Health Manpower Planning: An Econometric Approach

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Two econometric models that can be used to study health manpower policies are described. Both are models of the entire health care system, treating both demand for and supply of health services and health manpower. The first is a macroeconometric model utilizing aggregate data to investigate issues in comprehensive health planning at the national, state, and substate levels. The second is a microsimulation model treating the interactions of individuals, health manpower personnel, health service institutions, and health professions educational institutions in the analysis of health manpower policies for the nation as a whole. The conceptualization of both models is presented and their current implementation status discussed.

Econometric models of the health care system have enormous potential for analysis, forecasting, and policy evaluation. The purpose of this article is to describe two such models, currently under development at the Human Resources Research Center of the University of Southern California, that could be used to gain further insight into the complex nature of the health care system, to predict the future of that system, and to guide policy decisions by indicating the health manpower implications of such decisions.

Models can take a variety of forms, including verbal paradigms, geometric diagrams, mathematical relationships, and computer routines. The econometric models discussed here incorporate all these forms in that they are built on verbal and geometric models, they typically take the form of a set of mathematical relationships, and they can be programmed for computer simulation.

The extent to which a model serves a useful role in planning depends, of course, on the relevance and validity of the initial conceptualization, the adequacy of the mathematical equations to embody this conceptualization, the

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accuracy of the data used to fit the parameters, and the range of alternative policies the model treats.

A simple model, widely used in day-to-day manpower planning but failing to meet these criteria, is the ratio method [1]. This technique takes as constant the ratios of certain categories of health manpower to a population or a population subset. These ratios are then used for comparisons and projections. Using this approach it might be calculated, for example, that Arkansas, with a ratio of 0.8 physicians per thousand persons, "needs" an additional 1500 physicians in order to achieve an "adequate" level of medical care—assuming that the relatively high California ratio of 1.6 per thousand represents an "acceptable" standard of adequacy. The ratio approach is simple and inexpensive, but as a useful health manpower planning tool it has serious limitations. One is the obvious fact that only quantities of manpower—say, physicians—and numbers of persons are included; the implicit assumption is that changes in other variables are irrelevant. Thus it is implied that nurses, other ancillary personnel, and capital need not be considered, since presumably physician productivity is constant; prices and average incomes need not be considered, since presumably demands for health services are independent of prices and ability to pay; and wages and other costs need not be considered, since presumably supplies of health manpower and health facilities are independent of wages and other costs. Clearly, however, these "other variables" ignored by the ratio technique are important.

Econometric models of the health care system treat the variables ignored by the ratio technique. Two general types of econometric model are discussed in the economics literature: *macro* models, which focus directly on relationships among aggregate variables; and *micro* models, which deal explicitly with the behavior of individuals and institutions. A macro model of the health care system would be capable of predicting aggregate magnitudes such as total bed days directly from other aggregates such as total income and total population. A micro model could also predict total bed days by predicting bed days for each individual or institution in a representative sample and then aggregating. Both types of model can apply to a particular geographic area—whether a state, a region, or the entire nation. A micro model of a given geographic area would be more complex than a macro model of the area but would yield distributional as well as aggregate impacts of major policy initiatives (for example, impacts on different population groups such as the aged, the poor, or the nonwhite).

The challenge in developing a microsimulation model is to balance the desire for comprehensive analysis against the temptation to reach for too much detail and intricacy in modeling individual behavior. The challenge in developing a macroeconometric model is to balance the desire for a simple uncomplicated analysis against the necessity of building in sufficient detail to make the model useful to policy makers. Micro and macro models can thus be viewed on a continuum of degrees of detail and aggregation. The models discussed in this article represent a balancing of detail and aggregation: the macro model is more detailed than most other macro models of the health care system [2–5] and the micro model more aggregative than most previous microsimulation models of other systems. (There have been no previous microeconometric models of the health care system, although there are numerous operations research models that simulate individual health service institutions, such as the one developed by the Research Triangle Institute [6].)

Macroeconometric Model

The intent of the macro model being developed at the Human Resources Research Center is to assist regional and subregional Comprehensive Health Planning agencies in their efforts to deal with supply and demand; plan for health services, manpower, and facilities; examine the long-run as well as immediate impacts of changes; and analyze the simultaneous action of a wide variety of alternative policy instruments on many types of participants. The construction of the model has proceeded in three phases. The first phase is conceptualization —identifying the major economic features of the health care system and their demand-supply interrelations. The second phase is estimation of the model by the use of statewide data, determination of the quantitative importance of the interrelations, and examination of "outliers." The final phase is simulation of the model, to replicate the recent period and to provide conditional forecasts of variables under alternative policy initiatives. The basic model and some preliminary empirical results have been presented elsewhere [7].

The scope of the model represents a trade-off between intricate detail and greater relevance on the one hand and feasibility and data availability on the other. The model is presently limited to personal health services, not including mental health, drug, and dental services. The six categories of health service institutions and seven categories of health manpower included in the model—in part because of their relevance to health planning—are as follows:

Health service institutions:
- Voluntary and proprietary short-term hospitals
- State and local governmental hospitals
- Skilled nursing homes
- Outpatient clinics of nonfederal hospitals
- Offices of medical specialists in private practice
- Offices of surgical specialists in private practice

Health manpower:
- Medical specialists and general practitioners in private practice
- Surgical specialists in private practice
- Physicians employed by hospitals
- Hospital interns and residents
- Registered nurses
- Allied health professionals and technicians
- Nonmedical personnel (e.g., housekeeping, maintenance, clerical)

For each category of health service a demand and a supply equation are used to explain the utilization rate (quantity) and the price. The sum of the quantities of health services produced is used in determining the derived demands for each

Fig. 1. General structure of the macroeconometric model.

type of health manpower. These demand equations, in conjunction with the corresponding health manpower supply equations, yield market wage rates. (Some of these equations are only implicit in the econometric model, but all are included in the theoretical conceptualization of the personal health care system.)

Figure 1 illustrates the relationships among the participant groups in the model. Consumers, providers, and manpower are linked through services s and labor m markets (diamonds). The lettered arrows represent groups of equations in the model, while the symbols in each diamond are the variables determined: quantities (Q) and prices (P) of services and manpower. Demand-relationship arrows (A, C) point to the right; those pertaining to supply, to the left (B, D).

Since the model is specified for a region and is estimated by the use of statewide data, it can readily treat policy changes at the local or state level that are of major importance to regional and subregional CHP agencies. It can also be used to evaluate the effects of a national policy on a state, or on the nation as a whole provided that changes in other states are taken into account. Certain policies might, for example, have effects on the migration of physicians between states, necessitating consideration of other states. A sharp distinction must therefore be made between responses to policies implemented by only one state and responses to policies affecting all states.

The workings of the full model can be seen by tracing sequentially the interdependencies in the model via the description of a potential policy simulation. One policy examined by the authors within the framework of the model is a substantial extension of health insurance coverage by a large-scale federal program [8]. Since this is a national program, it would be necessary, when carrying out the actual simulation for a state, to adjust for the impact of the program on other states. Keeping in mind the necessity of such an adjustment, it is instructive to trace the probable impacts of national health insurance on the demand for health services, the supply of health services, the demand for health manpower, and the supply of health manpower, as shown from left to right in Fig. 2.

An extension of health insurance coverage of considerable magnitude would initially stimulate consumers in a state to demand greater amounts of patient days and patient visits from health care institutions. (See relationships 1, 5, 10, 14, 15, 19, and 21 in Fig. 2, which represent equations in the model).[1] This

[1] Certain definitional identities included in the model do not appear as numbered arrows in Fig. 2. These include the sum of nonfederal outpatient visits from emergency room and other clinic visits; total patient days, beds, and outpatient visits, calculated by adding the quantities pertaining to federal hospitals (which are treated as exogenous to the model) to the corresponding endogenous variables for nonfederal hospitals; and, in the health manpower sectors, the total numbers of interns and residents, hospital physicians, and private practice physicians.

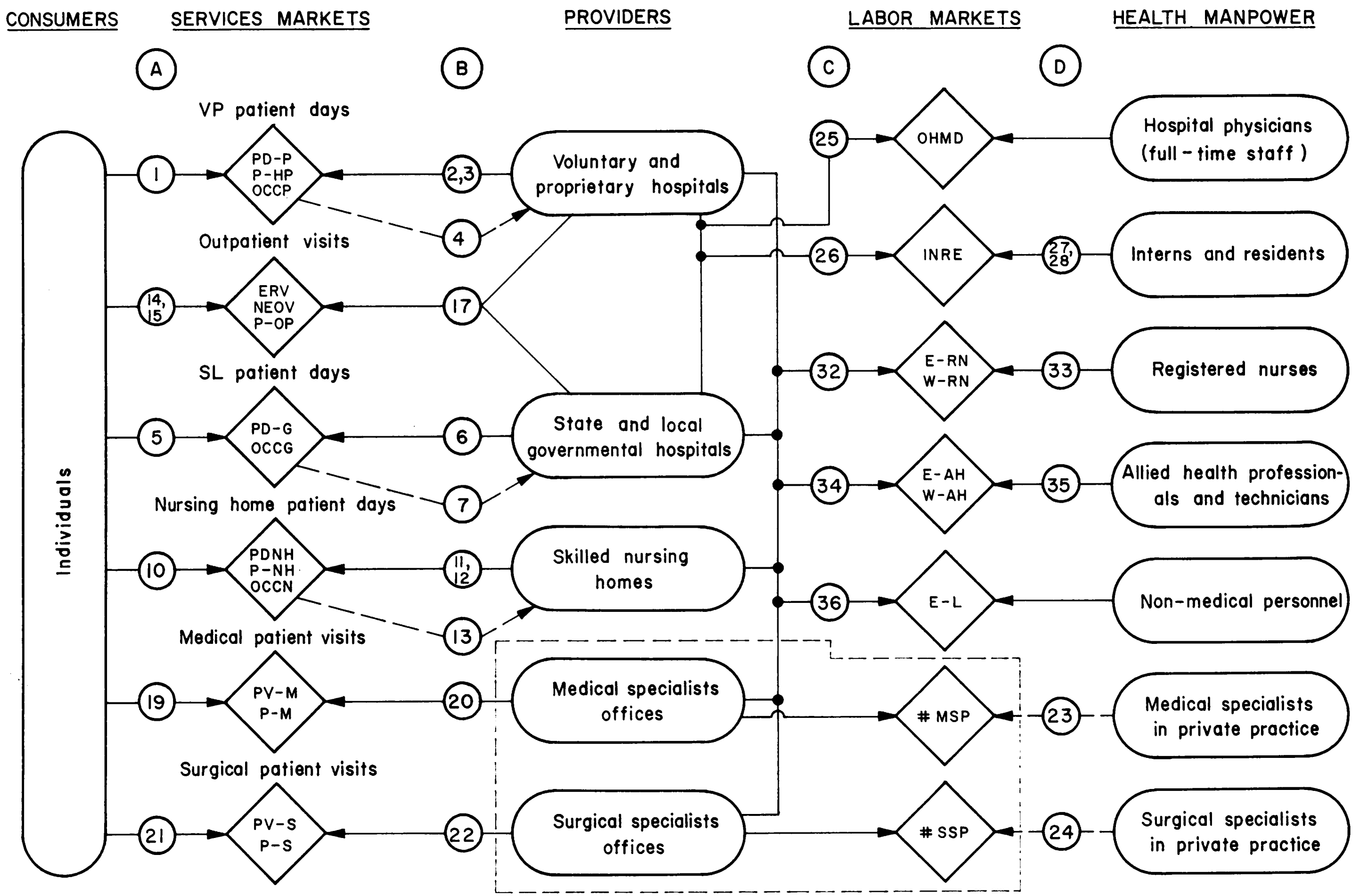

Fig. 2. Flow diagram of macroeconometric model for regional health planning.
(All variables pertain to an areawide unit of observation.)

Key to Fig. 2

PD-P	annual number of inpatient days provided by all short-term voluntary and proprietary (STVP) hospitals
P-HP	average daily service charge in STVP hospitals
OCCP	average occupancy rate in STVP hospitals
ERV	annual number of hospital emergency room visits
NEOV	annual number of patient visits to hospital outpatient clinics
P-OP	average revenue per visit at hospital outpatient clinics
PD-G	annual number of inpatient days provided by short-term state and local government (STSLG) hospitals
OCCG	average occupancy rate in STSLG hospitals
PDNH	annual number of patient days provided by skilled nursing homes
P-NH	average charges per patient day in skilled nursing homes
OCCN	occupancy rate of skilled nursing homes
PV-M	annual number of patient visits to medical specialists in private practice
P-M	price per visit to medical specialist (routine follow-up visit)
PV-S	annual number of patient visits to surgical specialists in private practice
P-S	price per visit to surgical specialist (appendectomy by general surgeon)
OHMD	number of physicians (nonstudent) employed by hospitals
INRE	total interns and residents employed
E-RN	number of RNs employed
W-RN	wage of hospital (general duty) RNs
E-AH	number of allied health professionals and technicians
W-AH	average wage paid to allied health personnel
E-L	number of nonmedical personnel employed by health service institutions
#MSP	number of medical specialists in priate practice
#SSP	number of surgical specialists in private practice

would tend, during the current period, to increase both prices and quantities in the health services markets, with the degree of price inflation being a function of the responsiveness of health services supply (2, 11, 17, 20, 22).

The number of beds is not influenced within the current period, so an induced change in capacity would not be immediately forthcoming. The increase in patient days would thus raise occupancy rates at inpatient institutions (3, 6, 12). Over several periods the increase in occupancy rates and the higher prices for inpatient services would lead providers to augment the number of beds, which, depending on how substantially the supply of beds responds (4, 7, 13), would tend to ameliorate the rate of price inflation.

The increase in patient visits to physicians and the increase in the prices for these visits would tend to increase the (implicit) demand for physicians, which would be manifested in the model by (perhaps small) increases in the number of medical and surgical specialists (23, 24).

Greater amounts of patient days in hospitals and larger numbers of visits to hospital outpatient clinics and emergency rooms would increase the demand for hospital-employed physicians (25), with similar effects on the number of residencies and internships offered (26). Since the number of domestic interns and residents is assumed to be insensitive in the short run, there would be no immediate increase in the number of such physicians (27), but higher numbers of residencies and internships offered would influence potentially the number of interns and residents from foreign medical schools (28). Thus the total number of residents and interns in the state would tend to grow (by perhaps small amounts initially), but it is also likely that there would be an increase in unfilled residencies and internship positions.

Larger numbers of services demanded and higher prices would stimulate the demand for registered nurses (32) and, depending on the availability of RNs (33), increase their employment and wages. Similar effects could be predicted for allied health personnel (34 and 35).

The increase in the services produced and prices of these services would also increase the employment of types of nonmedical personnel (36). An ample supply of such personnel is assumed to be available from other industries, so no significant wage change induced by the increased demand from this source of employment would be anticipated.

Microsimulation Model

The second model currently under construction at the Human Resources Research Center is a microsimulation model of the health care system [9]. The purpose of this model is forecasting and policy evalution on the national level of the demand for and supply of health services, health manpower, and health professions education.

The microsimulation model, unlike the macroeconometric model, deals explicitly with the behavior of a representative sample of the individual consumers and institutions making up the health care system. It includes all aspects of the production and utilization of personal health care except mental and dental health care; drugs and biomedical research, as well as environmental services, are excluded. Even with these limitations the system under consideration is extremely complex and rich in structural and institutional detail, involving as it does many different participants, institutions, complex multiparty transactions, and the like.

To cope with the complexities of the health care system in this degree of detail a modular approach has been employed, organizing the system into separate modules for health services, health manpower, and health professions education. These modules were chosen because interactions among the modules are fewer and simpler. Typically, the interactions within a module must be considered with reference to specific individuals or institutions, while those among modules can be dealt with in terms of aggregates over individuals or institutions. The modules and interactions, which summarize the conceptualization of the model, are displayed in Fig. 3 (p. 142). In this conceptualization there are five simulated populations. Three of the populations are composed of people: individuals, health manpower, and potential students. The remaining two populations consist of health services institutions and health professions educational institutions. The individuals and institutions in each of the simulated populations are described by the attributes or characteristics shown in the accompanying tabulation.

Each module contains markets corresponding to its particular sector of the health care system, and these markets are influenced by the simulated populations as shown in Fig. 3. Thus in the health services module the demand for health services is generated by the population of individuals, and the supply of health services is generated by the population of health service institutions. In the health manpower module the demand for health manpower is obtained from the population of health service institutions, as derived from the underlying demand for health services. The supply of health manpower is obtained from the population of health manpower. Finally, in the health professions education module, the demand for health professions education is generated from the population of potential students, while the supply is generated from the population of training institutions.

Some of the markets in each module may be characterized by widespread and persistent disequilibrium. This is reflected in the model by variations in waiting time, with shortages and surpluses allocated according to the nature of the disequilibrium.

Perhaps the best way to describe the set of interactions that takes place among the five populations is to summarize the events occurring in a typical simulation run. Before simulation begins, each of the five populations is generated and initial conditions are specified for values of the lagged variables. The solution sequence is shown in Fig. 4 (p. 144), in which linkages are indicated by their numbers in Fig. 3. Major clusters of these linkages are enclosed in the boxes lettered *A* through *F*.

Cluster A. A diagnostic condition is assigned to an individual from the gen-

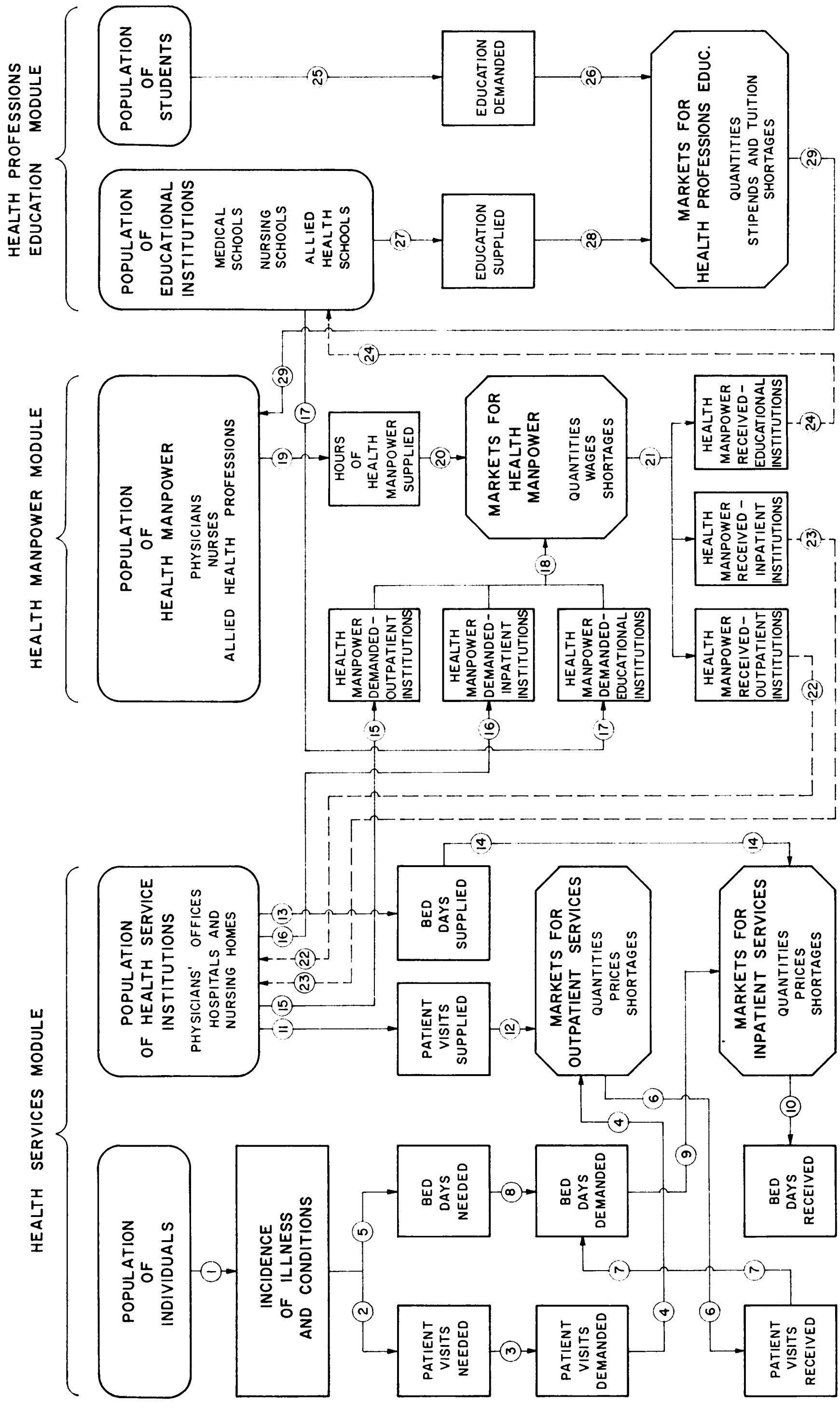

Fig. 3. Microsimulation model for health manpower demand planning.

Attributes of Populations Included in the Model

Attributes of individuals:
- Age
- Sex
- Ethnic group
- Marital status
- Residence
- Health insurance status

Illnesses and conditions:
- Infective and parasitic
- Respiratory
- Digestive
- Injuries
- Other acute
- Maternity and newborn
- Good health

Attributes of physicians:
- Specialty
- Age
- Career status (e.g., intern or resident, practitioner)
- Foreign or domestic medical graduate
- Type of employment (e.g., salaried, self-employed)

Attributes of nurses and allied health professionals:
- Age
- Sex
- Marital status
- Length of training

Attributes of students:
- Age
- Sex
- Ethnic group
- Marital status
- Type of previous education

Attributes of health service institutions:
- Physicians' offices
  - Specialty
  - Size
  - Nature of payment
- Hospital clinics
- Hospitals
  - Length of stay
  - Ownership or control
  - Size
  - Medical school affiliation
  - Nature of payment
- Skilled nursing homes
  - Size
  - Medicare certification

Attributes of medical schools:
- Size
- Ownership
- University affiliation

Attributes of nursing and allied health schools:
- Size
- Length of program
- Ownership

eral population, and his needs for patient visits (2) and bed days (5) are determined. His needs for patient visits are adjusted according to his income and the prices he faces, to yield his demands for patient visits (3). The demands for patient visits are then aggregated over all individuals to obtain market demands for outpatient services (4). The determination of bed days demanded is slightly more complex because of the customary requirement that a physician be seen before a patient is admitted to a hospital. As with patient visits, quantities of bed days needed are transformed into demands by taking account of prices and financial constraints (8). Additionally, however, estimates of the physician visits are employed (7) to adjust for the physician-approval aspect of hospital admission. Thus if fewer patients manage to see physicians, fewer patients will demand care from hospitals. Bed days demanded by individuals are then aggregated (9) to yield market demands for inpatient services.

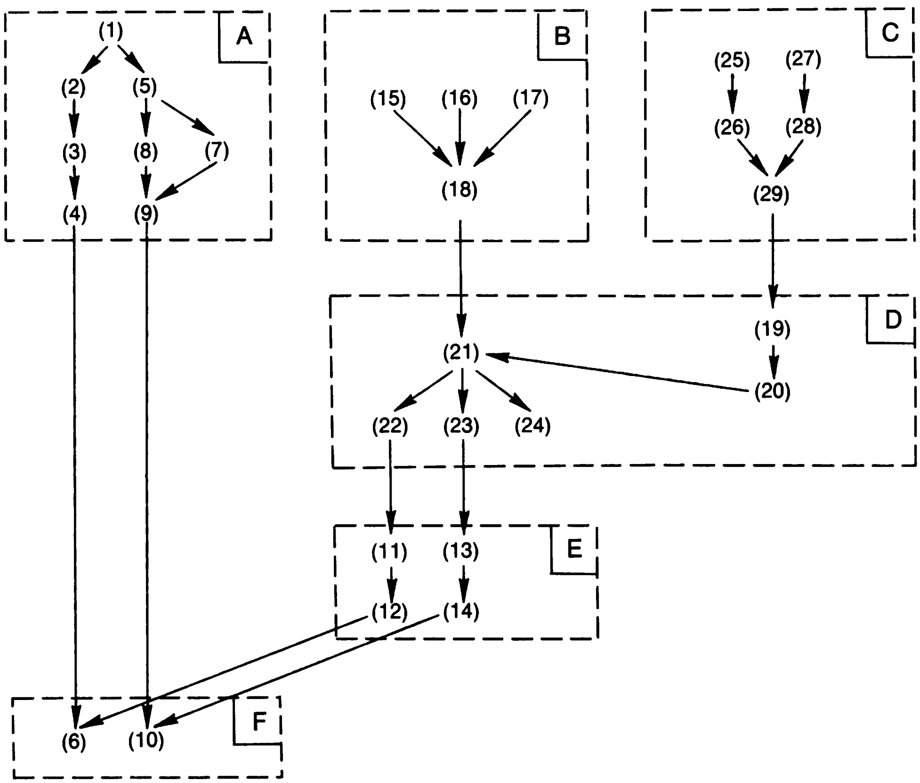

Fig. 4. Solution sequence of mircosimulation model for one period. Numbers refer to linkages shown in Fig. 3.

Cluster B. On the basis of the demands for the outputs of the service institutions, demands for health manpower are derived separately for the various types of outpatient institutions (15) and inpatient institutions (16). These manpower demands are aggregated to give part of the market demands for health manpower. Additional health manpower demands come from educational institutions for faculty (17). The demands for manpower from all three sources —outpatient, inpatient, and health professions educational institutions—are aggregated to give market demands for each category of health manpower (18).

Cluster C. The population of students generates individual demands for health professions education (25), which are aggregated to obtain market demands (26). The population of health education institutions meanwhile determines the supply of openings at individual institutions (27), which are aggregated to obtain market supplies (28). If market demands for education exceed available openings, as expected for physicians, the scarce openings are allocated among the students. Conversely, if the number of openings exceeds the number of qualified applicants, as expected in nursing programs, the vacancies must be allocated among the programs. Students graduating from the health education institutions (29) enter the various pools of health manpower.

Cluster D. The pools of health manpower, augmented by graduates, yield individual supplies of hours of work (19) which are aggregated over all similar types of individuals to obtain market supplies, in terms of hours of work offered, for all types of health manpower (20). These supplies interact with the demands previously determined in *B* to determine wage adjustments, shortages, and the actual allocations of manpower to various types of institutions (21), resulting in health manpower received by outpatient institutions (22), inpatient institutions (23), and educational institutions (24).

Cluster E. The health service institutions have now received the manpower inputs that constitute their capacity to provide services. The manpower allocation to outpatient institutions determines the supply of patient visits (11), which are aggregated to determine total patient visits (12). Similarly, the manpower allocation to inpatient institutions sets limits to the amount of bed days they will seek to supply (13), which are aggregated to determine total bed days (14).

Cluster F. Finally, supplies of patient visits interact with outpatient demands determined in *A* to produce changes in prices and waiting times and to result in allocations of physician visits to the different categories of patients (6). Similarly, supplies of bed days interact with inpatient demands determined in *A* to produce changes in prices and waiting times and to result in allocation of bed days to the various types of patients (10).

Additional periods are then considered by updating all populations and repeating the above solution steps.

Implementation of the Models

This article focuses on the conceptual design of two models similar in scope but utilizing quite different techniques. Conceptualization is, however, only the first of several steps in the process of constructing an operational model. Before a model is made fully operational, a considerable amount of data must be assembled, the parameters of the model must be estimated, and an extensive program of experimentation must be conducted to test the behavior of the model.

Data on all the variables specified in the macroeconometric model have been assembled at the national and state levels from such well-known sources as the American Hospital Association, the National Center for Health Statistics, the American Medical Association, and Medical Economics, Inc. These data are far from perfect. For example, although large amounts of data are available on both patients and health service institutions, data linking the characteristics of patients to those of institutions are scanty. Furthermore, a frequent limitation of published data of the sort employed in the implementation of both models is that they are presented in simple tabular form, which may suffice for reference purposes but is rarely adequate for rigorous statistical analysis.

In view of the deficiencies of the available data, the three choices were to undertake an enormous data collection project, to wait to implement the conceptualized models until more nearly "ideal" data were available, or to move ahead on the basis of existing data. The last approach was selected, since it was judged preferable to exploit the best data available, to state clearly their limitations, and to suggest ways by which the data could be improved. In fact, one of the benefits of constructing operational versions of the models presented is that this forces one to evaluate the available data from a different perspective. Indeed, the ongoing modeling efforts may well have some influence on the design of future surveys and the forms in which the results are presented. If so, the pool of data available for further work along these lines will be considerably enhanced.

After all the data have been gathered, the parameters of all relationships specified in the models must, of course, be estimated. The relationships specified in the macroeconometric model have all been estimated by regression analysis [8]. In addition, experiments have been started on the macroeconometric model to evaluate its performance over historical periods.

Implementation of the microsimulation model has begun only recently. Many of the data required for this model have been assembled and some of the relationships have been estimated. It is expected that an initial version of the model will be running within a year.

Discussion

There are important similarities and differences between the macroeconometric and the microsimulation models. While both treat the entire system, the macro model deals directly with aggregate behavior, whereas the micro model deals also with individual behavior. Both are highly simplified in contrast to the complex real-world health care system, but the macro model involves even greater simplifications than the micro model. Most significant, however, is the fact that the two models are highly complementary in modeling the complete system, with the macro model oriented toward comprehensive health planning in regional and subregional areas and the micro model emphasizing health manpower and health professions education for the nation as a whole.

Perhaps the most important reason for modeling the entire system is that such models can be of tremendous value in designing and evaluating policy with respect to national health programs. The alternatives are either to evaluate policy on the basis of studies focused on only one small part of the system or to experiment in the real world. But studies dealing with only isolated aspects of of the system—such as demand for hospital services or "shortages" of physicians —cannot account for the important interdependencies in the system. On the other hand, large-scale experimenting in the real world (e.g., Medicaid) can be extremely expensive in terms of both cost and human suffering.

With running macroeconometric and microsimulation models of the sort described, it would be possible to experiment on the models rather than on the real-world health care system. Comparable procedures are routinely used in studies of complex physical phenomena (e.g., the use of wind tunnels to study aerodynamic behavior). Within the next decade, econometric models could well be similarly used routinely to study and evaluate policies so as to obtain a more efficient allocation of health manpower and related resources.

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