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A MICROSIMULATION OF THE MACROECONOMY WITH EXPLICITLY REPRESENTED MONEY FLOWS

BY BARBARA R. BERGMANN*

A macroeconomic model is described whose structure features the delineation of decision-making at the microeconomic level. Each worker-consumer, firm, or bank takes account of its own position when making decisions. In each transaction, the seller's cash account is credited, the buyer's cash debited, the seller's inventory debited and the transaction added to the appropriate GNP account, thus generating consistent estimates of the flow of funds and the GNP accounts. Each week, firms make production, employment and price decisions, incomes are paid, consumers, firms and government make purchases of goods and make portfolio adjustments.

That macroeconomics should be anchored in descriptions of micro-economic behavior is a principle well understood and universally agreed to, although often only loosely honored in practice. This paper describes work in progress on a model of the U.S. economy whose purpose is the forecasting of macroeconomic variables —GNP and its major components, price indexes, interest rates, employment, etc., and whose chief feature is an explicit delineation of behavior at the level of the household, the firm, the bank, the governmental unit. The strategy employed is the construction of a simulated "representative" economy composed in the current version of the model of about 1,000 worker-consumers, six firms, a single bank, a financial intermediary, a fiscal decision maker for a single government and a monetary authority.

The computer is employed to keep track of the information about each firm which that firm requires for its own decision-making—its production possibilities, cost structure, prices of inputs and outputs, inventories, money holdings, other assets, current and past sales, etc. Actions by the firm affect the values of its own decision variables and those of other decision makers. Actions by the firm which contribute to changing the components of the Gross National Product are appropriately recorded as they occur, so that the national accounts can be built up from below, so to speak. The actions of households and the other decision-making units are treated analogously. The computer permits easy depiction of the inter-relation of decision makers' activities, and the combination of these activities into the macroeconomic result.

The major inspiration for the present model is the pioneering thought of Guy Orcutt (1960), although this model differs from the work of him and his associates considerably in terms of subject-matter focus, disaggregation of time periods, and econometric methodology.[1]

It is hoped that the model can eventually be used in short-term and medium-term forcasting, much as a conventional model based on simultaneous linear macroeconomic equations is used. However, the major contribution of the model is expected to be in uses which exploit the features of the model which sets it apart from other macroeconomic models—its delineation of the behavior of micro-units.

* Thanks are due to Clopper Almon, Robert Bennett and Margaret Buckler and to the University of Maryland for computer time.

[1] See Guthrie, *et al.* [7].

In the present version of the model, decision makers decide what to do mainly by consulting rules of thumb; explicit maximizing calculations are not made.[2] In building this initial version, effort has been concentrated on taking account of each decision-maker's effect on the others and on the macroeconomic result. Later versions may introduce more explicit optimizing.[3] Yet even with the present version, policies such as price controls or tax changes which change the rules of the game for the micro-units can be delineated with considerable realism and their effects on the macro-economy studied. Later versions of the model may also be able to make a contribution to the resolution of some long standing doctrinal disputes, such as those between the monetarists and their opponents, to the extent that these disputes turn on differing descriptions of micro-behavior and the way such differences "add up" to affect the macroeconomic result.

At the heart of the model is a computer routine which is performed ("called") whenever a transaction on the part of the decision-makers occurs. Each decision-maker has a cash account whose current size is kept track of. The transaction routine (TRANS) reduces the cash account of the buyer and increases the cash account of the seller. It reduces the seller's inventory of the good sold and increases the buyer's inventory. If the transaction is on income and product account, its value is added to the appropriate sub-account of the GNP accounts. TRANS is used for household purchases from firms, purchases by firms from other firms, and also for purchases of labor by firms, for the payment of taxes, interest and dividends and for the purchase of debt instruments. The consistent use of TRANS allows the construction of an integrated model which has the possibility of outputting estimates of the GNP accounts and of the flow of funds which are consistent with each other.

The basic unit of time in the model is the week.[4] In the course of the week, the following events occur, in the order shown:

1. Firms make production plans based on sales of their product and their inventory position (subroutine PROD).
2. Firms attempt to adjust the size of their work forces in accordance with their production plans; wages are set; the government adjusts its work force (subroutine EMPLOY).
3. Production occurs; inventory of output rises; inventory of inputs are drawn down; costs and profits are computed (subroutine COST).
4. Firms adjust prices of their output (subroutine PRICE).
5. Firms buy inputs and pay profit taxes, sales taxes and payroll taxes (subroutine INPUT).
6. Worker-consumers receive wage payments from their employer (some particular one of the six firms or the government); they receive transfer payments from government where appropriate; receive property income;

[2] For a macroeconomic model in which the behavior of a single representative firm is determined by optimal control theory, see Fair [5].

[3] There is a considerable literature suggesting that there are circumstances where rules of thumb are efficient economic strategies. See Day, Morley and Smith [3].

[4] The model "week" is slightly longer than a calendar week. I have adopted the convention that there are 48 "weeks" per year, 12 per quarter and 4 per month. This permits easier use of monthly data than would be the case in the 52-week year, but would obviously make it more difficult to use weekly data.

they pay taxes; make payments on outstanding loans (subroutine INCOME).

7. Worker-consumers decide on their savings; purchase consumer goods from firms; adjust their portfolios of assets (subroutine CONSUM).
8. Firms make decisions concerning investment in capital goods and/or they implement previous decisions (subroutine INVEST).
9. Government purchases goods from firms (subroutine GOVERN).
10. Firms make decisions on seeking outside financing. They expand or contract their bank debt (subroutine FDEPT).
11. Government plans its issuance of debt instruments (subroutine GDEBT).
12. The bank and the financial intermediary acquire the bonds of firms and government; the monetary authority buys or sells government bonds thus affecting bank reserves; interest rates are changed by the financial intermediary so as to reduce the difference between supply and demand for bonds (subroutine MONEY).

As the model has developed so far, all the actions of decision-makers are based on previously established values of the variables influencing the decision; there is no simultaneity whatever. Thus the model is never "solved." However, the output of the model for a month or a quarter would, of course, reflect the interactions which are customarily captured in macroeconomic models by simultaneity. For example, a matrix of input-output coefficients is used, and when production occurs, producers' inventories of inputs are appropriately drawn down and orders for their replenishment are given. The Leontief inverse is never calculated, but of course the indirect effects of an increase in demand for a particular good make themselves felt through time.

An important feature of the model is an explicit attention to constraints on behavior: no one is allowed to spend money he cannot raise, to sell anything he does not have, etc. This means that decision-makers' initial plans may be frustrated, and they may have to fall back to other plans. In this sense, the model depicts disequilibrium situations.

The simulated output of the "representative" economy is scaled up to the level of the United States economy by being multiplied by an unchanging ratio (the ratio of U.S. employment in January 1967 to employment in the "representative" economy in January 1967, set as an initial condition). Each of the six "firms," although treated as a decision-making unit, represents an industrial sector: motor vehicles, other durables, nondurables (including agriculture and mining), services, trade and construction. Each firm is assumed to set its price on a system based for the most part on cost plus a customary profit margin so that the existence of competition is a mooted issue in the current version of the model. Implication of this procedure for the delineation of markets is discussed below as are methods of parameter estimation employed. The model has the capability of outputting simulated values of endogenous macroeconomic variables on a quarterly, monthly, or weekly basis.

The reader will be better able to form an idea of the style and scope of the model and its potential usefulness by following the "scenario" of a number of its key subroutines. Although it is not necessary for comprehension, those readers who wish to do so may follow in detail the computer arrangements by referring to the listing of the FORTRAN programs which are provided in Tables I–III.

SUBROUTINE PROD

In this subroutine, the firm decides on its production plans, based on its sales and inventory position. It then decides how much labor it would like to employ for the coming week.

The firm starts by computing what its sales have been for the previous week (Table I, line 5). It does this by comparing its current inventory with the size of the inventory the previous week. As indicated above, individual sales of the firm's product result in a reduction of its inventory, through the operation of the TRANS subroutine by means of which all sales are handled.[5] The firm next computes a

TABLE I

```
 1.     C*****SUBROUTINE PROD:DESIRED PRODUCTION, DESIRED
 2.     C*****INVENTORIES AND DESIRED EMPLOYMENT ARE DECIDED.
 3.           DO 5 IFIRM=1,6
 4.     C*****CURRENT SALE AND MOVING AVERAGE OF SALES COMPUTED
 5.           SALE(IFIRM)=PINV(IFIRM,IFIRM)-XINV(IFIRM,IFIRM)
 6.          $  +XPROD(IFIRM)*AIO(IFIRM,IFIRM)
 7.           AVSALE(IFIRM)=(1.-A(15))*(SALE(IFIRM)+SHORT(IFIRM))
 8.          $   +A(15)*AVSALE(IFIRM)
 9.           SHORT(IFIRM)=0
10.     C*****DESIRED INVENTORY AND DESIRED OUTPUT DETERMINED
11.           DINV=A(3)*AVSALE(IFIRM)
12.           XPUT=AMAX1(AVSALE(IFIRM)+
13.          $                A(16)*(DINV-XINV(IFIRM,IFIRM)),0)+
14.           DPROD(IFIRM)=XPUT
15.     C*****PLANNED OUTPUT REDUCED IF CAPACITY RESTRAINTS
16.     C*****OR LACK OF RAW MATERIALS OCCUR
17.           IF(XPUT.GT.CAPCY(IFIRM))
18.          $  CAPSHT(IFIRM)=CAPSHT(IFIRM)+XPUT-CAPCY(IFIRM)
19.           IF(XPUT.GT.CAPCY(IFIRM))XPUT=CAPCY(IFIRM)
20.     C  TEST  FOR ADEQUACY OF INPUT INVENTORY
21.           DO 127 KK=1,6
22.           IF(XINV(KK,IFIRM).LT.AIO(KK,IFIRM)*XPUT)
23.          $WRITE(6,120)ITIME,KK,IFIRM
24.     120   FORMAT(3I10,'INADEQUATE INPUT')
25.     127   IF(XINV(KK,IFIRM).LT.AIO(KK,IFIRM)*XPUT)
26.          $XPUT  =XINV(KK,IFIRM)/AIO(KK,IFIRM)
27.     C*****LABOR REQUIREMENT FOR PLANNED OUTPUT COMPUTED
28.           X=0
29.           TLAB=0
30.           DO 1  JVIN=1,60
31.           IF(OPUT(IFIRM,JVIN).LE.0.) GO TO 1
32.           Z=(XPUT-X)/OPUT(IFIRM,JVIN)
33.           IF(Z.GT.1.)Z=1.
34.           TLAB=TLAB+RLAB(IFIRM,JVIN)*Z
35.           X=X+OPUT(IFIRM,JVIN)*Z
36.           IF(Z.LT.1.) GO TO 4
37.     1     CONTINUE
38.     4     DESEMP(IFIRM)=TLAB +EMPFIX(IFIRM)
39.     5     CONTINUE
40.           RETURN
```

[5] The use of the firm's own product as input is, in the current version, not treated as requiring a transaction.

TABLE II

```
C*****SUBROUTINE PRICE:
C*****RECORD OF LAST PERIOD'S PRICES KEPT
      DO 1 IFIRM=1,6
      PLAST(IFIRM)=P(IFIRM)
C*****IF INVENTORY LEVEL EXCESSIVE, BYPASS TESTS FOR
C*****PRICE INCREASE.
      IF((XINV(IFIRM,IFIRM)-XPROD(IFIRM)-A(3)*AVSALE(IFIRM))
     $   /A(3)*AVSALE(IFIRM).GT.A(6))GO TO 2
C*****RAISE PRICE IF DESIRED PRODUCTION EXCEEDS ACTUAL,
      IF(SHPROD(IFIRM)/A(7).GT.AVSALE(IFIRM)*A(8))
     $    P(IFIRM)=P(IFIRM)*(1+A(9))
      SHPROD(IFIRM)=0
C*****OR IF MARGINAL COST EXCEEDS PRICE,
      IF(P(IFIRM).LT.XMCOST(IFIRM))
     $                               P(IFIRM)=P(IFIRM)*(1+A(9))
C*****OR IF CUSTOMARY PROFIT MARGIN NOT MAINTAINED.
      IF((P(IFIRM)-ACOST(IFIRM))/ACOST(IFIRM).LT.
     $   A(10)*PMARG(IFIRM))
     $P(IFIRM)=ACOST(IFIRM)*(1.+A(11)*PMARG(IFIRM))
      GO TO 1
C*****REDUCE PRICE IF INVENTORY AND PROFIT MARGINS
C*****EXCESSIVE.
      IF((P(IFIRM)-ACOST(IFIRM))/ACOST(IFIRM).GT.
     $   A(12)*PMARG(IFIRM))
     $      P(IFIRM)=P(IFIRM)*(1-A(9))
  1   CONTINUE
      RETURN
```

weighted average of past sales, with heaviest weight for the most recent period (I, 7–8). Desired inventories are computed as a simple multiple of average past sales (I, 11). The firm next sets desired output equal to average past sales plus a fraction of the difference between desired inventory and actual inventory (I, 12–13). If desired output is greater than the capacity of the capital equipment of the firm to produce, planned output is reduced to a feasible level (I, 17–19). Next comes a test to determine whether the firm has on hand the needed "raw materials" for the planned level of production. The input-output matrix is AIO(JFIRM, IFIRM), representing here the physical quantity of the output of the *j*-th firm required per physical unit of output of the *i*-th firm.[6] If the firm's inventory of inputs is insufficient, planned output is reduced (I, 21–22). The firm's next move is to decide how much labor it would like to have on hand for the week now starting. It does this by exploring its production function. The firm maintains capital equipment in distinct vintages. Each vintage consists of a group of machines; the group has a maximum output (OPUT) in terms of physical units and a labor requirement for the production of that maximum output (RLAB) in terms of men. Having decided how much to produce, the firm plans its production by vintage, adding up the amount of labor required. It will produce as much as it can with its best vintage,[7] go on to the next

[6] One physical unit of the good of the i-th firm is $1 worth of that firm's product in the base period (first quarter, 1967). The motor vehicle industry is conceived of as selling its products in lumps of 3,000 physical units.

[7] In the current version of the model, inputs per unit of output other than labor do not vary with the vintage of a capital good and later vintages have higher labor productivity, so that the "best" vintage is invariably the most recent, regardless of prices and wages.

TABLE III

```
      C*****SUBROUTINE CONSUM:  EACH HOUSEHOLD
      C*****DECIDES WHETHER OR NOT TO BUY A CAR, DECIDES
      C*****ON SAVING,BUYS OTHER GOODS, ADJUSTS PORTFOLIO.
      C*****DECISION WHETHER TO PURCHASE AUTOMOBILE:
            IF(NOHH.GT.1200) GO TO 130
      C*****THE AMOUNT A NEW PURCHASER OF A CAR WOULD HAVE
      C*****TO PAY ON HIS LOAN MONTHLY IS COMPUTED.
            P1=P(1)*3000.
              TPAY=P1  *(1.-DOWN)*R/12.*(1.+R/12.)**NPA
           $/((1.+R/12.)**NPA-1.)
            MORSAV=0
      C*****IF THE CONSUMER IS IN THE GROUP WANTING A CAR
            INTEGER OWNCAR   -
            IF(OWNCAR.LT.1)GOTO 34
      C*****IF THE HOUSEHOLD'S CAR IS SUFFICIENTLY OLD,
            IF(ITIME-IDGAGE.LT.IA(1)) GO TO 34
      C*****IF THE CONSUMER IS NOT UNEMPLOYED,
            IF(IEMPST.EQ.0)GO TO 34
      C*****IF PAYMENTS NECESSARY ON THE NEW CAR ARE NOT
      C*****CONSIDERED TOO HIGH, A DECISION IS MADE TO BUY.
            IF(  TPAY.GT.A(61)*(YDIS-SUBSIS )) GO TO 34
      C*****IF ASSETS ARE NOT SUFFICIENT TO MAKE A DOWN PAYMENT,
      C*****ARRANGEMENTS ARE MADE TO SAVE MORE.
            ASSTS=HCASH+SAVACC
            IF(DOWN*P1  .GT.ASSTS-YDIS-AMORT)GO TO 29
      C*****IF ASSETS ARE SUFFICIENT, AND IF A CAR IS AVAILABLE,
            IF(XINV(1,1).LT.3000.)SHORT(1)=SHORT(1)+3000.
            IF(XINV(1,1).LT.3000.)GO TO 34
      C*****CASH IS MOBILIZED FOR THE DOWN PAYMENT WITH
      C*****A CALL TO SUBROUTINE SANDL.
            CASHN=AMAX1(DOWN*P1  -(HCASH-YDIS),0.)
            CALL SANDL(1,CASHN,HCASH,SAVACC)
      C*****A LOAN IS TAKEN OUT TO FINANCE THE REMAINDER
      C*****OF THE PURCHASE PRICE WITH A CALL TO IOU
      C*****IF THE BANK IS NOT LOANED UP,
            BORROW=P1  *(1.-DOWN)
            CALL IOU(HCASH,BORROW,0)
            IF(LNUP.EQ.1)  GO TO  34
      C*****THE PURCHASE IS CONSUMATED WITH A CALL TO TRANS
            CALL TRANS(HCASH,CASH(1),P(1),3000.,DUMP,XINV(1,1)
           $  ,SHORT(1),GNP(1))
      C*****AND THE TIME OF PURCHASE RECORDED.
            IDGAGE=ITIME
            GO TO 34
       29   MORSAV=1
        34  CONTINUE
      C*****SAVINGS BEHAVIOR:
      C*****ASSETS, DESIRED ASSETS, AND DESIRED EXPENDITURE
      C*****ARE COMPUTED.  THE LATTER IS A WEIGHTED AVERAGE
      C*****OF CURRENT INCOME AFTER DEDUCTIONS FOR TAX AND
      C*****LOAN DAYMENTS AND PAST EXPENDITURE.
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TABLE III—continued

```
            ASSTS=HCASH+SAVACC
            SAVMOR=MORSAV
            ASSTD=AMAX1(A(62)* (EXP-SUBSIS),DOWN*PI  *SAVMOR)
      C*****IF ASSETS ARE DEEMED SUFFICIENT, EXPENDITURE IS
      C*****A WEIGHTED AVERAGE OF PAST EXPENDITURE AND ALL
      C*****OF WHAT IS LEFT OF INCOME.
            EXPD=A(63)*EXP+(1.-A(63))*YDIS
            SRATE=A(64)+A(65)*SAVMOR
      C*****IF ASSETS ARE LESS THAN ASSETS DESIRED,
      C*****EXPENDITURE DESIRED IS A WEIGHTED AVERAGE OF
      C*****PAST EXPENDITURE AND A FRACTION OF WHAT
      C*****REMAINS FROM INCOME.
            IF(ASSTS-YDIS-AMORT.LT.ASSTD)EXPD=A(63)*EXP
           $    +(1.-A(63))*(YDIS*(1.-SRATE))
      C*****IF DESIRED EXPENDITURE IS GREATER THAN THE
      C*****REMAINDER OF INCOME, DISSAVING TAKES PLACE,
      C*****OTHERWISE SAVING.
            IF(EXPD-YDIS)62,62,63
      62    SAVE=YDIS-EXPD
            EXPA=EXPD
            YDIS=YDIS-SAVE
            GO TO 64
         63 DSSAVE=AMIN1(A(66)*(ASSTS-YDIS-AMORT),
           $    EXPD-YDIS)
            CASHN=AMAX1(DSSAVE-HCASH+YDIS,0)
            IF(CASHN.GT.0) CALL SANDL(1,CASHN,HCASH,SAVACC)
            YDIS=YDIS+DSSAVE
            EXPA=YDIS
         64 EXP=(1.-A(67))*EXPA+A(67)*EXP
      C*****PURCHASES OTHER DURABLES (GOOD 2), NON-DURABLES
      C*****(GOOD 3), AND SERVICES (GOOD 4)
            BUY2=A(68)+A(71)*(YDIS-SUBSIS)/P(2)
            CALL TRANS(HCASH,CASH(2),P(2),BUY2,DUMP,XINV(2,2),
           $ SHORT(2),GNP(2))
            BUY3=A(69)+A(72)*(YDIS-SUBSIS)/P(3)
            CALL TRANS(HCASH,CASH(3),P(3),BUY3,DUMP,XINV(3,3),
           $SHORT(3),GNP(3))
            YDIS=YDIS-BUY2*P(2)-BUY3*P(3)
            BUY4=YDIS/P(4)
            CALL TRANS(HCASH,CASH(4),P(4),BUY4,DUMP,XINV(4,4),
           $    SHORT(4),GNP(4))
            IF(NOHH.GT.1200)GO TO 55
      C*****THE HOUSEHOLD RETAINS A MAXIMUM OF $20 CASH.
            XCASH=AMAX1(HCASH-A(81),0)
      C*****THE REST IS DEPOSITED IN THE SAVINGS ACCOUNT.
            IF(XCASH.LE.0) GO TO 131
            CALL SANDL(0,XCASH,HCASH,SAVACC)
      C*****TOTAL SAVINGS IS RECORDED.
      131   SAVTOT=SAVTOT+SAVACC
       55   CONTINUE
            RETURN
```

best, and so on (I, 28–36). Finally, the firm adds to the labor requirement an amount of "overhead" labor not based on output, EMPFIX(IFIRM) (I, 38).

The quantities (computer memory locations) which must be assigned numerical values in order to perform this subroutine on the computer include the input-output matrix (AIO), the operating characteristics of the capital equipment (OPUT and RLAB), the weight of current sales in figuring average sales (A(15)), the ratio between desired inventory and average sales (A(3)), and the proportion of the gap between actual and desired inventory level which is made up in a week (A(16)). The values for the input-output table derive from Clopper Almon's Maryland Inter-industry Forecasting Model.[8] As the model starts to run, the operating characteristics of the capital equipment in each firm are currently based on simplifying assumptions about acquisitions of capital goods in the 15 years preceding the base period and about the rate of improvement through time in the operating characteristics of machines. However, in later periods, the size of the newer vintages of the firm's capital equipment is dependent on the rate of investment activity, which is endogenous.

Subroutine EMPLOY

In the previous subroutine, PROD, each of the six firms decided on the number of workers they would like to have on board in the current week. Subroutine EMPLOY starts by arranging for some of the workers in each firm, randomly chosen, to quit their jobs. Firms then lay off more workers if the size of their work force after the quits have occurred is judged to be too large. Those firms which want more workers will "interview" particular workers and make offers, some of which will be accepted. Some slots employers wish to fill will remain vacant, and the vacancy rate will affect employers' setting of wage rates.[9] This subroutine adjusts the size of the "representative" labor force and also keeps track of simulated employment and unemployment rates so that their value may be outputted.

The status of each job slot is kept track of through the value given to a status variable. If it is occupied by a worker the value of the slot's status variable is the worker's identification number. If the slot is vacant and the firm wishes to fill it, the status variable is given value zero; if the firm does not wish to fill the slot, the value of the status variable is -1. A similar system is used to keep track of individual workers, whose status value will equal their slot's identification number if they are employed, zero if they are unemployed and -1 if they are out of the labor force. The status value of a worker is used in subroutine INCOME to determine whether he receives a wage or a transfer payment for that particular week.

Subroutine PRICE

In this subroutine, firms adjust their prices, based on their costs, profit margins and their inventory positions.

[8] See Almon [1].

[9] See Bergmann [2] for details of the simulation of the search process. Papers by Holt, Mortenson and Phelps in Phelps, *et al.* [10] have suggested descriptions of wage dynamics which can be simulated.

The subroutine starts by storing in the memory space PLAST the value of the price which is about to be changed (Table II, lines 3–4). (This is necessary to permit calculation of the inventory valuation adjustment in subroutine COST.) Next, the firm compares its inventory position to desired inventory. If inventories of the firm's output exceed desired inventory by some fraction, the firm will not consider raising its price (II, 7–8), but will consider lowering its price by a fixed percentage. It does so if actual profit margins, computed by subtracting price from average cost, exceed customary profit margins by a set percentage (II, 22–23). If, on the other hand, inventories are not excessive, the firm considers raising its price. It will do so by a fixed percentage if shortage of capacity or labor or material shortages have kept it from producing all that it wanted to (II, 10–12). Next, the firm considers its marginal cost, which has been calculated in subroutine COST, and which depends principally on wages, material costs, taxes, and on the marginal capital vintage in use. The firm will raise its price (which already may have been raised because of shortages) by a fixed percentage if marginal cost exceeds price as currently set (II, 14–15). Finally, if the profit margin is less than the customary, a price rise will occur (II, 17–19).

The important parameters contained in this subroutine include those which set the triggers for the price increases or decreases and those which determine the amount of the jump which the price makes. Currently, these are assumed to be the same for all sectors, although subsequent econometric work with the model will undoubtedly allow the removal of that assumption.

Subroutine CONSUM

In this subroutine, consumers make decisions relating to the purchase of automobiles, decide to save or dissave, purchase consumer goods from the firms, and adjust their portfolios of assets.

In order to avoid bogging down in demographic detail in the early stages of the model's construction, I have treated each member of the labor force as a decision-making unit for consumer spending purposes and assumed implicitly that a labor force member has attached to him an average number of dependents, whose presence influence his spending pattern. This simplification eliminates explicit treatment of family composition in terms of size and age of members. It is this aspect of life which is covered in profuse detail in the simulation model of the Orcutt group.[10] As our model develops, and especially as the housing and taxation issues are given more explicit treatment, the family or the household will probably have to be reassembled within the computer memory.

The subroutine starts by a determination of whether the consumer wishes to purchase an automobile. He will not want to do so if his current car is of relatively recent vintage (Table III, 16), if he is unemployed (III, 18), or if the payments on it he would have to make at the current price for automobiles and current interest rates exceed a certain fraction of his discretionary income (III, 21). If he would like to purchase an automobile, he must consider whether his assets are sufficient to finance a down payment (III, 24–25). If assets are not sufficient, the consumer makes

[10] See Guthrie, *et al.* [7].

a note to save more than he otherwise would until the down payment is accumulated (III, 45). If assets are already sufficient for the down payment, the needed cash is mobilized (III, 31–32), a bank loan is negotiated (III, 36–37) with a call to subroutine IOU[11] unless the bank is loaned up (III, 38). Finally, the purchase of the car is accomplished with a call to TRANS, (III, 40–41) which specifies the buyer's cash account to be debited, the seller's cash account to be credited, price, quantity, buyer's inventory account, seller's inventory account, a "shortage" account in case of insufficient supply, and finally the GNP account to which the value of the transaction is to be added.

The consumer next decides how much of the remainder of his pay-check, YDIS, will go into savings. He is assumed to have two goals, which may not always be compatible: the achievement of a certain level of assets, and avoiding an abrupt transition from one spending level to another. He calculates his desired assets, which are a certain multiple of his discretionary income (III, 54). If desired assets are equal to or exceeded by actual assets, then desired expenditure is simply a weighted average of such past average expenditures and what is left of this week's paycheck. (If the consumer is saving for the down payment on a car, his desired assets may be higher than they would otherwise be.) (III, 58). If, on the other hand, actual assets have not reached the desired level, then desired expenditures are a weighted average of past expenditures and some fraction of the remainder of this week's paycheck (III, 64–65). If desired expenditure exceeds what is left of this week's paycheck, then dissaving will take place, and non-cash assets may be converted into cash form (III, 69, 74–78).

The consumer then divides the total amount decided on above on non-durables, services, and other durables in accordance with a Stone–Geary linear expenditure system. A call is made to TRANS for each purchase (III, 83–92). Finally, in this version of the model, the consumer's asset portfolio is "managed" in a very simple way: any cash left over exceeding some fixed amount is deposited in a savings account at the financial intermediary (III, 95–98).[12]

Optimization, Markets and Other Methodological Issues

The reader will by now be well aware that construction of the macro-micro model has not proceeded in the traditional manner of microeconomic theory, which might be characterized as an attempt to portray each decision-maker in the system as taking account of all of the elements in his situation which he knows about or can guess about within the framework of a single unified optimizing calculation. The individual consumers in our model, in making decisions on current consumption, take account of their own assets, of their own indebtedness, and the history of their own expenditures which depends on their own employment history. This may certainly be viewed as an advance in realism over the usual

[11] Subroutine IOU, in addition to transferring the principal of the loan to the borrower's cash account, also arranges for monthly payments to be made on the loan by that particular worker-consumer to the bank. The latter is taken care of in subroutine INCOME.

[12] Households do receive dividend payments from the equities they own in subroutine INCOME. In the model as it currently exists, however, they do not trade in equities. In future versions, they may be allowed to do so.

macroeconomic model. However, decisions which, in theory, ought to be made simultaneously (saving and spending on individual commodities in a given week, for example) are typically made sequentially, with earlier decisions influencing the later decisions, but not vice versa. Within the firm, production and pricing decisions are made sequentially, and no attempt is made by the firm in the current version of the model to take account of the price elasticity of demand.

The basic reason for adopting this approach is the desire to concentrate on the timely achievement of a system in which the inter-relationships of individuals and firms is accounted for and which has the potential of becoming a serviceable vehicle for the study of macroeconomic issues, perhaps at the expense of some crudity in the portrayal of the behavior in early versions of the model. However, it should be noted that the model is extremely hospitable to improvements in behavioral description, so that incorporating better ideas on any subject can be done relatively quickly.

All of the decision-makers depicted in the model currently make up their plans on the basis of decision variables expressed in physical units purchasable in current dollars. Of course in later, more elaborate versions of the model, there is no reason why, in the course of their decision-making they cannot take account of expectations of price change, or for that matter expectations concerning any other subject. What will be needed will be exogenous information on the state of expectations or the development of a "scenario" of how expectations are formed. Similarly, firms making decisions concerning price changes may be depicted in later versions of the model as paying attention to the expected effect on quantity demanded. In order to do so sensibly some provision would have to be made for allowing them to record and evaluate the information which might come to them concerning the likely magnitude of such effects.

Where is the market in the current version of the model? Prices are set to reflect average cost at current output plus a customary profit margin (or marginal cost, if this is higher). The firm will then sell all it can at that price.[13] If demand conditions are such as to cause inventories to accumulate or decumulate, the rate of production will change, and so will costs and thus the price will be reset. The change in production will have effects on the demand side, but the system can converge to a situation in which the price and the rate of production will remain constant. This "equilibrium" will be disturbed in the medium run by the introduction of new capital goods which shift the supply conditions. Thus the "market," viewed as a process for adjusting price and quantity to harmonize the desires of the traders, is represented in the model in its present version.

Strategies for Estimation of Parameters

The strategy adopted by the Orcutt simulation group, described by Guthrie, *et al.* [7], seems to be to estimate parameters to the greatest extent possible from bodies of microdata. At the other extreme is the usual strategy of macroeconomic model builders, which is to employ an algorithm on the macroeconomic data which

[13] This particular formulation of behavior I owe, not to casual empiricism, but to a lecture given by my old economic theory teacher, the late Professor E. H. Chamberlin, on the relation of "full cost" pricing to monopolistic competition.

assigns parameter values which cause the endogenously determined macroeconomic output of the model "best" to track the macroeconomic data. In the case at hand, we have not wished to devote the major resources which are required to work with microdata sets, nor are the algorithms commonly applied to macroeconomic models consisting of simultaneous linear equations directly applicable.

While we have taken over a number of parameter values from others' research (input–output coefficients and the like), our general strategy has been to rely on the macrodata as a source of estimates of most parameters. We have worked to develop an algorithm which searches for constellations of parameter values which, when used to run the model, improve the fit of the model's endogenous output to the data.[14] This work is still going on, and the model is currently being run with parameter values set and improved on an *ad hoc* basis.

We show in Table IV some recent quarterly output of the model as currently constituted starting with the first quarter of 1967. For each component, there is a column for simulated values (marked S) and for actual values (marked A). The latter are derived from the United States GNP accounts, including the price index, which is the GNP deflator. In the table, the simulated and true values of fixed investment and government expenditures are virtually identical, because in the run recorded here they are treated as exogenous.[15] All of the expenditure values in the table are in current dollars.

The run of the model which resulted in the output shown in Table IV included no "mid-course corrections," i.e., if the estimated value of a variable turned out to be grossly incorrect, it was nevertheless allowed to stand, and to influence the formation of subsequently simulated values.

An examination of the numbers in Table IV reveals some fitting problems which would never arise in a conventional macroeconomic model. Part A of Table IV represents a run of the model in which all prices are assumed to rise at the rate at which average prices rose.[16] The fit in part A of the table for personal consumption expenditure (PCE) is tolerable in the later years but the simulated values are too high in the earlier years. In a conventional model fitted by regression, the method of fitting the slope and intercept in the consumption function would insure that such an outcome would never happen: the slope of the "relationship" of consumption to income would be higher and the intercept lower. In the micro-macro model as currently set up we can affect simulated consumption by adjusting the parameters which control desired assets and the proportion of income which those who desire to save try to save. Experiments with differing values of these parameters have so far not been of great help in improving the fit. A source of poor fit in the early period may be the initial conditions, in this case average past income, stock of cars, distribution of assets and the like. Whether a set of initial conditions which corresponds better to reality will improve the fit of

[14] A compendium of search methods is contained in Goldfeld and Quandt [6].

[15] The differences derive from the process of translating GNP dollar expenditures into physical quantities of output purchased from the six industries and then valuing them at the model's endogenously computed prices.

[16] We are currently developing price indexes for use as exogenous variables and for purposes of comparison with simulated values which reflect the data on price change by sector. At the time of the runs which resulted in the output shown in Table IV, these were not available.

TABLE IV

QUARTERLY SIMULATED (S) AND ACTUAL (A) GNP COMPONENTS IN CURRENT DOLLARS AND PRICE DEFLATORS; I, 1967—IV, 1970

A. Fixed investment and government expenditure exogenous. All prices exogenously fixed to change at average rate. Personal consumption expenditures and change in inventory endogenous.

GNP		PCE		Ch. Invy.		Fix. Invt.		Gov. Exp.		Pr. Def.	
S	A	S	A	S	A	S	A	S	A	S	A
780	774	484	481	13	10	104	104	179	180	116	116
788	784	496	490	2	4	106	106	184	184	117	117
805	801	504	495	4	9	110	110	187	187	118	118
822	816	515	502	4	10	113	113	190	190	119	119
841	834	525	519	4	3	117	117	194	195	120	120
862	857	537	529	7	10	117	117	201	201	122	122
880	875	547	544	10	8	118	118	204	205	123	123
892	890	556	552	7	8	123	123	206	207	124	124
909	906	564	564	9	7	128	128	208	208	126	126
923	922	573	576	11	7	130	130	209	209	127	127
936	940	582	584	9	10	131	131	214	214	130	129
944	948	591	594	6	6	132	132	215	216	131	131
957	956	599	604	6	0	131	131	220	221	132	133
970	968	609	614	8	2	132	132	220	221	135	134
976	983	616	621	3	5	133	133	224	224	137	136
988	988	625	625	3	4	134	134	226	226	138	138

B. Same as A, except prices endogenous

GNP		PCE		Ch. Invy.		Fix. Invt.		Gov. Exp.		Pr. Def.	
S	A	S	A	S	A	S	A	S	A	S	A
780	774	484	481	13	10	104	104	179	180	116	116
787	784	496	490	1	4	117	106	184	184	116	117
803	801	503	495	3	9	110	110	187	187	117	118
820	816	512	502	5	10	113	113	190	190	117	119
839	834	522	519	6	3	117	117	194	195	119	120
856	857	532	529	6	10	117	117	201	201	119	122
870	875	541	544	7	8	118	118	204	205	121	123
884	890	548	552	9	8	123	123	204	207	124	124
900	906	557	564	7	7	128	128	208	208	124	126
916	922	566	576	12	7	130	130	209	209	126	127
928	940	575	584	8	10	131	131	214	214	128	129
944	948	584	594	12	6	132	132	215	216	131	131
948	956	593	604	4	0	131	131	220	221	132	133
960	968	602	614	5	2	132	132	220	221	133	134
968	983	609	621	2	5	133	133	224	224	134	136
981	988	616	625	5	4	134	134	226	226	137	138

personal consumption expenditures or whether a respecification of decision-making behavior will be called for is a subject for future research.

In part B of the table, a run of the model with prices for the six sectors set endogenously as in subroutine PRICE worsens the PCE fit, although the fit of the simulated price deflator to the actual is good.

The endogenously simulated change in inventory, which includes firms' inventories of inputs and of outputs, is also not an outstanding fit, but this was to be expected. Even with a perfect description of behavior with regard to inventories, small errors in simulated sales will cause relatively large errors in inventory change, because sales in this model draw down inventory.

USES OF THE MICRO-MACRO MODEL

The most obvious use for a model of the type we have described here is as a forecasting tool. Whether, when the monetary side is further fleshed out, the model will do as well as the Wharton School model, the FRB-MIT model, the DRI model, or any of their competitors in terms of the non-parametric measures listed by Dhrymes, *et al.* [4] remains to be seen. One of the problems in making the micro–macro model operational for purposes of timely short-run forecasting is the complexity, variety and sheer number of initial conditions which must be set up before the model can start to forecast. In the current version, many initial conditions have been set through the use of simplifying assumptions.[17] This will probably not be good enough if the aim is to get a good forecast for the coming four quarters, and alternative methods of setting up initial conditions for runs starting with the current period will have to be explored.

A second, and perhaps more valuable use of the model is as a tool of policy analysis. Many policy instruments can be delineated fairly realistically in a model such as this one, a capability which is lacking in conventional macro-models.

An example which comes easily to mind is that of the effect of price controls. A system of price controls can be delineated by removing from the system subroutine PRICE for the period of controls and substituting a subroutine which tells what the Cost of Living Council's rules are. Production of units which sell for less than marginal cost would have to be curbed. When controls are lifted, subroutine PRICE can become operational again, and production can revert to its old rules. The model can be run with varying price control rules for varying periods, and the course of prices and production during and after the control period can be charted.

A second example of a type of policy study to which the model lends itself easily and naturally is that of taxation. Here the simulation studies of Pechman and Okner [9] of the personal income tax have shown the power of this type of methodology. The micro–macro model provides an opportunity to study proposed tax changes realistically delineated in their full macro-economic context.

In addition to forecasting and policy analysis, one may expect a model of the type outlined here to be modestly useful in mediating some of the doctrinal disagreements so prominant in current discussions of macro-economic issues. The Friedmanites differ somewhat from their opponents in their descriptions of micro-behavior. However, it is probably fair to say that the major source of disagreement lies in the macro-economic implications which are drawn from an agreed-upon set of descriptions of micro-behavior. The model described above has the virtue of being extremely explicit in delineating how the interactions of micro-

[17] For example, it was assumed that non-asset-owning consumers had one uniform distribution of past average expenditure and asset-owning consumers had another.

units "add up" to achieve the macro-results. It might, therefore, in some later version make an acceptable vehicle for the testing out of the implications of alternative specifications offered by opposing schools of thought.

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References

[1] Almon, C., *The American Economy to 1975, an Inter-Industry Forecast*, New York: Harper & Row Publishers, 1966.
[2] Bergmann, B. R., "Labor Turnover, Segmentation and Rates of Unemployment: A Simulation-Theoretic Approach," (mimeographed) Project on the Economics of Discrimination, University of Maryland, 1973.
[3] Day, R. H., S. Morley, and K. B. Smith, "Myopic Optimizing and Rules of Thumb in a Micro-Model of Industrial Growth," *American Economic Review*, March 1974, pp. 11–23.
[4] Dhrymes, P. J. *et al.*, "Criteria for Evaluation of Econometric Models," *Annals of Economic and Social Measurement*, Vol. 1, No. 3, July 1972, pp. 291–324.
[5] Fair, R. C., "A General Disequilibrium Model of Macroeconomic Activity" (mimeographed), Princeton University, 1973.
[6] Goldfeld, S. M. and R. E. Quandt, *Nonlinear Methods in Econometrics*, Amsterdam, London: North-Holland Publishing Co., 1972.
[7] Guthrie, H. W. *et al.*, "Microanalytic Simulation of Household Behavior," *Annals of Economic and Social Measurement*, Vol. 1, No. 2, April 1972, pp. 141–170.
[8] Orcutt, G. H. "Simulation of Economic Systems," *American Economic Review*, December 1960, pp. 893–907.
[9] Pechman, J. A. and B. A. Okner, *Who Bears the Tax Burden?* Washington, D.C.: The Brookings Institution, 1974.
[10] Phelps, E. S. *et al.*, *Microeconomic Foundations of Employment and Inflation Theory*. New York: W. W. Norton & Co., 1970.