748
33	3	7	5	11	20.778
34	0	3	3	11	20.792
35	4	5	0	10	20.809
36	3	5	2	10	20.889
37	2	6	3	9	20.924
38	2	5	2	8	20.928
39	8	11	0	5	20.892

and again. Accordingly, for the remaining experiments, time period 21 is the first to be reported while 39 is the last.

The previous simulation showed that in the absence of disturbances, the model will settle down to an equilibrium at which turnover is minimal. In order to generate turnover, it was decided to subject the model to a continuing stream of shocks. These were applied to the firm's output demand functions according to equation (3). Remember that the output demand functions are rectangular hyperbolae, and that the initial value of the constant level of sales is 10.0.

This constant, B(J), is multiplied each time period by a shock which shifts the demand function permanently.

As expected, turnover (hiring) increases as the shocks get larger. The next to last column in Table 2 shows this. The reason for this is simply that the shocks cause firms to grow and contract which necessitates hiring and firing. Unemployment increases with turnover for most sequences of shocks. Real GNP reaches a maximum for some level of shocks, since the allocation of workers to jobs is improved, as firms are forced to hire and fire, the worst misallocations get corrected since underplaced workers are the first to quit and overplaced workers are the first to get fired. Thus a moderate amount of turnover improves the job-worker match. On the other hand, it may take a few time periods for the model to adjust completely to a major shock. With a continuing stream of large shocks, the market is perpetually in the process of adjusting, and the short run misallocations that result eventually exceed in importance the long-run benefits gained by stirring up the dead wood. Thus there appears to be an optimum size to the shocks in this model though it is difficult to be precise about its level since it varies with the particular sequence of random shocks used.

An interesting relationship between unemployment and output emerges here. For small levels of shocks, both variables increase with the size of the shocks. This is a confirmation of the importance of turnover for efficiency. While one of the costs of turnover is a high unemployment rate, one of the benefits is an efficient allocation of labor. Over some ranges, the benefits can outweigh the costs so that real GNP can be larger despite the higher unemployment rate if turnover is high.

Table 2. The Effect of Random Shocks of Different Size on Unemployment Equilibrium

Size of shock (DEV)	Real GNP	Quits	Fires	Hires	Unemploy-ment
0	414.7	243	65	339	259
.05	419.4	453	146	622	390
.10	421.8	482	163	664	446
.11	419.9	474	154	649	498
.12	420.0	547	202	772	523
.13	422.4	560	224	814	441
.14	419.8	544	230	799	510
.15	419.8	579	252	863	482
.16	418.3	588	247	863	467
.17	421.2	579	266	866	507
.18	419.5	595	301	921	593
.19	419.7	565	337	928	601
.20	417.9	597	362	978	577
.25	417.3	608	544	1166	877

The figures in Columns 2 through 6 represent sums of the values of the variables for the entire 19 periods of each simulation.

5. Conclusions

What can we learn from results of this kind? Certainly the model is not a replication of the U.S. economy. Hence, the quantitative results must be ignored. But I find the qualitative results to be very interesting.

(1) Even in a model with arbitrarily chosen parameter values for quit, hire, fire and wage decisions, there appears to be a cost to violating individuals' expectations about the rate of inflation.

(2) There exists, for every alternative specification examined, a positive level of unemployment associated with the maximum level of output. That is, there exists a rate of frictional unemployment which is efficient in the macro-economic sense.

Much remains to be done to guarantee that these results are not due to some unknown peculiar specification. My intention when building the model was to choose those functional forms which were least likely to generate problems of nonexistence, nonuniqueness, or instability of equilibrium and to keep the number of equations to a minimum. Cobb-Douglas' production functions, for example, probably behave more "regularly" than real world functions do. It is hoped, then, that the possibilities for strange results have been kept to a minimum. There is no way to guarantee that, of course, but the use of a small number of well behaved inputs have usually yielded well behaved outputs in other contexts.

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GDM, A COMPUTERIZED SYSTEM FOR SIMULATING MICRO-ORIENTED MACRO-ECONOMIC MODELS

Ebbe Yndgaard

1. The basic problems and purpose of the GDM-project

For the economist as well as the sculptor, one basic problem is to remove redundant material; the construction of economic models to a great extent is a question of removing irrelevant or misleading assumptions and/or data. In practice this is performed by testing theories against empirical evidence. This way of looking at the problem of model construction has been the guideline for the GDM-project, which is not (yet) an economic model, but a more general computer system for simulating a broad variety of micro-founded economy-wide models, varying according to the specification of the assumptions which are necessary to identify just one model.

The GDM-system is built as a modular system where each module represents an exchangeable part of a complete economic model; e.g. the behavioral assumptions as to investment determination constitute a module, which could be specified in various ways according to relevance and user preference. However, for reference purposes the system includes a default/standard economic model.

2. The default GDM-model

Space[1)] does not allow us a full description of the basic GDM-model; therefore we shall confine ourselves to a very broad sketch of the main elements of the model, emphasizing some of its main characteristics.

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1) For a full description the reader is referred to Yndgaard (1978).

The single period

The model represents a sequential economy in the sense that a solution is established for each period. As is further explained below, the GDM-system reproduces a series of consecutive temporary equilibria, which are mutually interdependent and consistent. During a single period, four categories of economic agents are active, viz., private households, private firms, a public sector, and a foreign sector.

The micro-unit-decision system of the default model most naturally classifies GDM as a Walras-Arrow-Debreu economy, i.e., the households supply labor (directly) and investment goods (indirectly) and money.

It is worth emphasizing that labor supply is heterogeneous, so that each individual has productive abilities which vary according to jobs (sectors/firms). Furthermore, the labor market is disaggregated so that a minimum real[1] wage rate per employed person is specified for each production sector; however, individual wages vary according to abilities; all employed persons achieve at least the minimum wage rate of the employing sector.

The dispersion according to abilities, as in Nichol's paper (in this conference volume), and minimum sectoral wages per employed individual implies explicit personal (wage-) income distributions (very much like observed distributions). This part of the model has strong similarities with Roy (1950).

The primary roles of the private firms/sectors, each producing one good only, as usual are, firstly to supply commodities for consumption, investment, intermediate products, and exports and secondly to demand capital and labor services, intermediate products, and imports; finance is obtained from private households, foreign and public sectors. In general, credit is included between <u>all</u> agents of the economy;

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1) In the default version an automatic price-indexation of wages takes place (as in Denmark).

all transactions are explicitly treated and saved for up-dating of individual historical records. The production structure consists of sectoral production functions with two arguments, labor services and capital services, remunerated by wages and dividends respectively. Intermediate products are calculated according to a fixed coefficient matrix (Leontief) and include imported intermediate products (e.g. oil).

In the default version the basic behavioral assumptions are utility and profit maximization for individual households and firms (sectors), respectively.

The instruments of the public sector include direct personal and indirect taxes, varying according to sectors, tariffs, dividend payments from the private sector, monetary supply, transfer payments to unemployed, stipends for students, public investment and consumption etc.

The foreign sector delivers various imported goods for intermediate, investment or direct consumption purposes. The sectoral export demand functions reflect international competitiveness; in the default version the rate-of-exchange is fixed.

A sequence of economies

It is hoped that the last section has revealed that the structure of the default version of GDM has many similarities with a single period Walras-Arrow-Debreu economy. Between periods, i.e. through time, a long series of up-datings takes place for both price consistency purposes and according to specific assumptions about the dynamic elements of the economy to be represented by the system.

The up-datings of the first type include revision of capital stocks with investment goods (in new techniques) net of depreciation, distribution of capital gains and losses, inventory stocks of final goods, inheritance of wealth between persons leaving and entering the labor force, etc.

The second type of up-dating stems from the behavioral assumptions; labor abilities are up-graded due to job-training and degraded due to age-effects; wage-rates may be redefined according to, say, a Phillips-curve theory; inflationary expectations may be respecified on the basis of the results from the last period etc. According to the specification of this set of assumptions the sequence of economies will vary, reproducing as one extreme a multisectoral golden-age system with a constant degree of employment and a constant balance between sectors; for a fixed rate-of-exchange a ruinous sequence with galopping inflation, a rapidly growing deficit on the balance-of-payment and a rapidly growing degree of unemployment could be set up as another example.

In short, the dynamic properties of the system depend on the specification of the assumptions. The exchange of assumptions in the GDM-system takes place by using logical (switch) variables.[1] The application of various combinations of switches from a reasonable set enables us to reproduce thousands of different economic regimes; hence, an identification of <u>the</u> economic model is extremely difficult.

Usually the endeavors of applied economists have been restricted to identifying <u>partial</u> mechanisms when analysing disaggregated (micro-)problems; what we have tried is to establish an instrument for integrating such partial models into a simultaneous complete framework. However, the GDM-project has not revealed <u>the</u> economy; hopefully we have established a fruitful instrument which might ease our endeavors in the direction of this ultimate goal, in itself probably moving through time.

3. Adjustment processes of GDM; solutions and equilibria

Referring to the figure, let Y_{11} be an initial vector comprising all - in general not mutually

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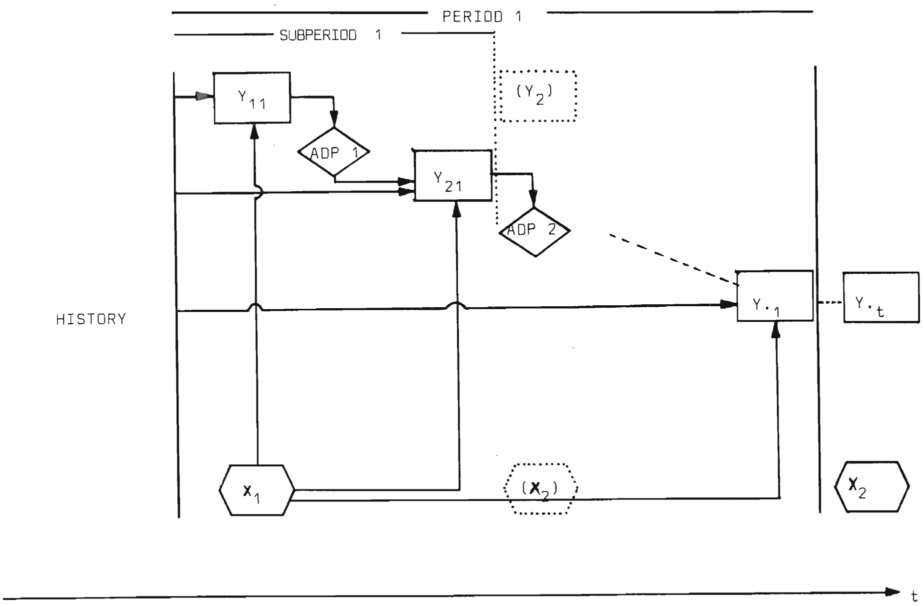
1) E.g., if the variable EXODEV = TRUE the rate-of-exchange will remain fixed; on the other hand, if EXODEV = FALSE an automatic de-/revaluation mechamism is activated, until the absolute deficit/surplus on the balance-of-payments is brought within prespecified limits.

consistent and realizable a priori values of all endogenous variables for period one, calculated as the result of all agents reacting to all relevant historical values as if a preliminary set of the common endogenous variables were solution values; typically the common endogenous variables[1] comprise prices, the rate of interest etc. The resulting signalled reactions from all agents are not realizable, e.g., total demand of a specific good may exceed total supply, including available stocks of the commodity in question. Keeping the historical (lagged) values fixed and also the exogenous, simultaneous variables $\underline{X}_1$, the box, called adjustment process 1 (ADP 1), re-



.......: subperiod interpretation of adaptation, cfr. text.

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1) The common endogenous variables are true, simultaneous variables; once given, all other endogenous variables may be calculated recursively.

defines the common endogenous variables according to some reaction paradigm, e.g., raising the relative price of the commodity just mentioned, etc.

The first (iterative) adjustment process leads to a redefinition of Y_{11} and changes it into Y_{21}, still for fixed historical and simultaneous, exogenous variables. Now let the interaction between adjustment processes and recursively determined redefinitions of agents' reactions continue in an iterative process, until all tensions are within certain prespecified tolerances. If this process converges, we end up in a limit value for Y_{i1} the solution corresponding to the predetermined (historical and simultaneous, exogenous) variables, assigned to period one.[1] (The solution algorithm, denoted the separable signal algorithm (SSA), described in Yndgaard (1978) will converge under rather broad assumptions and rests on an application of the Brouwer/ Kakutani fix-point theorems).

In the default version of GDM the endogenous macro market (common to all agents) variables are the relative commodity prices (the absolute level of prices is predetermined for the single period, but not necessarily predetermined in dynamic versions of the system), the firms' interpretation of the marginal product of labor (for details see Yndgaard (1978)), and the rate of interest. The rate-of-exchange is fixed in the standard version.

The adjustment process cannot normally be assigned any economic interpretation; it is a pure iterative technical solution algorithm leading to one (not necessarily unique, depending on assumptions and the width of the solution tolerance interval) solution, corresponding to the predetermined variables. Now, a comment as to principle is relevant; the adjustment process may, however, be interpreted as reflections of real economic phenomena in time; in fact that is what the new

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1) Due to discontinuities, created by hiring/ firing one 'finite' person at a time, the solution will always exhibit some slack.

micro-simulation models do; the tensions left in Y_{21}, say, are definitive then and must be absorbed somewhere in the system; buffer mechanisms must exist; in the GDM-model unplanned stocks' changes are the main buffers. The SSA-algorithm operates on both relative prices, labor markets' conditions, the rate of interest etc. If we interpret the single adaptive steps of the implicit tatônnement mechanism, the realized values in Y_{21} therefore will depend <u>on the relative speed of the various adaption mechanisms</u>, reacting to tensions in the system. While in the standard version of GDM we would call lim Y_{i1} a solution, the new micro-simulation models would interpret Y_{21} as a solution/ realized values for the subperiod. The extremely difficult problem of empirically verifying the single steps of the adjustment process has prevented us - at this stage - from the interpretion indicated, however. We feel that really serious autonomy problems are involved here.

Basically the difference in methodology between our model and the micro-simulation models consists of a redefinition of the predetermined variables already after the end of the subperiod, corresponding to Y_{21} ; i.e. the difference in the models hinges on the relation between the speed of the endogenous adaption process and the speed at which significant changes of the relevant exogenous variables and the relevant redefinition of historical values occur.

In the longer run the sequence of solutions $(Y_{.t})$ may constitute a dynamic equilibrium, e.g. of the golden-age type, again under proper assumptions.

4. GDM-applications

On a purely synthetic data basis the GDM-system may be used for theoretical explorations of a long series of mixed assumptions/ theories; the system has proved very effective to this end.

Both comparative-static and comparative-dynamic analyses are easily performed between various economic regimes. Some examples may illustrate the power of the system; from the comparative-static class of analyses at one extreme: comparison of solutions to economies with pure but different quantity signals (fix-price models of the Clower-Drèze-Benassy-Malinvaud type, i.e. economies with a relatively low price-adaption speed in comparison to quantity signal-adaption speed), comparison of the type just mentioned under different assumptions as to the mechanism determining the rate of interest. At the other end of the spectrum: effects on personal income distributions from variations in the scheme for price-indexation of wages, effects of relative changes of minimum wages, increased labor mobility etc.

The comparative-dynamic type includes, e.g., analyses of: vertical Phillips-curve models and other monetaristic theories; various inflation theories; the interaction between employment, technical progress, investment programmes and foreign trade (rate of exchange policy) etc., etc. In short, the possibilities are legion. However, even though "theoretical" explorations on synthetical systems are often fruitful exercises from an applied point of view, we are left with the basic identification problem: what is currently the most realistic model of a specific economy?[1] We consider the choice of time period and estimation of the relative speed of adaptation parameters really difficult ones, due primarily to observability problems. We must postulate that any realization of economic variables in a measurement on a process in motion, i.e. in disequilibrium in a broad sense, and we are lacking both experience in this respect and relevant observations. The basic problems stem from the fact that the predetermined variables are changing significantly at a speed which is so high that the endogenous tensions do not bring about a final solution before the next set of conditions rules.

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1) Naturally the broad definition of identification includes estimation of all relevant parameters (or calibration).

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WORK IN PROGRESS

A SOCIOPOLITICAL DECISION AND INDICATOR SYSTEM FOR THE FEDERAL REPUBLIC OF GERMANY – AN OVERVIEW OF SPES

Ralph Brennecke

The label SPES[1] is an acronym based on the title Sociopolitical Decision and Indicator System. Within the SPES-Project economic and statistical scientists as well as sociologists of the Universities of Frankfur and Mannheim are working on a foundation of social politics. We understand social politics as an active part of public policy in a broader sense. Our research, however, is concentrated on special parts of public political aspects in the Federal Republic of Germany.

1) Within the decision system, effects, side-effects and interdependencies of specific public political measures are examined. The basis of this examination is the development of a simulation system which is representative for the Federal Republic of Germany. The system is divided into modules for population, education and mobility, labour force participation, income, income maintenance and transfers, uses of income, health, housing and modes of traffic. The decision system connects these modules with each other and with macro-economic systems.

2) Within the indicator system the goals of political activities and their success are examined. The goal variables of the decision system are part of the mor complex goal catalogue of the indicator system.

The indicator system is divided into three parts, the first of which is a system of goal dimensions of each of the subject scopes. Second, each goal dimension is measured by specific social indicators and third, the system contains the time series of all indicators,

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[1] The SPES-indicator system has recently been published in a comprehensive book with the translated title: Conditions of Life in the Federal Republic of Germany (Zapf, 1978). This book is the result of our investigations with respect to the goal areas of the modules mentioned above. In addition, there are reports on social status and on participation within the Republic.

most of them from 1950 to 1975. (Figure 1 explains, for example, part V of the indicator system: consumption.)

The major part of the indicators has to be calculated within the decision system. In order to do this, as well as for the microsimulation, a data base is necessary which contains the essential characteristics or attributes of individuals and households.

For this purpose the members of the SPES-Project have constructed two merge files called Integrated Microdata File (IMDAF) for 1962 and 1969. The IMDAFs are based on the income and spending cross-section samples (EVS) of 1962 and 1969, the microcensus -- both of them are issued by the Federal Statistical Office -- and on information from the tax statistics. The EVS contains information about approximately 48,000 households and their individuals. Unfortunately this data base is not representative with respect to the German population and to high income families. We therefore have constructed additional households by using the information mentioned above (Kortmann, 1977).

Compared with smaller data bases, there is sufficient information in IMDAF with its total of 68,000 households to analyse small groups like poor people or old people in one-person households. This database is called startfile in the following.

The structure of the decision and indicator system is reflected in Figure 2. By following the scheme of economic policy of Fox and Tinbergen we have symbolized policy decisions and instruments by boxes. In analogy with the goal variables of Tinbergen, the box 'social indicators' symbolizes the goal dimensions and the indicators used to measure states and changes in these dimensions.

The system itself is composed of two connected parts: the microanalytic and macroeconomic simulation systems. The technical part of the macroeconomic system has been developed by our group and allows the simulation and linking of various econometric models in an efficient manner. However, we did not develop macroeconomic models of our own, but rather use the models of Krelle, Lüdeke, Hansen and Westphal, etc.

The economic and social processes of the microanalytic simulator can also be seen in Figure 2. The simulation starts by using the IMDAF, called startfile. The characteristics of one household are read into the transformation circuit, beginning with the population modules and the cross-reference procedure and continuing with education, etc.

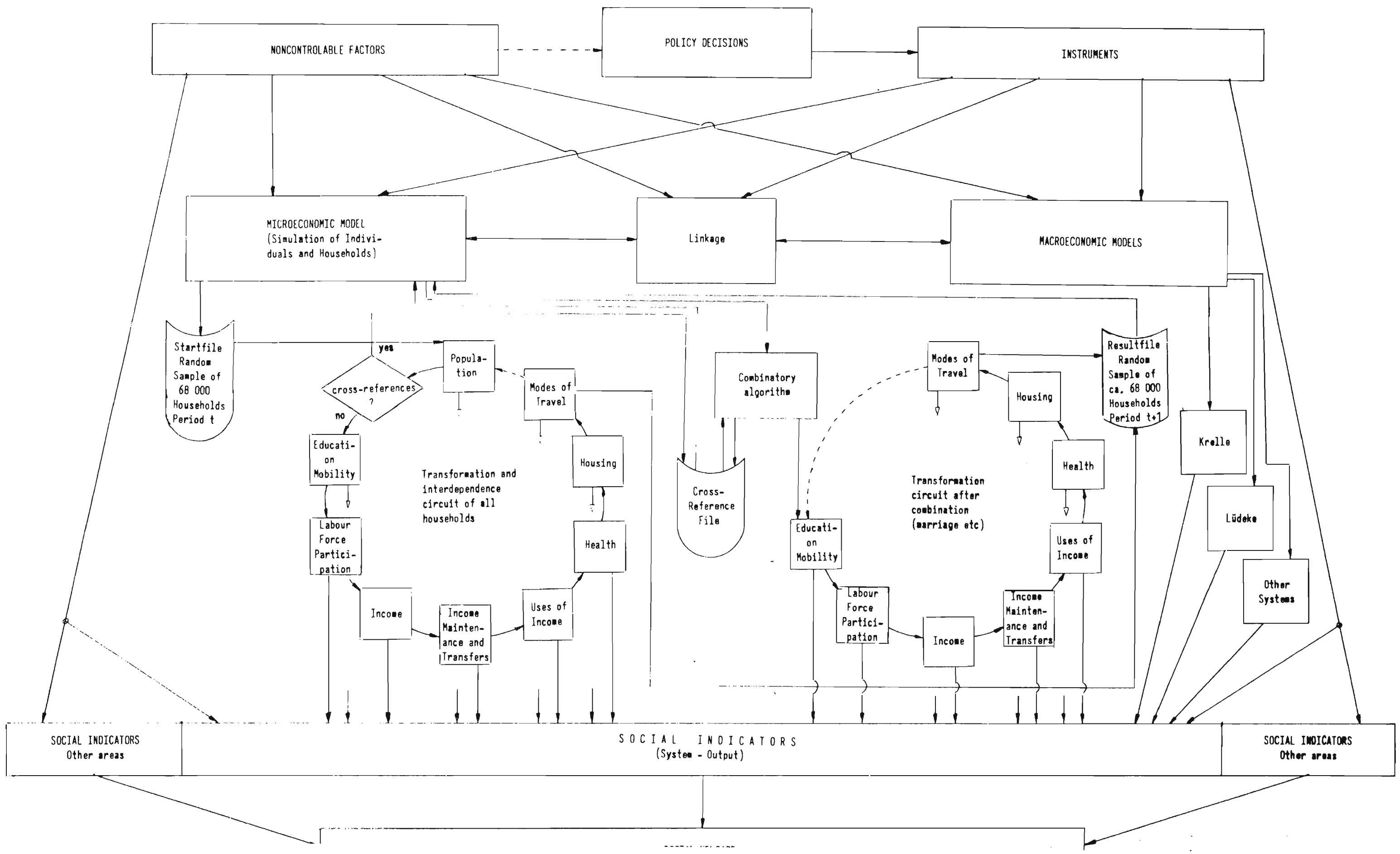
Figure 1. Summary of Part V of the SPES-Indicator* System 1976. Consumption

goal dimension	No.	SPES-Indicator 1976	Measure	Values 1955	1960	1965	1970	1975
1. Level, growth of income	95	private consumption per capita	DM	2507	3304	4042	4921	5582
	96	Private consumption growth rate, per capita	%	9,2	6,9	5,4	7,3	2,6
	97	Tax rate on private consumption	%				(9)	
	98	private energy consumption per capita	Tsd.kWh			12,2	16,5	18,5
	99	protein consumption per day and per capita	g	79	80	80	81	83
	100	Daily domestic work per household	h	10,5		10,1	8,8	
	101	Average leisure time	h	2,7	2,9	3,2	3,5	
	102	Rate of vacation travellers	%		26,4	33,9	37,5	
	103	Rate of household with telephone	%			8,3	19,9	46,8
	104	Rate of household with deep frozers	%			2,0	18,5	52,2
	105	Rate of household with dish-washing machine	%			1,1	2,1	9,5
2. Consumption security and stability	106	Aver. fungible property (mothly cons. multiple)	a)	3,2	7,3	7,7	10,3	
	107	Consumption security costs, % of GNP	%				35,3	40,1
3. Freedom of expenditure choices	108	Share of non-restitutive income	%	33,9	38,8	43,3	47,6	54,7
	109	Share of income of consumption	%		88,9	88,4	85,6	85,2
	110	Share of income not for reproduction	%		30,0	31,7	33,2	39,9
	111	Saving ratio of private households	%	13,4	15,0	15,9	16,6	14,6
4. Inequality in consumption	112	Gini index private consumption	a)				0,278	
	113	Lowest quintile consumption share	a)%				8,2	
	114	Highest 5 % consumption share	a)%				12,3	
5. Poverty in consumption	115	Households spending 70% for neccessities	a)%				23,4	
	116	Households with less than 10% directionary income	a)%				5,3	

* The name of the SPES-Indicators come to a compromise between an abbreviation and a definition. The definition of the indicators which are labeled with a) is very complex.

Source: Wolfgang Zapf, Applied Social Reporting: A Social Indicators System for West German Society, SPES-Workingpaper No. 70, Frankfurt 1977, p. 9.

Figure 2. SOCIOPOLITICAL DECISION AND INDICATOR SYSTEM FOR THE FEDERAL REPUBLIC OF GERMANY



As an example, I would like to describe in more detail the population module and the cross-reference procedure. Figure 3 symbolizes the basic structure of this module. After having read the characteristics of one household, the ages of all persons are modified. Secondly the probabilities of death, divorces, household independency of adult children, and marriages are determined.

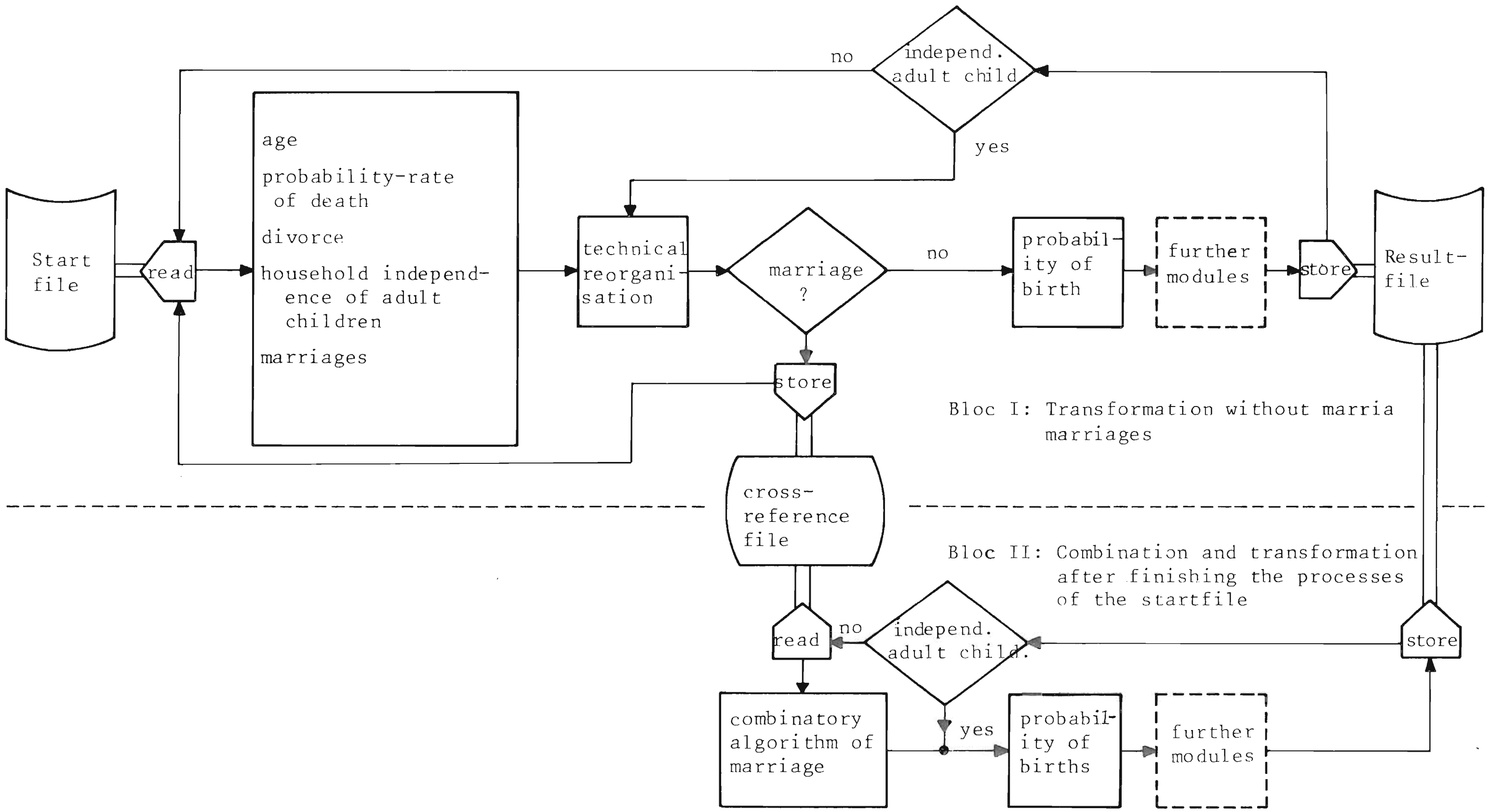
The technical reorganisation of the characteristics with respect to the results follows. After that a separate computation of the characteristics of marriageable men and women is effected. These attributes are written into the cross-reference-file and, depending on splitting parameters, the characteristics of the next household are being read. In the case of non-marriage the probability of births is simulated and in some cases the characteristics of new born (zero years old) children are determined.

Now the additional transformation process follows according to Figure 2. The simulation of school and university processes is effected within the education module. For persons at work, a possible change of employment is generated. Having determined this, various members of the household receive factor income dependent on their age, their profession and the macroeconomic development.

The income maintenance and transfers module has several functions. Transfer payments, e.g., pensions, are calculated, but also unemployment relief, additional social payments, etc. The total income sum is subject to the tax system. The payments for health, old age and unemployment-insurance are likewise computed by this module. The net income of the household now established can be used for simulating the distribution and uses of income. We are working on a method of calculating the expenditures together with other modules for durable commodities, e.g. cars and refrigerators.

The remaining modules deal with specific questions, especially with regard to the development of the social indicators within the years. The uses of medical facilities are simulated in the health module, the housing module places the criteria of population maintenance with living space of different levels at our disposal. Purchases and expenditures of cars are simulated in the traffic module.

Figure 3


Start file
read
age
probability-rate of death
divorce
household independence of adult children
marriages
technical reorganisation
marriage ?
no
probability of birth
further modules
store
Result-file
independ. adult child
no
yes
store
cross-reference file
Bloc I: Transformation without marria marriages
Bloc II: Combination and transformation after finishing the processes of the startfile
read
no
independ. adult child.
store
combinatory algorithm of marriage
yes
probability of births
further modules

Upon transformation of the characteristics of the household the result is stored into the resultfile. After this it is determined - as illustrated in Figure 3 - whether new households are founded by grown-up children, and in this case the attributes of the new household are calculated. These characteristic combinations are transmitted through the transformation circuit.

After all processes resulting from the characteristics of the household including the storage into the resultfile have been concluded, the attributes of a new household are read. This sequence continues until all attributes of all households of the startfile have finished the transformation process. Now a complete cross-reference-file is available which can be used for the construction of new households by marriages. As stated above, for each new household the probability of births and the transformation of all other variables are simulated (compare Figure 2, right circuit). Here it is checked whether the newlyweds remain with their parents or if they establish a new household. Therefore, the characteristics of two or three households have to pass the transformation circuit. Upon finalisation of the cross-reference process, the result-file contains a new fictive random sample of the year t+1 which can be used for evaluation and as a new startfile.

We hope that the system in its essential parts will be finished by the end of 1978. Later on the following work has to be done: the integration of a new database (the IMDAF of 1973), the further development of those modules which up to now could only be constructed incompletely, and the continuous application of the system. Moreover we have planned to investigate whether subjective social indicators, for instance satisfaction measurements, can be integrated into the simulation process. These problems, however, include a research perspective of approximately 10 years.

Literature

A more detailed description of the SPES-Project is given in the SPES-books, -working papers and -reprints and in: Ralph Brennecke, Hans-Jürgen Krupp: Das Sozialpolitische Entscheidungs- und Indikatorensystem für die Bundesrepublik Deutschland, Genesis, Ziele, Struktur und Stand des Forschungsprojektes, in: H.J. Hoffmann-Nowotny (ed.): Soziale Indikatoren, Huber-Verlag Frauenfeld und Stuttgart 1976, pp 139-163.

Kortmann, Klaus und Günter Schmaus: Generierung des Mikrodatenfiles 1969 für die Bundesrepublik Deutschland (IMDAF 69), published in: Nachrichtendienst des Deutschen Vereins für öffentliche und private Fürsorge, Heft 5, 1976, pp 144-149.

Zapf, Wolfgang (ed.): Lebensbedingungen in der Bundesrepublik Deutschland - Sozialer Wandel und Wohlfahrtsentwicklung, Campus Verlag, Frankfurt/New York 1977.

THE SWARTHMORE PRODUCT ALLOCATION SIMULATION MODEL – A REPORT ON SPASM

Frederic L. Pryor

A. Purpose and Progress

This micro-analytic simulation model was designed to investigate the determinants of instability in relatively competitive commodity markets. For most uses the model does not encompass the entire economy but rather focuses on particular subsectors, introducing events from the rest of the economy either explicitly or in terms of random shocks to particular functions or variables.[1]

Three phases of work on the model were planned. In the first phase, a considerable number of alternative specifications of the model were investigated to determine in what manner they would influence the functioning of the model and results obtained. The second phase involved linking a series of such market models together into a miniature economy to investigate particular problems of interaction. Such experiments focused primarily on the impact of various types of trade barriers. The third phase of the project involves calibrating the model to fit an actual commodity market and then using the model to investigate a series of policy questions regarding this market.

B. The Model

1. An Overall View

The key decision-making units of the model are producers and buyers. The financial sector is introduced by specifying certain financial constraints on production levels and by specifying certain conditions for obtaining credit by the two sets of actors.

[1] Work on the model in 1977-78 was financed by the U.S. National Science Foundation; computer expenses were born in part by the Institut univertaire de hautes études internationales and the Université de Genève.

The government sector is introduced by specifying taxes and trade barriers.

For each decision-making unit, financial accounts are kept. In addition, each decision-making unit is constrained by prespecified technologies. Further, the various decision-making units can be given different decision rules. A vast number of different types of markets can be specified and a larger number of experiments can be performed.

A central focus of the experiments that were actually made was the investigation of the impact of risk upon the aggregate behavior of the market. This was carried out by specifying the firms as utility-maximizing units with a utility function that allowed possible fluctuations of profits to become a key aspect in the decision-making process. Such a focus distinguishes the model from most other micro-analytic simulation models which represent relatively determinant processes.

2. Technical Aspects

The simulation model is embodied in a computer program written in FORTRAN that consists of about 2,000 cards. The program is designed to be easily adapted to any kind of standard computer and to require a core of less than 32,000. Most runs have cost less than $5.00; expenses mount when the number of participants in the market or the number of markets or the complexity of the search routines are increased. The program is highly modularized to permit changes to be made easily. Special software has been written that includes random number routines, special input routines, and a variety of routines to calculate various statistics for analysing the results.

3. The Supply Side of the Model

On the supply side, the individual firm faces a vector of input prices and knows the basic parameters of its production function; however, such a production relationship can be subjected to random shocks so that actual production falls only within some confidence interval. Since production takes a certain number of (prespecified) periods, the producers must predict the price in that future period; this is done with the aid of a price expectations formula plus information about how successful such predictions have been in the past. Given the predicted price and production level, the confidence limits around both of them, and a function relating profits to utility, the producers try to select a level of production to maximize expected utility.

Given the utility of the long run average profits (or losses), the firms also invest or disinvest, a process that takes a certain time to take effect. Rather than predict what the price will be, the model can be altered so that the firms can set their own prices and engage in a type of search for the ideal price. In addition, the maximization of utility can be extended over a longer time horizon so that the firms store inventories to sell in future periods. The objective function of the firm can also be easily changed so that instead of maximizing expected utility of profits, they can maximize expected utility of profits/worker or expected utility of profits given the constraint that workers cannot be fired, or some other maximand. Producer parameters of risk, as well as other production parameters and other constants, can also easily be changed.

4. The Demand Side of the Market

The individual consumers are given a demand function which can be quite simple or which can be a multi-period function. They can also be made to engage in various types of commodity speculation. They can either be programmed to accept whatever is the ruling market or, if producers offer different prices, to search for the lowest price and follow different stopping rules.

5. Price Setting

The model features a number of price-setting mechanisms. A standard excess-demand function can be chosen, which changes the price in the next period according to the difference in this period between the quantity placed on the market and the quantity demanded at the current market price; such a mechanism means that, at any one period, the market may not clear. Other mechanisms based on inventory behavior or cost mark-ups or various types of pricing decision-rules by producers can also be selected by the simulator.

6. Other Features

If desired, a futures market can be added to the model so that the demand and supply of commodity futures can influence the current price. In addition, the commodity market can be linked with others so that a complete miniature economy (including a labor market) can be operated. These kinds of experiments, however, become quite costly.

C. Results

Given the fact that an enormous number of experiments were run on the model, it is difficult to summarize the results concisely. Since the model has not been calibrated on actual data, most of the results are in the form of theoretical propositions: Given conditions A, B,...Z, markets will be more unstable (or have higher long run prices, or have longer cycles, etc.) if M occurs, rather than M'. Several examples will have to suffice:

1. Much of the blood spilled by theoretical economists concerning the "best" price anticipations rule has been in vain; none is clearly superior in terms of profits. However, the predominant rule used will strongly influence the stability of the market. (This result was obtained by having all firms but one use a given rule and having the maverick firm use a variety of rules.

2. An increase in risk may lead to an increase (rather than the commonly predicted decrease) of the capital/labor ratio; further, changes in the risk entering in the model by random shocks to the production function or to the demand function greatly differ in the influence on the model with respect to cyclical behavior.

3. Consumer speculation concerning the price has relatively little impact on the results since offsetting behaviors of the production and consumer sides are induced; however, consumer speculation regarding quantities is highly destabilizing.

4. Consumer search behavior greatly influences the perceived elasticity of demand by producers and, in turn, the manner in which they respond. Thus, different search rules by consumers lead to very different aggregate market behaviors.

5. By examining the behavior of inventories and unfilled demand, we can determine in a number of cases whether firms are engaging in cost-plus pricing (in contrast to pricing rules that emphasize excess demand or inventory behavior).

Some of the results of the experiments performed have relevance to policy making. For instance:

a. If one compares the impact of various types of barriers to international trade, e.g., a tariff, a production subsidy, a quantitative restriction, or a variable levy (a sliding scale tariff used extensively by Sweden), each of which has the same static tariff equivalent, one finds that the variable levy leads to the greatest misallocation of resources and, in addition, induces the greatest destabilization of production and trade of the partner nations.

b. Constraints regarding the firing of workers lead to more stabilized markets under most circumstances.

c. Sales taxes have almost no influence on the dynamics of prices.

D. Additional Remarks about the Model

Without calibrating the model to an actual market, one must be extremely cautious in applying any kind of policy results of the model to a real life situation. Nevertheless, the model has proved useful, at least to the author, in generating a number of propositions that can be econometrically tested (many of these are presented in the articles I have submitted for publication) and, equally importantly, clarifying the interrelations of a complex market model, especially with respect to the impact of risk.

GENERAL DISCUSSION

GENERAL DISCUSSION

Under this heading we have entered some of the discussion during the main seminar and notably on the theme of estimation of micro simulation models. In that sense this part of the proceedings has been edited. To organize the lay out we have also rearranged the ordering of comments to obtain a better clustering of themes. Finally each discussant has been given the opportunity to modify and elucidate the preliminary write ups of their statements. Some discussants have also been asked directly to expand on particularly interesting remarks.[1]

The final discussion, summing up the IUI-IBM Sweden Micro Simulation Seminar in Stockholm centered around the following issues:

- What are micro simulation models supposed to be good for?
- For whom are they built?
- How to do it?
  - Ambition/Costs
  - Strategy for building models
  - Estimation
- What minimum Micro/Macro relationships are needed (optimal aggregation)?
- How should a micro unit be specified and described?
- What is the role of expectations and plans in micro models?

EXPECTATIONS

Bergmann: Reading Jim Albrecht's paper, I feel we would like to have expectations included also in our model. But before we can do that, we need to know more about how expectations are formed and used in decision making in actual firms. How cogent is the process to form them, and what methodology has been used to feature expectations in the Swedish model? How much do people trust their own expectations?

Albrecht: In the Swedish model the way firms make up their plans, how expectations enter plans and how plans are realized is modelled on the basis of Eliasson's large study on how more than 60 business firms actually

[1] The editing has been done by Jim Albrecht (University of Columbia), Louise Ahlström (IUI), Gunnar Eliasson (IUI) and Gösta Olavi (IBM Sweden) on the basis of notes taken during the discussion.
All participants in the symposium are listed at the end of this part.

plan. I don't think many model projects have been proceeded by a 6 year pilot study like that. How exactly businessmen interpret their historic environment to envision their future is of course a very difficult task. Albert (Hart) and I have been on it for some time now and we can say that it is difficult to estimate expectations functions on those few expectations data that we have.

Hart: Economists know too little about how businessmen (and households) use ex ante data, and how they form their expectations on the basis of history or ad hoc experiences etc. I think the minimum requirement for a theory (or model) to carry the pretentious label "dynamic" is that ex ante (expectations) and ex post be made explicit and that we allow for the presence of mistakes. One feature of the Swedish model, which I don't see elsewhere, is that it handles decision units (firms). This makes it very natural to enter expectations.

Bergmann: I am wondering whether serious use of expectations is ever very prevalent within the firm.

Eliasson: It depends on what you mean with expectations. Decision makers always interpret their environment before they decide. These interpretations concern the future and are based on the past and the current state of affairs in some sense. Let us call it expectations, even though the decision maker may not be numerically aware of them. I think this is what Albert (Hart) means, and I believe he is very right. The question is whether we can enlighten each other's minds by modelling the mind of the decision maker by introducing in turn a concept that is hardly measurable. I think so, and this is not the first time this happens in economic theory.

Ruist: Maybe we could use methods from the behavioral sciences. I believe economists and econometricians are too introverted in their academic pursuits.

Pryor: The micro simulation technique is well suited to open up an interface to other disciplines such as psychology, sociology, or even politics. I agree with Ruist.

Clower: Expectations add to the complexity of a model with few justifying gains. Another feature often left out of models, and most times for less reason, is an explicit treatment of flow as opposed to stock variables. Since we will seldom be able to measure expectations we might as well drop the concept and connect the history directly with the decision.

Bergmann (supported by *Hart*): There are some areas where expectations are very important, such as firms' investment decisions. How should we handle them empirically?

Hart (on Clower): "The decision" is modelled in terms of a gap between actual and "desired" levels of the stock variable. The desired level is not an observable in the *ex post* data-book, and gets replaced by proxies of Rube Goldberg character. But the *ex ante* data book includes observations of desired levels in the form of capacity-targets 4 years out. To "drop the concept" of expectations is to abandon the observable key variable of investment theory.

ESTIMATION

Bergmann: Large-scale microsimulated models present the builders with two estimation problems:

1) We need computation procedures which search efficiently for parameter values which will optimize our chosen objective function, say the sum of squared errors, and that also fit a normal research budget.

2) We need methods to interpret the parameter estimates stochastically.

I would tend to give item (1) the highest priority. Knowing the stochastic characteristics of an estimator is cold comfort, if you can't compute it. This is one reason. Secondly, I have never been able to give much credence to the confidence intervals computed in ordinary linear models. What do they mean if you know that the proper specification is something entirely different?

Another problem relates to the size of the system. Should we fit the parameters of each piece of a system separately or should we try to fit all of the parameters simultaneously? The former would be analogous to the single equation, ordinary least squares methodology in conventional models; the second would be analogous to a simultaneous equations approach.

Bentzel: To find such routines is certainly an important research task, but I have a feeling that what we need in the first place, is something else. To me it seems necessary to start with forming a firm theoretical base of the estimation procedure and I must say that I have great difficulties seeing how this will be possible without specifying the models in a stochastic manner. If we look at the history of the traditional econometric approach we must admit that an enormous scientific progress was made by the introduction of stochastic model formulations and by the introduction of assumptions concerning the residuals as a theoretical base for the estimation of parameters. Isn't it necessary to go the same way also with the microbased models?

Without a firm theoretical base for our estimation procedure we don't know what we are doing. And we don't know anything about the statistical properties of the estimates. And we don't know anything about the probability properties of the forecasts we are producing. Isn't it absolutely fundamental to have knowledge about these properties? And how can you handle the identification problem if you are not working with stochastic models?

Clower: The first and essential task is to get the assumptions right. That includes much more than getting the parameters numerically right. The ordering of your entire model comes before estimation. How are you going to interpret that stochastically? You enter it as part of your maintained hypothesis instead.

Albrecht: I think it is going a little bit too far by *requiring* that a stochastic interpretation of the parameter estimates be possible. Scientific inference does not restrict us to such a narrow range of possibilities. Literature is full of alternatives. A general requirement, however, is that we know what we are doing and that we are able to tell others how, so that they are able to try it themselves. In the case of micro simulation models this will demand of the others to put in a sizeable mental effort. If the model has got something to tell you, it is, however, worth it. The merit of the conventional econometric approach is that it is quite simple, everywhere taught and well known. I don't believe, however, if you scan applied econometric research that the stochastic side of the method is generally taken by far as seriously as Bentzel demands today of Barbara.

Sørensen: At this conference, too much traditional knowledge has been discarded. Price/volume interactions are still an important part of economics. Empirical production and consumption studies still have a value, etc.

Klevmarken: We aim at an empirical stability of our models, and hence a sound empirical base is needed. Orcutt suggests that we should choose to analyse units such that we could observe the treatment – response mechanism. I suppose that these units may in most cases be the same as the decision making units. I tend to agree, but if you would ask who is treating and who is responding some ambiguities and difficulties to obtain operational definitions will certainly remain. I believe it is true to say that we are still in the beginning of the art of model building. Furthermore, one has to know something about the properties of the observed variables we want to relate in order to obtain stable structures. After all, considering all the efforts put into aggregate studies, we probably know more about the behavior of aggregate variables than about single households, firms etc.

Orcutt: An important advantage of microanalytic modeling is that it permits us to use understanding and relationships which can be subjected to testing at the microlevel to draw implications at the macrolevel. Effective testing of hypotheses about micro-behavioral entities is enormously facilitated by the rapid growth of panel and cross sectional data relating to microunit behavior. The development of computers and computer techniques has made it feasible to effectively use the emerging microunit data base for testing and estimation. These computer-oriented developments have also made it possible to solve and use microanalytic models by means of simulation – Monte Carlo techniques. The most basic long-run impact on economic science of microanalytical modeling will be, in my opinion, on the encouragement given to microunit data collection and their use for hypotheses testing.

Since microanalytic system models do generate implications at the macrolevel, it will continue to be important to do whatever testing is possible at the macro level as well as at intermediate and micro levels.

Bergmann: I don't know what Sørensen means with discarding traditional knowledge. I think we have been very concerned throughout the conference with getting as much empirical knowledge as possible into our models. That knowledge has to be gathered from past research. The point is that when we modify some of the behavioral specifications of the model which the micro simulation technique allows, some *new* properties (results) may emerge. This is indeed very interesting and should teach us something, for instance, that traditional knowledge may be wrong.

Brennecke: There is a need for collecting aspirations and other intangibles, as well as for "hard" data.

THEORETICAL OR EMPIRICAL MODELS?

Bergmann: In my eyes, one interesting aspect of the Swedish MOSES model is the ability to go in and study a few companies from the inside – that is the strength of the model. Its micro units are proper decision units.

Eliasson: Once you find numbers in a model, people seem to think you are doing empirical research in contrast to theory, and vice versa. How valid is a "Numerical example using synthetic data" as empirical work? I think Don Nichols had a quotation of Koopmans with that question phrased as a proposition on the front page of his paper.

With our model, we could say that we gradually move from a very generally specified set of numerical examples (a theory) to an empirical model, as the calibration proceeds. And the micro approach enables us to get very close to the basic behavioral assumptions at the micro level and to measure and assess them without crude and remote methods of econometrics at the macro level. Bob Clower is of course very right. The validity of your model rests on your ability to get the assumptions right, rather than fitting ones model, although – I should add – fitting your model might be one of several indirect checks on your assumptions. What we are doing is investigating the implications of a set of micro assumptions that we think we know. If the implications at the macro level also match observations well it is fine, but the second step in testing. Our particular problem is that we have a few micro parameters that it will take a long time and a lot of effort to measure properly. Until then we will have to do with crude approximations or assumptions.

There is another misconception that I want to rectify. Even if some want to model reality to the level of minute details, and to forecast details, I do not believe that this should be a prime concern of micro based models or any models concerned with the entire macro economy. We should abstain from the impossible ambition to build "All-purpose-models" with all possible detail entered. A good theory or model is based on the basic behavioral relationships that handle the chosen problem, and little more. What we can capture in our micro- macro model is the dynamics of the *market process* at the micro level and how market information signals are interpreted by decision makers. If we desire to understand the *decentralized capitalistic system* at work, I think we have to capture one of its most salient features – *the market.* We believe that the market process is important for macro behavior and especially the interaction over time between prices and activity levels. We are, however, not at all interested in predicting micro or sectoral detail.

Ahlström: I certainly agree that the effort involved in compiling the data bases and (NB!) the reliability and internal consistency of the numbers should be emphasized.

Hart: I think the Swedish model could be a very useful tool in sorting out what is relevant and what is not relevant in received theory – perhaps even better than extensive empirical research, due to the inability to get hold of empirical data. It seems as if this model has a very general specification from micro to macro and contains a number of those disequilibrium features that we consider important today. It also seems to be able to generate any output one may desire, and there seems to be a considerable amount of empirical knowledge built into the model even though we have not yet reached consensus as how to assess that knowledge.

Orcutt: What level of detail? There is no reason why a micro model should be more complex than a model or hypothesis at the macro level. The (micro) *data bank* can be very detailed and complex, still leaving room for a fairly simple model *specification*. I think Eliasson and Bergmann will have difficulties in discriminating between different behavioral theories, if testing is primarily restricted to the macro level. They will meet problems similar to those of multi-collinearities in traditional models. Instead, it is necessary to find a way to do most of the needed testing on the *pieces* of a model, that is to perform the testing at the micro level.

Eliasson: I agree with Guy (Orcutt) there. Perhaps we are criticising each other for what others are doing.

However. Can't we skip that ridiculous distinction between theory and empiricism that we seem to carry around? What is economic theory without empirical knowledge built into it? Nonprofessional mathematics without context, I would say.

Klevmarken: I agree with Professor Orcutt that macro data contain much less information than we would like to have. We sometimes have difficulties to discriminate between models. I have recently completed a comparative study of complete systems of demand functions on aggregate data which showed that different models gave vastly different income and price elasticities but they only showed small differences in fit. I believe this is an experience which is not too uncommon, and it seems to be something we have to reckon with in micro simulation models.

In aggregate studies we badly need all the *a priori* information we can get, for instance of the kind listed in the beginning of Guy Orcutt's paper. In passing I would, however, like to object to the statement that these assumptions would be necessary for a macro study. They are not necessary but sometimes desirable.

Ståhl: What level of detail? More complexity can make a model more realistic, but will make model verification very intricate – big computer programs are bound to contain programming errors. Also, the problems with round-off errors increase when model complexity is increased.

Pryor: Yes, but the micro approach has the advantage that it allows for easy separation of the program into independent modules, which can be verified separately. I think we should try to be clear about whether we talk about the detailed knowledge we put in as assumption or use to test our assumptions on the one hand and the detail we take out as predictions on the other. The first is the important advantage of the microsimulation method, the second is the potential danger we should stay away from.

Brennecke: Different firms, for instance, behave differently. The task in micro simulation is to weigh these behavioral schemes together – a shaky procedure. And how is it possible to test the validity of the result? Common sense judgment will always have to enter into the model predictions in an important way. I think we should accept that as being normal and not necessarily bad and be very explicit about it. Micro simulation models offer unique ways of being very clear about the importance of *a priori* assumptions. Furthermore – don't forget that – this problem is probably as large and more difficult to handle in large scale macro modelling.

OPTIMAL AGGREGATION

Klevmarken: Orcutt suggests that in macro studies we are analysing "unique entities" and that "hypotheses about entities that must be treated as unique are so close to being untestable as to be useless or even dangerous for prediction of policy responses". I share the view that it would probably be useless to try to forecast or test hypotheses about unique entities like for instance one single household or one particular firm. As I understand it this is not the purpose of micro simulation modelling – at least not the Swedish model that I have had the opportunity to look at. I understand that economists have had some difficulties to model the behavior of *the* central bank, and I also distrust attempts to explain for instance the negotiated wage increase which is the outcome of central negotiations with only a few persons involved. We do not have the tools for that in economics and econometrics. We have to be content with studies of group behavior. The best we can hope to do is to say something about distributions of micro units.

Olavi: Does that mean that if we tell our model MOSES to generate a scatter of individual model firm rates of return year 1 on the same rates of return year 5 or 10 (as we have done) and compare them with a similar scatter for real firms, then one could device a test for the models' ability to generate realistic "micro variation" over time?

Klevmarken: That may be another way of saying the same thing. If I may go on with what I was just discussing, I have to admit that I do not quite understand why Guy Orcutt says that macro studies are studies of "unique entities". We do not analyse the treatment and reaction of one dog but the sum of the treatments and reactions of many dogs. It is true that we lose information by the aggregation process, but sometimes it *is* possible to extract useful information from macro data. After having heard the presentation of yesterdays papers, one might say that the criticism for analysing unique entities and treating aggregates as unique entities is more valid for some micro simulation studies.

This brings me to the problem of *optimal* aggregation. There are at least four considerations which might help us to choose the level of aggregation. Let me use the blackboard:

1) The purpose of the study
2) The empirical stability of relationship at different levels of aggregation
3) Considerations of statistical efficiency
4) Considerations of project economy.

Suppose we have a very simple micro model:

(1) $Y_{it} = \alpha_i + \beta_i X_{it} + \epsilon_{it}$; $i=1...n$, $t=1...T$.

If we want to analyse the distribution of *Y* we would probably need each micro relation or at least information about the distribution of the micro parameters but if we want to predict macro behavior we can derive the relation for $\overline{Y}_t$.

(2) $\overline{Y}_t = \overline{\alpha} + \frac{1}{n} \sum ß_i X_{it} + \overline{\epsilon}_t$.

This relation seems to indicate that we need to know all micro X values and all micro ß values to predict $\overline{Y}_t$.

However, this is not so because relation (2) can be rewritten in the following form:

(3) $\overline{Y}_t = \overline{\alpha} + \text{Cov}\ (ß_i X_{it}) + \overline{ß}\overline{X}_t + \overline{\epsilon}_t$.

This relation shows that all we need to know is the average values for Y and X and the covariance of the micro parameters ß and the micro values of X and, furthermore, if this covariance is a constant all we need is macro information. Thus, we do not need the micro relations to predict $\overline{Y}$. Aggregate data are in this sense sufficient. Orcutt may object that the micro relations you are working with are much more complex and cannot be reduced. I would like to ask if you have tried. Some aggregation might help to reduce the dimension of your model. If analytic solutions are difficult to obtain, simulations might trace out the macro relation and suggest a convenient approximation formula. Of course, the simulation approach cannot be used until you have some rough idea of the magnitudes of your macro parameters.

Unfortunately this is not the whole story. The estimates of the macro parameters based on macro data may have large variances and more efficient estimates might be obtained from the micro relations. It depends, for instance, on the interrelation of the micro X variables.

If n is large one might group the micro relations into subgroups and estimate the analog of (2) or (3) for each group. The grouping should be done in such a way that we obtain only a small loss in efficiency and at the same time a protection against specification errors. This was one of Guy Orcutt's major points. He suggested that we should match micro observations with simular characteristics to pairs of observations. One might of course go one step further and group more than two observations.

Eliasson: I am not wholly convinced that (as many have advocated here today) a preferred procedure should be to test the behavior of each micro model module at a time. If we are talking about estimating individual micro unit behavioral relations on micro unit data there is no disagreement. This is one great advantage of the micro-macro modelling approach.

However, with enough dynamic feedback, as we at least have, some modules of the system (like say, the investment financing module) will nevertheless perform oddly at the macro level and you will have to make some adjustments. This is an experience all large scale model builders have. At least in our case we do not think it is practical to isolate one module at a time by "exogenization" and calibrate it. The modules are not "autonomous", and they should not be if you have a realistic model. Our experience is that you cannot make small changes in one module of the system without creating disturbances elsewhere. There definitely is a point in testing the model at the macro level as Barbara also does. The point is that you need a reasonable method to test the whole system simultaneously at that level, since the micro information you have put in (even though of a higher grade than what the macro people use) is still not perfect and so far as a rule quite incomplete.

Bentzel: One question I have to Barbara Bergmann and also to Eliasson and Olavi, who suggest the same thing in their paper on estimation: Why do you use the sum of squares as your loss function? Since you have not formulated your model in stochastic terms you cannot motivate your choice by the combination of normal distribution and maximum likelihood. And what sum of squares are you thinking on? Is it the sum of squares of percentage errors of different variables? If it is, I can't see the rationale for such a loss function. And this question raises another question. Looking at a micro simulation model which simulates simultaneously a number of variables *x, y, z* etc, is it then meaningful to introduce a loss function as some type of function of the errors of the different variables? Isn't it so that such a model is intended to give answers to a number of different questions and that there is a separate loss function associated with each one of these questions? And, more generally, is it really up to the model builder to construct a loss function? Isn't that a task for the users of the model?

Olavi: I think Bentzel has got a point there with our choice of loss function. It is quite arbitrary. We have been traditional.

Bergmann: Bentzel has given us a very wise lecture on what one should do to stick to clean and well received procedure. I have taken note of all and what is not already there will be there in our final text. However, and I think Bentzel's final words are significant, there may be different loss functions for different users of the model. Different recipients of ones wisdom might want different numbers on the same structure or even different models and each problem needs its own tools.

I think we modelbuilders are running the risk of trying to do too much with one model, perhaps. But if there are no good all-purpose-models, as someone phrased it, neither is there one single estimation and inference method.

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MICRO SIMULATION SEMINAR
IBM Nordic Laboratory, Lidingö, Sweden 1977-09-19 to 22

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MICRO SIMULATION SEMINAR

Stockholm September 19-22, 1977

(Original program)

September 19, Monday

Session A
Chairman: R Clower, UCLA, USA

A1	The Transaction Model of the United States	B Bergmann, University of Maryland, USA
A2	Microanalytic Modeling and Simulation	G Orcutt, A Glaser, Yale University, USA
A3	A Microsimulation Model of a National Economy	G Eliasson, IUI, Sweden

September 20, Tuesday

Session B
Chairman: D Nichols, US Department of Labor, USA

B1	Hypothesis Formulation Testing and Estimation	G Orcutt, Yale University, USA
B2	Choices of Strategy in Assigning Parameter Values in a Microsimulated Model	B Bergmann, University of Maryland, USA
B3	Stepwise Parameter Estimation of Micro Simulation Models	G Eliasson, IUI, Sweden G Olavi, IBM, Sweden

September 21, Wednesday

Session C
Chairman: B Bergmann, University of Maryland, USA

C1	The Equilibrium Level of Unemployment: A Simulation	D Nichols, US Department of Labor, USA
C2	Simulating the Distribution of Wealth - a Progress Report	G Orcutt, S Franklin, Yale University, USA J. Smith, Pennsylvania University, USA
C3	How does Inflation Affect Growth - Experiment on the Swedish Model	G Eliasson, IUI, Sweden
	Demonstration of Swedish Model	G Olavi, IBM, Sweden

Session D
Chairman, A Hart, Columbia University, USA

D1	Microanalytic Simulation and the Study of Comparative Economic Systems	F Pryor, Swarthmore College, USA
D2	Expectations, Cyclical Fluctuations and Growth, Experiments on the Swedish Model	J Albrecht, Columbia University, USA

September 22, Thursday

Session E
Chairman: G Orcutt, Yale University, USA

E1	Banks and Financial Intermediaries in the Micro Simulated Transaction Model of the US Economy	R Bennett, University of Maryland, USA

Special Project Reports

E2	A Description of the Aggregation Scheme Used in the Swedish Model	L Ahlström, IUI, Sweden
E3	The Sociopolitical Decision and Indicator System for the Federal Republic of Germany; A Review	R Brennecke, Frankfurt, W Germany
E4	The Computer Aided Planning System for the German Federal Student-aid PROGRAM	D Bungers, GMD, Bonn, W Germany
E5	Estimating the Rate of Technological Growth in the Swedish Model	B Carlsson, IUI, Sweden G Olavi, IBM, Sweden
E6	MICS- A Micro Simulation Model for Wage-earner Households	Ch Sørensen, Allerød, Denmark
E7	Computerisation of Micro Founded Macro Econometric Models	E Yndgaard, Aarhus, Denmark
E8	General Discussion	

End of program

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1980

Micro Simulation – Models, Methods and Applications (eds. B. Bergmann, G. Eliasson, G. Orcutt). IUI Conference Reports 1980:1. 409 pp.

Generalised Farrell Measures of Efficiency. An Application to Milk Processing in Swedish Dairy Plants. Finn R. Førsund and Lennart Hjalmarsson. Booklet No. 105. 22 pp.

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A Comparative Study of Complete Systems of Demand Functions. Anders Klevmarken. Booklet No. 101. 27 pp.

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Industrins utlandsproduktion och export (Foreign Manufacturing and Exports). Birgitta Swedenborg. Booklet No. 102. 41 pp.

Utrikeshandel, inflation och arbetsmarknad (Foreign Trade, Inflation and the Labor Market). Special Studies for the IUI Medium-Term Survey 1979. Vol. 1. B. Axell, S. Gustafsson, B. Holmlund, E. Ch. Horwitz. 199 pp.

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