

A Microsimulated Transactions Model of the United States Economy

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Chapter 1. Introduction

All analyses by economists of the determinants of macroeconomic magnitudes—aggregate output, average price levels, unemployment rates—have to some extent been based on purported descriptions of the behavior of individual decisionmakers and descriptions of their interactions. Formally speaking, however, the conventional macroeconomic models we have known, from the early work of Klein and Goldberger down to the present models of Klein, Eckstein, Evans, Almon, and others, consist of collections of macroeconomic equations; in each such equation, one macroeconomic magnitude is dependent on other macroeconomic magnitudes (Klein and Goldberger 1955; Duesenberry et al. 1965; Evans 1969; Almon 1965). Descriptions of individual behavior do figure in the making of those models—they influence which macroequations are chosen and the variables that appear in each. However, there is little or no place in the traditional macroequations for the formal incorporation of any qualitative description of individual or institutional behavior.

The research effort laid out in this book represents an attempt to move away from macroeconomics through macroequations; it attempts to integrate the description of individuals' and firms' behavior more closely into the formal structure of a model that is macroeconomic mainly in the sense that its purpose is the determination of aggregates. The model we present here is microsimulated—it consists entirely of explicit descriptions of decisionmaking and the consequent actions and interactions of individual decisionmakers. The model's action on the macroeconomic level is made completely consistent with the action on the microeconomic level, since the macro derives exactly from the micro. This is accomplished by adding the microeconomic results into the macroeconomic results numerically, by computer.

The introduction into economics of the basic idea on which our model

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is based is due to Guy Orcutt (1960, 1976). He and economists working with him have pioneered the construction of models of the household sector in which groups of representative individuals and families are delineated as following certain postulated behavior rules. Models of the type introduced by Orcutt have been used extensively by the federal government of the United States to characterize the first-round results of government policies having direct impact on the household sector. They have been particularly useful in gauging the distributional effects of such policies, as well as their effects on aggregates such as total labor force and population size. A methodologically similar research effort is the analysis of the structure of the personal income tax by Joseph Pechman and Benjamin Okner (1974). Their work depicts individual families paying taxes according to historic or hypothetical versions of the federal income-tax code and has been used to study the effects of tax-code changes on total revenues and on the distribution of tax liabilities among taxpayers.

Other pioneers of microsimulation methodology include Frederic L. Pryor (1973) and Alan S. Blinder (1974), who utilized it to study the mechanics of income distribution. Ray Fair (1974) has the distinction of being the first to apply such methods to macroeconomic issues. Irma Adelman and Sherman Robinson (1978) microsimulated production, price formation, and income distribution in a developing economy. Donald A. Nichols (1980) has used microsimulation to study the unemployment/inflation nexus. The behavior of firms with respect to competition and innovation and the consequences of that behavior for long-run growth have been studied with microsimulation methods by Richard R. Nelson, Sydney G. Winter, and Herbert L. Schuette (1976) and Richard R. Nelson and Sydney G. Winter (1982).

Our microsimulation work is closest in form to that of groups led by Orcutt and that of Pechman and Okner. However, their work has been restricted to one major sector of the economy—the household sector. Our work (and the contemporaneous work of Gunnar Eliasson [1976] in Sweden) also microsimulates the household sector but extends the methodology to the business and government sectors. This results in a model that can be used to study the effects of policies whose primary impact is on business firms. It can also be used to investigate the full effects (as opposed to just the primary impact) of any policy, as those effects are passed back and forth from sector to sector. The unique advantage of the microsimulation methodology—the ability it gives the analyst to characterize government policies in a way that reflects their essential features—is thus extended and developed in our model, which we characterize as the Transactions Model, to highlight the level at which activities are represented. In this book, the aptness of the model for policy studies is displayed by applications to two subjects: the fiscal and monetary effects of the issuance of indexed bonds

and the employment and productivity effects of changes in the scheduled hours of work.

Major Features of the Transactions Model

The behavior represented in the Transactions Model is the familiar repertoire on which macroeconomists have traditionally focused—consumption, saving, money holding, financial-asset acquisition, real investment, production, employment, wage setting, price setting, and interest-rate setting. This model differs from conventional models in the methodology of representing the behaviors. Major features of the model are:

1. The decisionmakers whose behavior is simulated in the model are ten firms who among them produce the economy's goods and nonfinancial services; a bank; a financial intermediary; a federal government; a state/local government; a monetary authority; and 700-plus employed and unemployed workers who are members of households that consume and that hold assets.
2. Each individual decisionmaker's experience and situation in the simulated economy are kept track of and enter into the decisionmaking process. On the occasion of any action on the microeconomic level (such as a transaction), the variables that record the situation of the individuals involved in it are changed appropriately. For example, making a purchase for cash results in a reduced money balance recorded in the computer for the purchaser, whereas taking a loan results in an increased money balance recorded for the borrower.
3. The interaction of individual decisionmakers 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. The events treated as transactions in the model, in addition to purchases of the output of the firms, include loans, amortization of loans, payment of taxes, payment of interest, payment of wages, and transfer payments.
4. Each time a transaction occurs, the effect of that transaction on all simulated macroeconomic variables—nominal GNP accounts, flow-of-funds accounts, price indexes, and so on—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. The use of an unchanging, multiplicative scale factor brings the macroeconomic output up to the scale of the U.S. economy.

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5. The model operates on the assumption that all decisions controlling behavior are made once a week, on the basis of the position of the decisionmaker at the time of the decision. The model is thus completely recursive; there is no simultaneity. Although the microeconomic behavior underlying aggregate variables is taken to be adjusted weekly by the decisionmakers, each simulated aggregate is accumulated for the time interval for which the corresponding U.S. data series is available: monthly for employment and unemployment, and quarterly for the components of the national income accounts and the flow-of-funds accounts.
6. Economic data for the United States have been used to construct the data base for the model and to fit the parameters of behavioral rules specified for the actors in the model.

Ideally, the novel form of the Transactions Model should be matched with appropriate novelties in econometric methodology. We cannot pretend that we have, at this writing, advanced very far in the development of techniques for parameter estimation especially suitable to models of this type. We have used macroeconomic data almost exclusively. For some of the behavioral equations, we have adapted a simple version of the iterative-search techniques used to simulate engineering problems. For others, where it seemed to give a reasonable result, we have, with some reluctance, used the standard techniques for dealing with parameter estimation in conventional macroeconomic models—fitting macroequations and translating the result onto the microeconomic level.

Data Bases for the Transactions Model

Microsimulation models of the Orcutt or Pechman/Okner type use samples of actual households and apply the behavior patterns they postulate to the individuals in the sample. Such a sample serves as the data base of the simulation. The information about the characteristics of each individual contained in the data base is used to determine, in part, the nature of the simulated behavior and the nature of the simulated outcome for that individual. For example, in Orcutt's model, a person's age, marital status, sex, and number and ages of children affect that person's labor-force participation. In the Pechman/Okner model, a person's marital status affects the basis on which taxes are figured.

In the Transactions Model, the data base for households has been constructed out of microdata from the Bureau of Labor Statistics' Consumer Expenditure Survey (CES) of 1972–73. These data contain information about income from financial assets by type, and from them we have estimated a portfolio of assets for the year of the CES for each of the households

into which the simulated individuals are collected. The CES also contains information about labor-force participation, marital status, car ownership, home ownership, and occupation.

An analogous procedure is, in principle at least, available for firms. Information on the income accounts and balance sheets of large and medium-sized firms is publicly available in the United States, and a sample of actual firms might thus have been used as a data base for the business sector. In constructing the business sector of the Transactions Model, however, it became apparent that constraints on computer time and real time made it desirable to keep the number of firms, in this initial version at least, quite small. We needed to retain a large number of items of information about the current and past position of each firm, many more than were retained for each labor-force member. This reflects the fact that the repertoire of behavior of the firm is considerably more extensive and complex than that of the individual. (Over 300 words of information are stored concerning each firm, and only twenty seven-words for each labor-force member.) In the version of the model presented here, we have represented only twelve firms. Obviously, no set of twelve U.S. firms drawn randomly or selected in any other way could be representative of the business sector of the U.S. economy.

A second consideration, which would have operated even had the number of simulated firms been considerably larger, was the desirability of representing the flows of particular product groups between firms, from firms to households, and from firms to governments. We wanted to distinguish flows of vehicles, other manufactured durables, manufactured nondurables, agriculture, mineral extraction, banking services, capital-intensive services, and other services. This consideration suggested that the most appropriate decisionmaking unit for the business sector of the Transactions Model is the business establishment (a production site devoted to a particular type of product) rather than a business firm (not infrequently a conglomerate of establishments producing a wide variety of products). Nevertheless, we use the term *firm* to indicate these businesses.

Each firm in the Transactions Model is constructed with characteristics representative of a particular industry group in its input/output relations, age distribution, size and characteristics of its capital stock, debt and asset structure, cost structure, and profit margin. We set the characteristics of these representative firms by using data in the national income and product accounts and flow-of-funds accounts of the United States. For example, for the firm representative of nondurable manufacturing, the time series of investment in capital equipment by nondurable manufacturing establishments was used to construct the characteristics and age distribution of the stock of producing equipment.

In one important respect, the Transactions Model's firms are not at all representative of actual establishments. The size of each simulated firm (the

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value of its output, size of its labor force, and so on) is governed by the aggregate size of the corresponding U.S. industry, rather than by the size of individual establishments in that industry. Thus an industry consisting of relatively small establishments (the “other services” industry, for example, which includes law firms; or the “trade” industry, which includes retail stores) is represented in the model by a firm that may be as large as the firm representing automobile manufacturing.

The one-firm-per-industry method of representing the business sector obviously poses limitations on the kinds of problems that can be studied with the Transactions Model in the form we present it here. Applications in which competition among firms in an industry and the distribution of an industry’s business activity among its firms are of crucial concern could not be fruitfully made. Nevertheless, the treatment of the firm in the Transactions Model, despite the synthetic construction of the business-sector data base, does offer certain considerable advantages over conventional macroeconomic models, even over those that give detailed treatment to input/output relationships among industries. Among other things, each firm in the model has the ability to remember its debts and pay interest on them, to reflect the acquisition of cost-saving equipment in its pricing decision, and to examine the age distribution and productivity of its currently owned capital equipment when making investment decisions. Representation of such processes gives us the possibility of studying in a realistic framework a wide variety of government policies that impinge on firms’ decisionmaking, operations, and environment.

Decisionmaking and Its Consequences in the Transactions Model

Most economists who specialize in microeconomics construct theories of behavior that have as their mainspring the attempt at maximization of some quantity—utility in the case of the consumer, profit in the case of the business firm. Many macroeconomists have been rather looser in their descriptions of individual behavior, tending simply to postulate the direction of individuals’ reactions to changes in their economic environment, frequently without recourse to rigorous maximization modeling. A microsimulated model, such as the one presented here, would seem to be an ideal vehicle for the incorporation of the virtues of microeconomic theory into macroeconomics. This is the tack taken in the simulation work of Ray Fair, who has created a model representing one firm and one consumer/worker, in which both actors decide on their upcoming behavior by solving optimal-control problems.

Unlike Fair, we have not embedded maximization submodels into the structure of the Transactions Model. In general, our actors use rather simple

rules of thumb in deciding what to do, although of course these rules take account of conditions the actors face in ways that previously developed maximization models might certainly suggest. While we would not wish to argue that a macroeconomic model based on microtheoretic methods is not a worthwhile objective, our efforts have been directed toward different goals.

One of our aims has been the development of a more exact and faithful accounting and depiction of what might be characterized as the semi-automatic consequences of behavioral decisions. To take an example, a decision to borrow and a decision to lend result in a loan, and from these decisions a considerable number of consequences come about. The loan takes the form of a flow of funds from the lender to the borrower. Later flows of funds to take care of interest and amortization occur; the rated capacity of the borrower for future borrowings and the capacity of the lender to make further loans change; the flow of goods and services financed by the proceeds of the loan occurs; the future income of the lender is affected. None of these consequences requires any decisionmaking complex enough to attract the interest of economic theorists, yet they are all of considerable practical importance. In the Transactions Model, we handily represent all of these consequences as occurring, and the effects of these consequences on future decisions and future behavior can be allowed for.

Over 90 percent of the computer code in which the Transactions Model is written depicts interactions between decisionmakers that follow on decisions. One commentator on our work has characterized this elaboration of the consequences of decisionmaking as an emphasis on accounting, albeit in a rather expanded sense of that word. A somewhat more sympathetic way of putting the same idea is that we have paid a great deal of detailed attention to the kinds of behavioral activity that in most macroeconomic models are taken care of in a cursory way under the heading of accounting identities—or are not taken care of at all. We have elaborated our treatment of the consequences of decisionmaking in the belief that a careful accounting for and depiction of these kinds of behavioral activity brings important advantages. Such an accounting improves the clarity of our understanding of economic processes and illuminates the process whereby the effects of exogenous shocks and policy changes are transmitted from one sector of the economy to the others.

A second goal to which we have directed our efforts in designing the Transactions Model is to provide a framework within which policies can be represented with a degree of realism greater than is possible in conventional macroeconomic models. The characterization in microsimulation models of the actors as individuals, each with a recorded history, represents a considerable increase in our ability to make realistic representations of policies, as experience with models of the Orcutt and Pechman/Okner variety has shown. For example, in the Transactions Model we have the

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capability to represent an excess-profits tax, with the definition of excess based on price changes, cost changes, profit changes, or any combination thereof. Or we can represent a subsidy program under which firms are rewarded for hiring workers who have had a spell of more than, say, twelve weeks of unemployment, because the computer can maintain a memory of how long each unemployed person has been unemployed. It can also remember how long each employed person has been with his or her present employer, so that a time limit on benefits to the employee can be incorporated if desired. To take another example, a change in the model's tax code in the direction of allowing for more accelerated depreciation directly affects the cash flow of our firms. Furthermore, the prospect that investment in a piece of equipment carries with it a delay in taxes paid out of profit can easily be made to affect the simulated firm's decision as to whether to purchase that piece of equipment. All that is required is that a subroutine be created in which the firm figures the present value of the interest-free loan from the government and subtracts this from the cost of the equipment.

The policy studies with the Transactions Model, which appear in the last chapter, have been chosen not only for their intrinsic interest but also to display the model's special capabilities in representing policies and their implementation.

Simultaneity in the Actual Economy and the Simulated Economy

Analyses of the macroeconomy traditionally represent the economy by simultaneous equations. Originally, simultaneous-equations formulations were developed to describe 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 that are so long that the actors must react more than once in a data period to actions of others in the same period. Within a calendar quarter, for example, there is time for a fall in production, a resulting reduction in consumption, and the reaction to this of production. The simultaneous solution of behavioral equations that specify such reactions purports to represent the stable

situation, after all of these actions and reactions have taken place and behavior has settled into a pattern in which all actions are mutually consistent (in the sense that no decisionmaker wishes to act differently, given everyone else's behavior). If we were to think concretely (perhaps, some might say, to the point of mistaken concreteness) of what kind of economic system might be exactly represented by an empirical, quarterly simultaneous-equations model, it would be an economy where law requires that a *tatonnement* take place before business hours on the first day of each quarter and 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 provides 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 during it. We represent each calendar quarter as being made up of twelve 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 operating 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 intraperiod reactions) frees us to postulate realistic behavior rules (if we know any) without having to worry that the mathematics of the solution process will be too difficult. As noted above, in the present version of the model, we have not used this freedom to go beyond our macroeconomist predecessors in the elaboration of the decisionmaking process but only in the elaboration of the practical consequences of the decisions.

The one form of simultaneity actually observed in economic life is, of course, the coincidence in time of economic events—many acts of production, consumption, and exchange 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 that 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 the implausibility of representing activities that are continuous in the real world by action concentrated at particular instants.

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In the operation of the Transactions Model, the ability of an actor to carry out a decision is usually not affected by whether that actor is first or last in line to implement the decision, since in the real world and in the simulated world that mimics it, there is usually ample excess capacity. In the rare case of temporary shortages, however, the ability of individuals to carry out decisions is 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.

Treatment of Expectations

A simulation model provides an excellent opportunity for the incorporation of material on expectations. In the context of such a model, it is relatively easy to represent individual actors as forming expectations concerning future economic environments by any method thought to be a realistic representation of how decisionmakers actually do form them—by taking moving averages, by using Box/Jenkins (1976) extrapolation methods, or even by formulating, fitting, and forecasting with a conventional macro-model of considerable complexity. The simulation model can also show how the actors react to the expectations they form—it can present an elaboration of how expectations affect the actors' decisions.

The reader may well judge that in building the present version of the Transactions Model we have taken rather scant advantage of these opportunities for dealing with expectations. Expectations of the future are shown in the model as entering only into those of our actors' decisions from which considerable damage is possible if the future is very different from the present.¹ Most decisions in the model, such as those having to do with what price to charge, how much to produce, or which job to accept, are relatively easily compensated for in the short run and thus can be made on the assumption that things will remain much as they are at the moment of decision. If this expectation proves false, new decisions, which repair the situation without much damage, can usually be made and implemented.

We have represented the formation and use of expectations by the actors in two areas of decisionmaking: one is the investment by firms in new capital equipment, and the other is the adjustment by firms and households of their portfolios of financial assets. In the case of real investment, firms make simple forecasts of their near-term future output. They then use these forecasts to decide whether to produce the forecasted output on their currently owned equipment or to produce some of it on newly acquired equipment. Output forecasts are made in the present version by a moving-average

method. In the case of portfolio adjustment, the actors are made to favor long-term bonds over shorter-term bonds to a greater extent when they forecast that future long-term interest rates will be lower than they currently are. They make such forecasts when current long-term rates are higher than a moving average of past rates.

At this point, it is worth emphasizing that any piece of decisionmaking machinery currently in the model can easily be entirely replaced by another piece of machinery that 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 solution processes. Since individual components of the model may be replaced with great ease by very different ones, the present version of the model should be seen as a collection of hypothesized decision rules—many of which are by no means novel—assembled by means of a framework for which we claim considerable novelty. This framework would serve equally well for the assembly of a set of decision rules with different elements, elements perhaps more to the taste of the reader than those the authors have included in the present version. It is for the framework itself, rather than the details of any particular items of hypothesized behavior, that we claim the reader's attention and interest.

Chapter 2. Framework of the Transactions Model

In this chapter, we give summary descriptions of the actors represented in the Transactions Model, the commodities they produce and trade, and the financial assets they hold and exchange. We also give a brief account of the repertoire of behavior they are programmed to follow.

The Scale

The Transactions Model represents the U.S. economy by a simulated economy—one that is, of course, much smaller in scale than the actual. In any run of the model, whatever the historic calendar date taken to be the start of that run, the model's labor force starts out at 675 persons. A scale factor is used in each run to convert the output of the model's labor force (in conjunction of course, with the model's capital stock) into an output on the scale of that produced by the U.S. labor force:

$$\text{SCALE} = \frac{\text{historic size of U.S. labor force at starting period of run}}{675}$$

For example, for a run of the model with a starting period of January 1973, when the U.S. economy had 88.1 million persons in its labor force, the scale factor would be 130,519:1. The scale factor set at the beginning of a run holds throughout the run for physical production, physical capital, and financial stocks and flows, as well as for employment, unemployment, and labor force. In the course of a run, the size of the labor force and the pace of activity change as it tracks the historic course of the actual economy, but the scale does not change. It is as though we were studying actual railways by operating model railways and used HO scale for some runs and X scale for

Table 2.1. Characteristics of labor force, by occupational group (end of 1979)

Characteristic	Managers and Professionals	Clerks and Salespersons	Craft Workers and Operatives	Service Workers and Laborers ^a
Number employed	179	168	188	140
Number unemployed	3	7	12	10
Average weekly wage of employed (dollars)	391	240	324	175
Average value of assets (dollars) ^b	48,158	20,622	15,740	28,020
Proportion female	.27	.61	.20	.45
Proportion married	.67	.71	.59	.59
Proportion homeowners ^b	.63	.64	.67	.61

^aIncludes farm owners and operators.^bFor married persons in different occupations, half of assets and homeownership is allocated to each occupational group.

other runs, adding or subtracting boxcars and tracks of the appropriate scale in the course of a run to represent growth and shrinkage of the system.

The Individuals

An individual in the simulated economy takes the form of an identification number and a vector of numbers in the computer memory, which represents information about his or her characteristics and economic situation. Labor-force members belong to one of four broad occupational groups, whose size and average attributes are shown in table 2.1. Persons not in the U.S. labor force who are in households that do include labor-force members are not directly represented in the model; consumer expenditures are made and assets are held by the household's labor-force members on their behalf. People not in the labor force who have financial assets are represented as individuals.¹ Households with no labor-force members and without financial assets are represented only as a group and receive transfer payments, which they use exclusively for purchasing consumer goods and services.

Labor-force members are differentiated by sex and marital status. An individual may be marked as the spouse of another individual in the labor force; their incomes and assets are treated as pooled, and their savings, consumptions, and asset management are determined jointly. Home ownership and car ownership are kept track of. On average, in the simulated

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economy as in the real one, members of the better-paid occupational groups have lower probability of unemployment, pay a higher average rate of personal taxes, have more assets, and obtain more income from assets. (In the current version of the model, age, educational attainment, and the number of household members apart from spouses are not explicitly represented.)

The number of persons represented as entering the labor force is influenced by the unemployment rate. The unemployed search for jobs by being available for random selection as a candidate when an employing firm seeks a worker in a particular occupational group. Their acceptance of a job may be affected by their eligibility for unemployment-insurance payments. A worker newly entering the labor force may apply for a job in any occupational group, subject to quotas that differ by sex. He or she ordinarily retains the occupational identity of the first job. A worker experienced in one occupation is allowed to become a candidate for an opening in another occupation only in times of shortages in the latter occupation.

After receiving their incomes, negotiating consumption loans, paying their taxes, and making payments on previous loans, households follow a Stone/Geary linear-expenditure system. Although all 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, they compare rates of return of the various available assets and vary the mix of assets they hold according to relative rates of return. The size of the portfolio each household has to manage at any point in a run of the model depends on the assets assigned to it at the beginning of the run and on the sum of previous savings decisions.

The Firms

Private production of goods and nonfinancial services in the simulated economy is divided into ten firms, each of which represents a U.S. industry group. In addition, there are a bank and a financial intermediary which are set up as service-producing firms but which also maintain the actors' financial accounts and set interest rates. Table 2.2 lists these firms and their contributions to various aggregates.

For each run of the model, a physical unit of output of each firm is defined as the amount of its product that could have been bought in the starting period with one dollar. Physical units of capital goods, called machines, are also defined for each run of the model on a physical basis. A machine is specialized to the firm in which it is used and is defined as a bundle of the outputs of up to eight of the twelve firms (see table 2.2). The machine bundle is scaled in physical units so as to cost one dollar in the starting period. The physical quantities of the goods that make up a machine

Table 2.2. Firms and their employment and output (starting January 1980)

ID Number	Firm	Employment		Share of Output Value	Share of Machine for Firm 5
		White Collar	Blue Collar		
1	Agriculture	0	19	0.057	0.000
2	Mining	1	4	0.037	0.000
3	Construction	7	28	0.063	0.244
4	Automobile manufacturing	1	3	0.029	0.086
	Other durable				
5	manufacturing	24	52	0.177	0.600
6	Nondurable manufacturing	16	35	0.184	0.000
7	Capital-intensive services	9	23	0.096	0.006
8	Trade	85	56	0.113	0.062
9	Other services	86	50	0.162	0.002
10	Real estate	6	0	0.046	0.000
11	Financial intermediary	16	1	0.028	0.000
12	Bank	8	0	0.008	0.000

NOTE: Agriculture represents farming, forestry, and fisheries; mining represents all extractive industries; capital-intensive services represent transportation, communications, electric, gas, and sanitary services; real estate includes sales and rentals of dwelling units.

used by a particular firm are assumed not to change through time, although the cost of buying a new machine changes as output prices charged by the firms producing parts of the machine bundle change. The capital-goods setup of the model may be characterized as “clay-clay” (see Wonnacott [1978, 456–57]). A firm cannot choose among varieties of capital goods; it must buy the capital goods (appropriate for its type of output) currently on sale. Each machine is assumed to be born with a particular labor requirement and a particular rated output. A machine lasts fifteen years, and its operating characteristics improve over its lifetime, as a result of “disembodied” technical change—more educated workers and improved workplace organization.

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 units from older vintages. Typically, a new machine gives more output in a standard workweek and requires fewer workers for the production of its rated output than machines produced in the preceeding period. The rates of change of the output capabilities and labor-input requirements of newly produced machines of successive vintages are among the basic parameters of the model, since they are an important component of productivity change.

Purchases by each firm of the outputs of others as noncapital inputs to current production (flow inputs) are governed by the 1972 input/output

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table, and are taken to be unchanging over the time period of the simulation and to be unaffected by capital-goods purchases.

Firms have U-shaped, short-run average cost curves for two familiar reasons: the presence of substantial fixed costs and a rising marginal cost. Larger outputs cause the firm to bring into production successively older vintages of capital goods with smaller output/labor ratios. A firm's cost curve shifts whenever the prices of labor and flow inputs change; it also shifts when investment results in the acquisition of new capital goods, which are more labor saving than the best of the old capital stock.

Firms set prices in the course 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 a moving average of sales. They set desired employment by a lagged adjustment to production, making adjustments in weekly hours to achieve man-hour targets for the current week. Their portfolio management and borrowing activities depend on their cash inflow from sales, cash outflow for purchases and dividend payments, and investment plans. Like consumers, they are sensitive to current and expected relative rates of return when choosing the form in which to hold their financial assets. In making decisions about investment in capital goods, firms forecast future sales and consider the costs of operation of their older equipment, the purchase price and operation cost of newly available equipment, and the cost of the funds to finance the purchase.

The Financial Institutions

Two of the firms, the bank and the financial intermediary, have the special function of providing financial services to the other actors. At the end of each round they set the interest rates that will apply to newly issued debt in the subsequent round.

The bank gives bank loans on request to all of the nongovernment actors, up to a limit on outstanding stock of loans for each actor. All of the cash held by the actors is a liability of the bank (as are all the savings deposits), and cash is created by payments from the bank to other actors and is destroyed by the reverse. The bank must observe reserve requirements, and it changes interest rates on new bank loans in accordance with its reserve position. Among its assets, the bank holds mortgages, government bills and bonds, and loan instruments.

The financial intermediary makes a market in open-market securities (such as treasury bills, treasury bonds, and private securities) by buying all that it is offered and making all requested sales. It raises interest rates on newly issued securities when the supply exceeds demand enough that the size of its holdings increases above that which it wishes to hold; it lowers

interest rates in the opposite case. It adjusts prices of previously issued securities to accord with the current interest rates.

The Governmental Entities

Three actors in the model represent the government sector: a federal government, a state/local government, and a monetary authority.

The federal government collects personal income taxes each round from the households by setting rules for exempted income and applying a schedule of marginal rates to nonexempted income. It also collects excise, corporate-profits, and payroll taxes. It employs some of the labor force, makes purchases from the firms, and makes unemployment-insurance payments and other transfer payments. When it runs a deficit, it issues new bonds and bills, which are sold for cash to the financial intermediary, through which they are sold to the other actors. Bills and bonds coming due are paid off or rolled over. The operation of the state/local government is similar to that of the federal government, with some differences in function and in scale.

The monetary authority conducts open-market operations by transactions with the financial intermediary. It sets a reserve ratio and a maximum interest rate for savings accounts. It also influences the amount of the bank's discounting by setting a discount rate.

The Rest-of-World

The rest-of-world sector is depicted in the model as a firm that purchases exports from U.S. firms and sells imports to U.S. firms and households. It holds a portfolio of claims on the U.S. firms and governments and issues liabilities and equities held by U.S. firms and households. This sector does not directly employ any labor. It sells to the other actors from an unconstrained inventory of specific commodities and financial assets at prices and quantities set exogenously. Its purchases from U.S. firms are at exogenously determined quantities but endogenously determined prices.

In addition to these transactions in goods and services, the rest-of-world receives transfers from the federal government in the amount indicated in the national accounts. It makes payments to the bank and the financial intermediary for interest on its debt obligations and receives interest on its portfolio, in amounts consistent with the net values of interest and dividends from the national accounts. The rest-of-world also receives payment from and makes payment to the monetary authority for the authority's purchases or sales of foreign exchange, which are set at the level

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indicated in the flow-of-funds accounts. Holdings of financial assets and issues of financial liabilities by the rest-of-world are forced to conform with the flow-of-funds accounts.

Running the Model

Each run of the model is done for a particular reason or set of reasons: projecting into the future or rerunning the past with policies or conditions different from those actually in force. The purpose of each run, of course, governs the detailed form of the run, but the general outline is similar for all runs.

A run of a conventional macroeconomic model requires that values for macroeconomic variables appearing in lagged form in any of the model's equations be supplied as initial conditions. Setting up the initial conditions for a run of the Transactions Model is a considerably more demanding task, requiring that each actor be assigned values for those variables that will underlie his or her first round of decisions. At the start of each run, firms are supplied with (1) initial values of capital stock, distributed by vintage, (2) inventories of stocks of their own and other firms' goods, (3) initial prices, and (4) financial assets and liabilities of various types and maturities. Workers are supplied with (1) the identity of their employer, if employed, (2) the length of their spell of unemployment, if unemployed, (3) assets, (4) liabilities, (5) recent level of expenditures, (6) sex, (7) marital status, and (8) the identity of the spouse if married.

As in a macromodel, the initial conditions for a run of the Transactions Model depend on the historic period chosen for the starting period. An account of the methodology of creating initial conditions is given in the next chapter, where the use of data both for setting initial conditions and for parameter estimation is considered in detail.

Once the initial microconditions have been set up, the actors are programmed to go through their behavioral routines in a fixed sequence. Twelve times each calendar quarter, a round of microeconomic events occurs—the actors go through the entire repertoire of decisions or activities in the regularly scheduled order of table 2.3 (the chapter in which it is detailed follows each event).

A decision at one step influences events later in the round; for example, wage-setting decisions influence household expenditures for goods and services, which in turn influence the demand for financial assets.

The round starts with a decision by each firm on how much of its product it prefers to produce. The decision is based on its inventory position and on sales in the recent past. The firm then decides how many people it wants to lay off or hire and tries to carry out these decisions by interviewing unemployed workers. The number of workers aboard and the distribution of

Table 2.3. Sequence of events in a round

Event	Chapters In Which Event Is Described In Detail
1. Firms make tentative production decisions.	4
2. Firms make decisions on hiring and weekly hours.	4
3. Workers are laid off or quit; firms and governments search for workers to hire; workers search for jobs; workers are hired.	4
4. Firms set wage rates for each occupation.	4
5. Production occurs, affecting firms' inventories.	4
6. Firms compute cost, profits, and taxes owed.	4
7. Each firm sets price for its product.	4
8. Firms purchase flow inputs from other firms.	4
9. Firms pay taxes to governments.	4,5
10. Firms make investment decisions and purchase capital goods.	4
11. Real-estate firm makes decision concerning housing stock.	4
12. Events which give rise to imputed items in GNP but no flow of funds.	5,6
13. Firms and governments pay wages	5
14. Government makes transfer payments to unemployed.	5,7
15. Some households receive property income.	5
16. Households pay income and social security taxes to government.	5,7
17. Households make payments on mortgages and bank loans.	5,6
18. Households make decisions about home and car ownership.	5
19. Households make consumption decisions and purchase goods and services.	5
20. Households make portfolio-management decisions and take action on them.	5
21. Government purchases goods and services from firms.	7
22. Rest-of-world sells to and purchases from firms.	4
23. Government makes debt-management decisions and takes action.	6,7
24. Nonfinancial firms make finance and liquidity decisions and take consequent actions.	4
25. Financial intermediary adjusts cash position.	6
26. Monetary authority makes decisions and takes action on open market.	7
27. Bank reacts to reserve position: sets loan policy; discounts with monetary authority; sells or buys open-market securities.	6
28. Financial intermediary readjusts cash position.	6
29. Bank sets current interest rates for consumer loans, business loans, mortgages, and savings accounts.	6
30. Financial intermediary sets current bill and bond rate.	6
31. Government and nonfinancial firms pay interest on existing obligations at original rate to financial intermediary; firms pay dividends.	4,5
32. Financial intermediary pays interest to nonfinancial firms on their holdings of bonds and bills.	6

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the firm's capital stock by vintage determine the amount produced. At this point, production occurs in the form of a drawdown of the firm's inventories of material inputs and an increase in its inventory of its own output. Wage and price decisions by the firm follow, and it replenishes its materials inventories by purchases from other firms. The firm pays taxes, makes investment decisions, and receives lagged shipments of previously ordered capital goods from those firms whose products constitute parts of the machine bundle.

In the next sequence of events, household members receive wages and property and transfer income, pay taxes, and make interest and amortization payments on their outstanding debts. They then make their decisions on consumption, in the course of which they may increase or decrease their outstanding debt. At this point, they adjust the composition of their assets portfolios, transferring funds between cash and savings accounts and buying or selling securities.

Next, the federal and state/local governments purchase goods and services from the firms. (Government payments of wages to its own employees occurred in step 13, while interest payments by governments on their outstanding debts occur in step 31.)

The rest of the activity in the round is taken up by an assortment of financial dealings and decisions. The governments issue bills and bonds to take care of deficits and rollovers and allocate their financial assets among cash and open-market securities. The monetary authority 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. It sets the discount rate, the maximum savings-account rate, and the reserve ratio. Next, the commercial bank calculates its excess or deficient reserves and makes its decisions to discount and to increase or decrease its holdings of open-market securities. It has made loans at interest rates announced at the end of the last round, and its loan inventory may have undergone (within limits) involuntary changes that reflect excess loan demand at current rates. On the basis of the sign and magnitude of the excess demands for bank loans, the bank adjusts the savings-account rate, the business-loan rate, and the consumer-loan rate.

At this point in the round, all portfolios have been adjusted, with the exception of the portfolio of the financial intermediary. The latter makes the market in open-market securities, having purchased or sold all that were offered or demanded at yields announced at the beginning of the round. On the basis of excess demand or supply for open-market securities, it adjusts rates for treasury bills, treasury bonds, state and local bonds, private bonds, and home mortgages.

The round ends with interest and dividend payments by governments and firms. They are sent in bulk to the bank that distributes these funds to households in the subsequent round.

Table 2.4. Market participation by sector

Sector	Input Markets		Final-Demand Markets				Financial Markets											
	Labor Services	Interfirm Purchases	Consumer Goods	Fixed Capital	Net Exports	Government Purchases	Long-Term Claims					Short-Term Claims						
							Corporate Bonds	Federal Bonds	State/Local Bonds	Mortgages	Equities	Treasury Bills	Bank Loans	Money	Time & Savings Deposits	Discounts & Advances	Bank Reserves	
Households																		
Labor-force households	S		D			S	D	D	D	S	D	D	D	D	D	D		
Other households			D															
Nonfinancial firms																		
Agriculture	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Mining	D	DS	S	D	DS	S	DS	D	D	D	S	D	D	D	D	D		
Construction	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Automobile manufacturing	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Other durable manufacturing	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Nondurable manufacturing	D	DS	S	D	DS	S	DS	D	D	D	S	D	D	D	D	D		
Capital-intensive service	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Trade	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Other service	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Real estate	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	D		
Financial firms																		
Financial intermediary	D	DS	S	DS	DS	S	DS	D	D	D	S	D	D	D	D	S	S	D
Bank	D	DS	S	D	DS	S	DS	D	D	D	S	D	S	S	S	S	S	D
Government ^a																		
Federal	D	DS	S		DS	DS	D	S		D		S						
State/local	D	DS	S		DS	DS	D	D	S					D			D	
Monetary authority							D	D				D		D			D	S
Rest-of-world		DS	S		DS	S	DS	D	D		DS	D	DS	DS				

NOTE: S and D indicate participation on the supply and demand side, respectively. In financial markets, those on the demand side may sell already existing claims in their possession, but only those on the supply side may create new ones.

^aIncludes government enterprises.

Markets

Market participation by the actors is summarized in table 2.4, where each horizontal line represents participation of each actor as buyer or seller in each of the markets for a good or a financial claim. Prices in each of these markets are set once in a round by designated actors, 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. The market-clearing equations of conventional macroeconomic models have been replaced by sets of behavioral specifications for those actors who set the prices and hold the buffer stocks of each commodity. They are required to decide on target levels for the stocks and to make adjustments in the price or the production of the item when disparities between amounts flowing out of the buffer stock and amounts flowing in drive the level of the stock away from the target. Inventories of goods and financial claims thus become central to the operation of the model's markets.

For goods and services produced by nonfinancial firms, prices are ordinarily set by producers on a cost-plus basis, and firms sell all they can at the set price. An exogenous shift upward in average costs is followed by a price adjustment, which leads in turn to a reduction in quantity demanded by households and by firms that use the product as a machine ingredient.² The extent of the reduction depends on 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. If producers of goods and services are unable to replenish their buffer stocks to desired levels, either because they lack capital capacity or because supplies of labor or purchased inputs are insufficient, they are programmed to raise prices, even if profit margins are ample. Conversely, an undesired buildup of buffer stock is conducive to decisions to lower prices or delay price increases that might have occurred by reason of rising costs and narrowed profit margins.

Wage changes are made by firms and vary directly with productivity and cost-of-living change. The demand for labor 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, reduces 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 theorists. 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 or decumulating inventory of an item beyond what it desires on its own account, it changes the price in the next round.

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 decisionmaker to another and the passing of demand deposits in the opposite direction. Each transaction is accomplished by a subroutine named TRANS, which is called into action whenever any decisionmaker buys anything from any other decisionmaker. TRANS is the principal means by which the interactions of decisionmakers are depicted, and it is also the principal means by which action on the microlevel is made to contribute to the GNP and the flow-of-funds accounting.

Before TRANS is brought into operation, the details of the transaction have already been decided upon: the identity of the buyer and seller, the identity of their cash accounts, the price, the number of physical units of the good to be traded, the inventory records of the seller, and the GNP account to which the transaction is to be credited, if any. The operation of a transaction is diagrammed in figure 2.1. Before the transaction is implemented, a check is made for the adequacy of the buyer's cash and the adequacy of the seller's inventory. If the transaction is feasible, the seller's inventory is drawn down and the buyer's inventory is increased by the number of units of the good traded. Money changes hands—the buyer's cash account diminishes and that of the seller increases. The appropriate GNP accounts are credited with the transaction if the transaction is on income and product account.

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 (money, financial claims, and goods) are built up or drawn down in accordance with the flows that the microunits decide shall occur.

In some transactions, the merchandise being purchased may be merely a claim given up by the payee. For example, a tax payment purchases the cancellation of a claim for that amount by the government. A purchase results in a record of an inventory buildup of the merchandise by the purchaser only where such a record is useful in explaining the purchaser's subsequent conduct.

Table 2.5 summarizes all events in the model that trigger cash flows by

Table 2.5. Cash flows between sectors, by type

Sector Receiving Cash Flow	Sector Generating Cash Flow					
	Nonfinancial Firms	Households	Government	Financial Intermediary	Bank	Monetary Authority
Nonfinancial firms	IO purch. Invstmt. goods	Cons. goods & svcs. Cons. debt int./prin. ^a	Govt. goods & svcs.	IO purch. Invstmt. goods Home purch. ^b Home repair ^b Govt. sec. int./prin. ^b Bus. bonds ^b	IO purch. Invstmt. goods Loans	Exports
Households	Wages Cons. loans		Wages Transfer pmts.	Wages Cons. loans Home mortg. issues ^b Dividends ^b Govt. sec. int./prin. ^b Bond int./prin. ^b	Wages Cons. loans	
Government	IO purch. Sales taxes Profits taxes Payroll taxes	Cons. goods & svcs. Income taxes Soc. ins. taxes	IO purch. Federal grants in aid to state/local	IO purch. Sales taxes Profits taxes Payroll taxes Home taxes ^b Home mortg. int./prin. ^b Govt. sec. int./prin. ^b	IO purch. Sales taxes Profits taxes Payroll taxes	Note Tax Exports

Financial intermediary	IO purch.	Cons. svcs.	Govt. goods & svcs.	IO purch.	IO purch.	Govt. sec. purch.	Govt. sec. purch.
	Dividends ^b	Cons. debt	Govt. sec.		Dividends ^b		Bus. sec. purch.
	Bond int./prin. ^b	int./prin. ^b	int./prin. ^b		Loans		Bond int./prin.
	Govt. sec. purch. ^b	Home purch. ^b	Home mortg.		Home mortg. purch. ^b		
Bank	Bus. bond purch. ^b	Home repair & taxes ^b	Govt. sec. purch. ^b		Govt. sec. purch.		
		Home mortg. int./prin. ^b			Bus. bond purch.		
		Bond purch. ^b					
	IO purch.	Cons. goods & svcs.	Govt. goods & svcs.	IO purch.	IO purch.	Discounts	Exports
Monetary authority	Loan int./prin.	Cons. debt		Loan int./prin.			Loan int./prin.
		int./prin.		Home mortg. int./prin. ^b			
		Deposits to svg. accts.		Govt. sec. int./prin. ^b			
				Bus. bond int./prin. ^b			
Rest-of-world				Govt. bond int./prin. ^b			
	IO purch.	Cons. goods & svcs.	IO purch.	IO purchases	IO purch.	For. exch. purch.	
			Transfers	Govt. sec. int./prin. ^b	Loans		
			Govt. goods & svcs.	Bus. sec. int./prin. ^b			
				Bonds ^b			

^aint./prin. is interest and principal.

^bCash payments that accrue to financial intermediary in its capacity as agent for account of others or that are made by them in that capacity.

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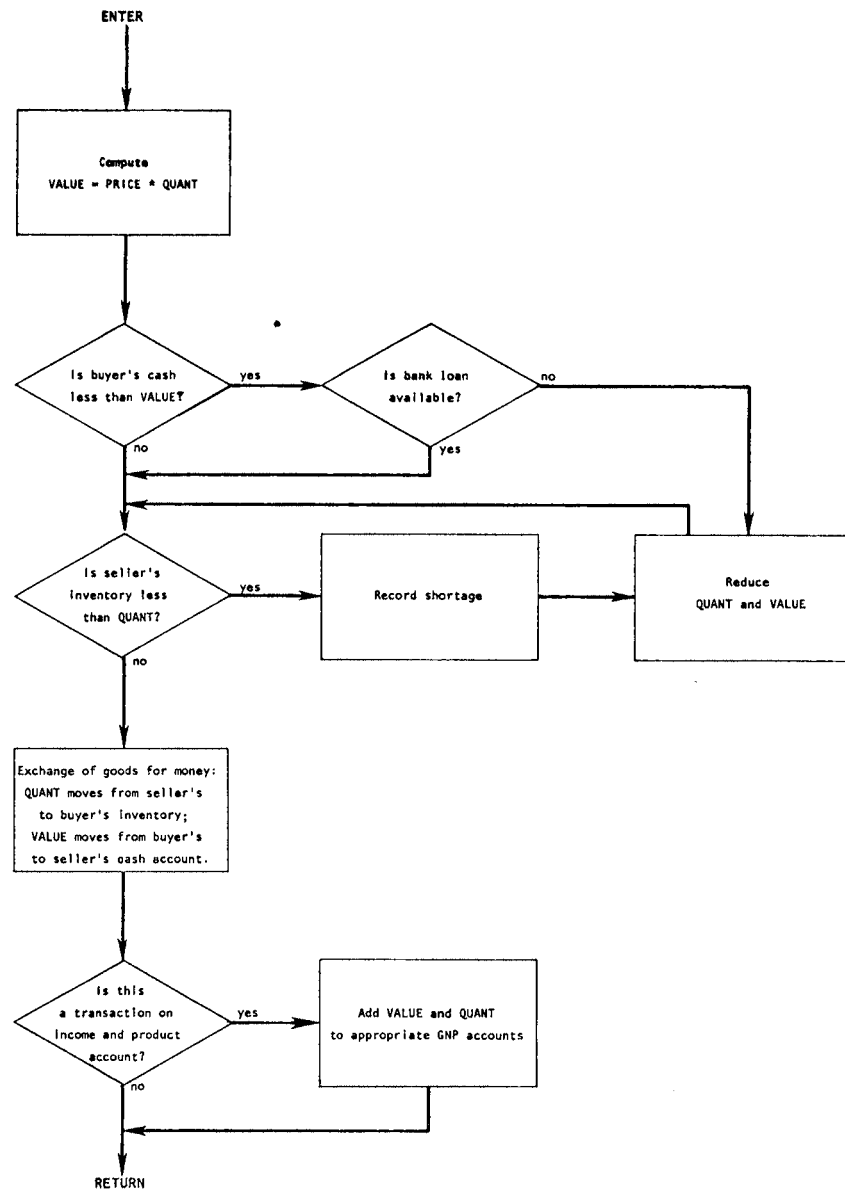


Figure 2.1. Diagram of a Transaction

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 firms are held for safekeeping by the financial intermediary, 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. All payments are made by the transfer of demand deposits from one actor to another within the computer's memory. In this sense, the model mimics the world of the future, when all cash flows will be checkless and electronic.

Notes

Chapter 1. Introduction

1. See Arrow (1951). Our treatment of expectations is more thorough in the indexed-bond experiment in chapter 9.

Chapter 2. Framework of the Transactions Model

1. When in the course of a run of the model, people leave the labor force, they continue to be represented as individuals, and their assets and/or liabilities remain with them.
2. Flow inputs, following the input-output tradition, are not price elastic.

Chapter 4. The Firms

1. So that the text can serve as a guide to the FORTRAN program of the model, we have attempted to make the equations in the text conform to the greatest extent possible to the program. Thus, there are some magnitudes, such as total cost (TCOST) that are obviously different for different firms but that have not been given firm-specific subscripts because they do not have them in the program.

2. The production setup of the firm and the specification of the change in the productiveness of new capital equipment are similar to the system described by Salter (1960) and Solow et al. (1966).

3. Firms and sectors with no inventories are capital-intensive services, other services, financial intermediaries, bank, the federal government, and state/local government. The product of wholesale and retail trade is a service, but since that product is only demanded in association with the goods of other firms as a markup, we treat its product as a good. The construction firm, although its final product is structures, is represented as maintaining no inventories of finished goods. This follows the procedures of the

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