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A MICROECONOMETRIC MODEL OF THE HEALTH CARE SYSTEM IN THE UNITED STATES*

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A microeconometric model of the health care system of the United States was estimated by applying econometric techniques to extensive data. The model treats the microanalytic behavior of individuals and institutions comprising the health care system, and is structured in terms of five submodels pertaining to consumers, hospital and physician services, physician and nonphysician manpower. In each submodel there is an economic market on which demands and supplies from the individuals and institutions interact and on which the allocation of resources is determined. A detailed treatment of participant attributes facilitates study of the distributional impacts of alternative policies.

1. INTRODUCTION

Experience in the United States with Medicare, Medicaid, and other Federal programs clearly demonstrates the need to take account of factors affecting health services supply as well as demand in formulating and executing national health manpower policies. The research summarized in this paper is part of an effort under way at the Human Resources Research Center (HRRC) to develop a microsimulation model of the U.S. health care system which will permit forecasts which take into account the complex interrelations between the demand for and supply of health services and health manpower.†

Major Federal programs affecting the health care system of the United States, such as Medicare and Medicaid, have been launched with very imperfect forecasts of their likely impacts on the entire system. While it was obvious that health services utilization by the poor and the elderly would be directly affected, neither the magnitude of their responses, nor, more importantly, the impacts upon the rest of the entire health care system were accurately forecasted. But clearly, to make adequate forecasts of the system response requires an explicit treatment of all major components—health services supplies, and health manpower demands and supplies. In this respect we share the view expressed by Feldstein and Friedman (1974) as follows:

> A serious weakness of all previous microsimulation studies of national health insurance . . . has been the neglect of the supply and price response to national health insurance . . . . Most of the debate about the effects of national health insurance has focused on the uncertainty about the responsiveness of household demand. The current study shows that our uncertainty about supply response may be even more important.‡

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† For a detailed description of the conceptualization of the model see Yett, Drabek, Intriligator, and Kimbell (1970).

‡ Feldstein and Friedman (forthcoming).

We refer to our model as a "microeconometric" or "microsimulation" model because we have followed the tradition of Orcutt and his colleagues who start by explaining the behavior of representative individual participants (e.g., consumers, firms) and then reach predictions about the entire system by explicitly aggregating over these individual predictions.* Accordingly, we share their emphasis on the distributional impacts of public policy on specific types of persons or firms (e.g., elderly white females, small voluntary hospitals, solo pediatricians). Distributional impacts can only be addressed very crudely and indirectly using macroeconometric approaches, but can be easily studied using microeconometric approaches. Another natural advantage of this approach is that it can readily exploit economic theory that concentrates on individual behavioral units. It is rarely the case that relationships which are postulated to hold for each of many individuals will necessarily imply that the same relationship will hold for aggregative variables.† Alternatively, the "aggregation problem" usually implies that one can only assert "analogous" relationships, not ones rigorously and explicitly derived from microanalytic foundations. The obvious disadvantage of the microeconometric approach is that it is more demanding in terms of data, estimation and validation.‡ Furthermore, the empirical results for aggregate variables may turn out to be similar to those identified by "analogous" macrorelationships.

Another model which resembles ours in certain technical ways is the Detroit Prototype of the NBER Urban Simulation Model.‖ Although the phenomena being simulated are quite different, both models attempt to deal with large sets of participants by modeling their demands or supplies of services, the resulting market interactions and, therefore, the process of resource allocation by explicit microanalytic simulation. Both are policy-oriented operational tools in the early stages of development. Each is primarily based on large cross-sectional data files, and each generates substantial detail in depicting the processes at work in the sector studied. Each has been made feasible by the rapid advances in computer technology for the statistical estimation of large numbers of relationships using large files and for simulation of the complex events taking place. Neither model resembles in these respects the macroeconometric models that were developed in the sixties, not even the so-called "large-scale" macroeconometric models, such as the Brookings–SSRC model.

It is not surprising, therefore, that the technical problems encountered in the development of the NBER Detroit Prototype model parallel those we have encountered. These difficulties include lack of adequate price data, especially severe regarding the problem of cross-price elasticity estimation when the number of

* See Guthrie, Orcutt, Caldwell, and Peabody (1972) and Orcutt, Greenberger, Korbel and Rivlin (1961).

† Cf. Theil (1954) who shows this even for the simplest case of *linear* relationships.

‡ We have found that the computation cost differential between the construction and use of our microeconometric model of the health care system (discussed here) and our macroeconometric model [discussed elsewhere, see Yett, *et al.* (1974)] is negligible. One reason is that our microeconometric model uses expected values for individual types of persons, not Monte Carlo random number generation (e.g., we use the expected [mean] patient visit rate for poor white females aged 30 to obstetricians for given prices, rather than a draw from a complete probability distribution). If the sample size is large enough to give reliable results, then the average value of many random drawings will be very close to the expected value under the conditions present in our model. A detailed comparison of the two approaches is presented in Yett, Drabek, Intriligator, and Kimbell (1970).

‖ See Ingram, Kain and Ginn (1972).

alternative products is considerably larger than the two-good textbook examples.* Problems of model "validation" are also shared, since a model that is very specific in its behavioral implications for each of many phenomena, for each of many years, cannot possibly be accurate for each and every prediction made. In particular, "the" accuracy of an ambitious model cannot be addressed with the simple concepts which may describe the accuracy of single equation models (e.g., the R-square of a single regression equation model provides a much abused scalar measure of "fit"). Even if the model depicts many relationships quite well, there are so many predictions attempted that there are always some that do not work well initially. An excellent introduction to the problems of model evaluation is provided by Dhrymes and his colleagues.†

Work to date on the development of the HRRC Microsimulation Model has been guided by several considerations—in particular, the constraints imposed by currently available data and the difficulties inherent in empirically implementing certain theoretical constructs even when adequate data are at hand. We adopted as our research strategy the implementation of a prototype containing most of the basic features of the full-scale model, rather than concentrating on the refinement of individual sectors in isolation from the rest of the system. In this manner, we are now in a position to evaluate the desirability, and likely consequences, of further developing each sector. Finally, at all stages of the research we tried never to lose sight of the fact that the intended use of the model is for policy analysis.

The resulting model has several unique features. It incorporates numerous feedback mechanisms which allow the effects of a change in one sector to be transmitted over time to other sectors of the health care system. Thus, for example, when it is used to simulate the impacts of alternative National Health Insurance proposals, the results will reflect not only the configurations of the services supply and manpower sectors but also the linkages between them.‡

The remainder of the paper is organized into three sections. The first presents an overview of the prototype model and describes each of its interrelated submodels. The second reports the results of an historical simulation run for the hospital sector, and outlines our plans for further research. The third reports some preliminary conclusions.

2. Description of the Model

2.1. *Overview*

The HRRC Prototype Microsimulation Model consists of five major components or submodels. Each submodel is largely self-contained from a computer programming standpoint. That is, in developing the overall model, each submodel

* As Ingram, *et al.* express it, "The difficulty of devising an *operational*, yet theoretically defensible, technique of forming prices in a dynamic context may have been the greatest single obstacle to the development of a market model of housing choice and residence location" [emphasis added]. Our experience has also been that it is relatively simple to develop an *abstract*, general equilibrium, *theoretical* model of resource allocation, but it is much more ambitious to find robust *operational* content to implement this theoretical vision.

† See Dhrymes, *et al.* (1972).

‡ By contrast, Wilensky and Hollahan (1972) present a detailed study of the impacts of NHI proposals on consumer demand assuming a perfectly elastic supply of medical care resources.

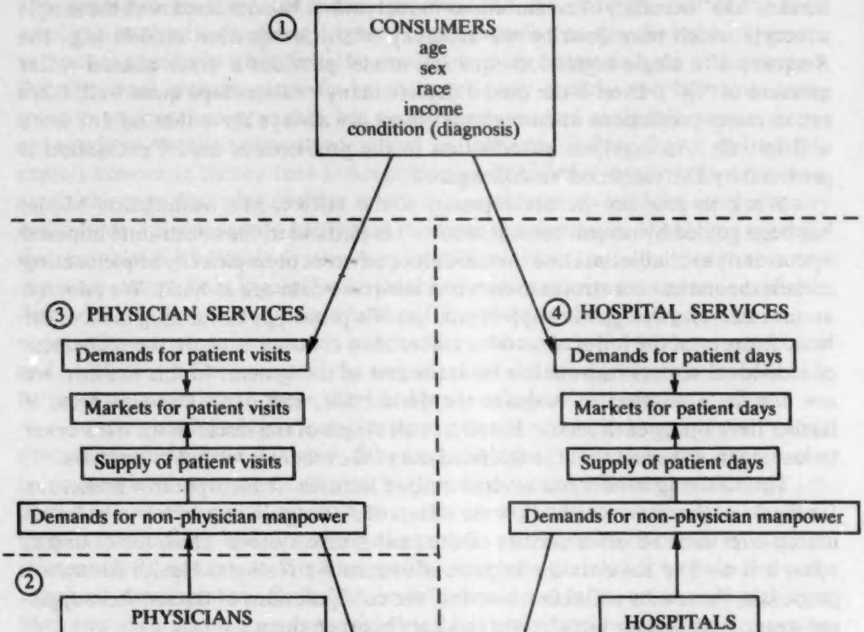

Figure 1 Block Diagram of the HRRC Microsimulation Model

was coded and "debugged" in isolation from the rest of the model. Moreover, in some instances it is efficient to perform experiments by manipulating the relevant submodel before allowing its effects to be transmitted to the rest of the model. Figure 1 illustrates the overall model and the role played by each submodel.

The first submodel generates a population of consumers or individuals who demand medical services. The computer program outputs annual estimates of the nation's population subdivided into cells according to the attributes age, sex, race, and income. This is accomplished by annually updating an initial population in response to exogenously determined birth, death and immigration rates.

The second submodel involves a similar computer program which generates a population of physicians, providing annual estimates of the stock of MDs subdivided into cells according to their age, specialty, and type of professional activity. Since U.S. and foreign medical school graduates differ dramatically in terms of their attribute distributions separate computer subroutines are used to generate the populations of the two types of physicians. The former are influenced by the volume of graduates from the nation's medical schools and physician deaths. The latter are influenced by net migration.

The two submodels which project the population of consumers and physicians over time are run first. Output from these submodels is then used as input to the other three submodels. This reflects our current simplifying assumption that these populations affect the rest of the health care system but are not affected by the processes endogenous to the other submodels.

After the consumer and physician submodels generate their respective populations, the physician services submodel computes: (i) the demands by each consumer group for patient visits from physicians in private practice and hospital-based clinics; (ii) the supply of patient visits by MDs in office-based practice; and (iii) their demands for aides (i.e., non-physician manpower). The discrepancy between demand by consumers and supply by physicians leads to adjustments in the prices of patient visits, which, in turn, affect the solution of the submodel in the next period (year).

The fourth submodel computes the demands by each consumer group for patient days at short-term and long-term hospitals. More precisely, the number of patient days is derived from separate equations for the admissions and average length of stay for each cell. Hospitals are characterized by ownership and bed size. Skilled nursing homes are included as a type of long-stay hospital. Hospital demands for non-physician manpower are based on patient days and outpatient visits to clinics and emergency rooms (determined by the previous submodel). The price of hospital care is primarily dependent upon labor and non-labor costs and the occupancy rate of hospitals. Over time the supply of hospital capacity, as measured by the number of hospital beds, adjusts to changes in the volume of patient demands.

The fifth submodel computes the supply of non-physician manpower. The routine for generating the stock of registered nurses is similar to the physician submodel, but the supply of RNs is influenced by the changes in their wage rates. Because of data limitations, the supply of licensed practical nurses (LPNs) and allied health professionals is presently treated as exogenous. The supply of other personnel is also exogenous to the model, but for a different reason. The supply of such manpower (e.g., clerks, secretaries, janitors, etc.) is largely exogenous to the health care system itself and, thus, in the model it is assumed to be perfectly elastic. The manpower demands by physicians and hospitals, together with the supply of manpower, are used to adjust wage rates for RNs, LPNs, and allied health professionals.

The solution of the third, fourth, and fifth submodels is repeated in the same sequence for each period (year) of the simulation.

2.2. *Consumer Population Submodel*

The function of the consumer population submodel is to provide data on the composition of the population. Initially, we are only concerned with the impact of changes in the population on the demands for health services. The present submodel is sufficient for this purpose. In further research we intend to draw on the knowledge accumulated by demographers and economists who have developed more sophisticated models of population generation.*

As previously noted, the consumer population projection submodel employs the expected value rather than the Monte Carlo approach to microsimulation in order to minimize computational complexity and cost. For each year the population data are stored in 344 cells which are derived from 86 age cohorts subdivided by sex and race.† The first cohort includes births that occur during the previous year and the eighty-sixth cohort contains individuals of age eighty-five and older. With this distribution established for an initial year, the population of individuals for any succeeding year is the joint distribution of the previous year adjusted for deaths, births and immigration which take place within each cohort during the period. Historical estimates are used in simulating the recent past, while nonlinear extrapolations are employed in making projections.

Predicting the distribution of income over time is a formidable task, even though income distribution has been the subject of considerable economic analysis at both the theoretical and empirical levels. In the context of the prototype model our primary concern was to link the population generation submodel to the National Center for Health Statistics Health Interview Survey (HIS) data on consumer utilization of health services. The HIS collects data on total household income from all sources; and, in the processing of these data, individuals are regarded as family members.‡ By contrast, other data sources such as the Census Bureau focus on total family income or on individual earnings. Our approach was to calculate from the HIS data the percentage distribution of indiviuals in each age/sex/race cohort for three household income classes (less than $5,000, $5,000–

* As long as population is exogenous to the rest of the model, it would be relatively easy to merge another submodel with the rest of our model. However, there are some important linkages concerning illnesses and conditions which we intend to introduce in further research. At that stage the compatibility of our model with others is less clear.

† The general population submodel produces a more detailed age distribution than is currently used in the rest of the model (i.e., the population is aggregated into 9 age groups to get the demands for hospital and physician services). Nevertheless, this detail on the age distribution should be useful in the design of experiments affecting health services utilization. Moreover, the output from this submodel will eventually form the basis for the demand for health professions education (e.g., the demand for nurse education depends to a considerable extent on the number of 18 year old females).

‡ See U.S. National Center for Health Statistics (1971).

$9,999, $10,000 and over) as of 1969. For the years 1960–1970, we also obtained data on family income by race from the Current Population Survey.* The computer program adjusts the HIS percentages for each cohort in each year using the CPS data.

2.3. *Physician Population Submodel*

The physician population is characterized in our prototype model by the attributes specialty, age, activity, domestic-foreign trained.† The fourteen specialties exhibited in Table 1 are the most common types of specialists, with no other specialist type representing more than 2 percent of the stock of physicians.‡ Age is maintained at the one-year level of detail in order to facilitate annual updating, since with one-year intervals each cohort simply moves to the next cell. The activities represented are: (1) office-based practice, (2) interns and residents, (3) full-time physician staff of hospitals, (4) other professional activity (i.e., medical teaching, administration, research, and other), and (5) inactive.

Domestic vs. foreign medical school graduation is another attribute maintained in the population, since the activity choices of U.S. and foreign-trained physicians are quite different.

The domestically-trained physician population in our prototype model is characterized by the attributes age, activity, and specialty. It is advanced over time by adding the projected number of new graduates, then applying to each cohort physician-specific survivor and participation rates (both of which are higher than those of the general white male population).‖

Perhaps the most difficult problem in projecting the active physician stock is that of dealing with foreign medical school graduates (FMGs). This is true for a number of reinforcing reasons. First, the data on gross flows to and from the U.S. are poor by comparison with data on the stock of physicians.§ Second, the process

* See U.S. Bureau of the Census (1972).

† Currently only MDs are explicitly included. Eventually, data on DOs may be available which would permit osteopaths to be included. This would constitute a relatively minor refinement since the number of active osteopaths is small (11,381 in 1967) relative to the number of active MDs (294,072 in 1967). See U.S. Public Health Service (1969).

‡ In our prototype model the number of physicians is exogenous to the physician services submodel since we assume that variations in the endogenous variables (e.g., physicians' fees) will not alter significantly the number of physicians trained, immigrating to the U.S., dying or retiring. Subsequent refinements of the model may enable us to improve upon the current specification. Specifically, we are working on the problem of making specialty choice endogenous. This is not very important for short-run projections since it would be a number of years before variations in residency choices would impact significantly on the total stock of physician specialists.

Factors affecting specialty choice (and location of practice) are being studied in connection with a related HRRC project under a grant from the Robert Wood Johnson Foundation. One initial finding is that the specialty choice of recent medical school graduates does not appear to be significantly related to the relative current incomes of various specialists. For example, for quite a few years pediatricians have consistently reported the lowest earnings among the five largest specialties, yet the number of residents choosing this specialty has continually increased at a substantial rate.

‖ The prototype model assumes a constant life cycle activity selection for each specialty. However, using constant activity rates for each age-specialty cell does not fix the overall activity distribution, since, as each cohort matures, it also alters its activity patterns.

§ See Butter (1971) for a detailed description of the problems encountered in her attempt to obtain accurate figures on the gross outflow and inflow of FMGs.

TABLE 1

BASIC PROJECTIONS OF U.S. AND FOREIGN MEDICAL GRADUATES BY ACTIVITY AND BY SPECIALTY

	U.S. Medical Graduates					Foreign Medical Graduates					Total Graduates				
Year	Office	Inres	Hosp	Adms	Inact	Office	Inres	Hosp	Adms	Inact	Office	Inres	Hosp	Adms	Inact
1970	171459.	34580.	24305.	26359.	20111.	20980.	16648.	10563.	5951.	3075.	192439.	51228.	34868.	32310.	23186.
1971	175303.	35593.	24843.	27663.	19484.	21594.	17718.	11007.	6148.	3325.	196898.	53311.	35850.	33811.	22809.
1972	178505.	36625.	25585.	28709.	20087.	22236.	18836.	11471.	6354.	3586.	200741.	55460.	37056.	35063.	23672.
1973	181904.	37287.	26510.	29839.	20736.	22906.	20004.	11956.	6569.	3858.	204810.	57291.	38466.	36408.	24594.
1974	185253.	38254.	27890.	31008.	21434.	23607.	21225.	12463.	6794.	4143.	208860.	59479.	40354.	37801.	25578.
1975	188107.	40934.	29348.	31719.	22165.	24339.	22501.	12993.	7029.	4441.	212446.	63435.	42341.	38748.	26606.
1976	191912.	43933.	30063.	32786.	22873.	25105.	23834.	13546.	7274.	4753.	217017.	67767.	43609.	40060.	27625.
1977	195866.	47119.	30724.	33884.	23608.	25904.	25227.	14125.	7531.	5078.	221771.	72346.	44849.	41415.	28685.
1978	200287.	49871.	31542.	35112.	24374.	26740.	26683.	14729.	7799.	5418.	227027.	76553.	46271.	42910.	29792.
1979	205085.	51850.	32687.	36451.	25171.	27613.	28204.	15361.	8079.	5773.	232698.	80054.	48048.	44530.	30944.
1980	210069.	53078.	34426.	37804.	25998.	28526.	29794.	16021.	8371.	6144.	238594.	82872.	50447.	46175.	32142.

U.S. Medical Graduates (Assumes an Increase to 13,944 per Year in 1980)

Year	GP	IM	PD	O. Med	GS	OBG	OPH	ORS	O. Sur	Anes	Psych	Path	Rad	O. Spec	Total
1970	59335.	37077.	15029.	14951.	25846.	16497.	9822.	9035.	16598.	7759.	16924.	7414.	9459.	31068.	276812.
1971	58748.	38331.	15432.	15153.	26841.	16837.	10105.	9505.	17072.	7940.	17566.	7717.	9933.	31706.	282885.
1972	58165.	39682.	15870.	15372.	27913.	17205.	10414.	10009.	17585.	8135.	18256.	8042.	10439.	32425.	289509.
1973	57577.	41061.	16315.	15592.	29005.	17577.	10729.	10521.	18108.	8331.	18957.	8372.	10953.	33177.	296273.
1974	56997.	42581.	16808.	15840.	30210.	17988.	11080.	11083.	18689.	8546.	19727.	8734.	11517.	34039.	303838.
1975	56440.	44252.	17351.	16120.	31537.	18441.	11471.	11698.	19336.	8781.	20574.	9130.	12133.	35009.	312273.
1976	55910.	46071.	17943.	16432.	32982.	18936.	11901.	12365.	20046.	9036.	21495.	9561.	12802.	36086.	321566.
1977	55405.	47946.	18553.	16753.	34474.	19446.	12346.	13053.	20781.	9298.	22444.	10004.	13492.	37207.	331200.
1978	54920.	49879.	19181.	17085.	36015.	19970.	12808.	13763.	21541.	9565.	23422.	10462.	14202.	38373.	341184.
1979	54445.	51825.	19813.	17416.	37565.	20495.	13273.	14478.	22307.	9832.	24406.	10922.	14917.	39551.	351242.
1980	53973.	53780.	20449.	17747.	30126.	21019.	13743.	15198.	23080.	10099.	25396.	11385.	15638.	40742.	361373.

Foreign Medical Graduates (Assumes an Annual Growth Rate of 4.5%)

Year	GP	IM	PD	O. Med	GS	OBG	OPH	ORS	O. Sur	Anes	Psych	Path	Rad	O. Spec	Total
1970	8146.	6645.	3649.	3196.	5523.	3181.	933.	934.	2632.	3338.	5163.	3178.	1465.	9234.	57217.
1971	8021.	7021.	3845.	3313.	5943.	3366.	957.	980.	2757.	3479.	5341.	3379.	1552.	9659.	59792.
1972	8258.	7414.	4049.	3436.	6382.	3560.	982.	1027.	2888.	3626.	5526.	3588.	1643.	10102.	62482.
1973	8318.	7825.	4263.	3564.	6840.	3762.	1008.	1077.	3025.	3780.	5720.	3807.	1739.	10566.	65294.
1974	8381.	8254.	4486.	3697.	7320.	3973.	1035.	1129.	3168.	3941.	5923.	4036.	1838.	11050.	68232.
1975	8446.	8703.	4720.	3837.	7820.	4194.	1064.	1183.	3318.	4108.	3135.	4275.	1943.	11557.	71303.
1976	8514.	9172.	4963.	3983.	8344.	4424.	1094.	1240.	3474.	4284.	6356.	4525.	2051.	12086.	74511.
1977	8586.	9662.	5218.	4135.	8891.	4666.	1125.	1299.	3638.	4467.	6588.	4786.	2165.	12639.	77864.
1978	8660.	10173.	5484.	4295.	9462.	4917.	1158.	1361.	3808.	4659.	6829.	5059.	2284.	13217.	81368.
1979	8738.	10708.	5763.	4461.	10059.	5181.	1192.	1426.	3986.	4859.	7082.	5345.	2408.	13820.	85030.
1980	8820.	11267.	6054.	4636.	10683.	5456.	1227.	1494.	4173.	5069.	7346.	5643.	2538.	14451.	88856.

of simulating the migrations is generally harder than that of simulating mortality. Third, migrations are more subject to emigration policy decisions which are substantially unrelated to health care issues, and can change quite abruptly. Fourth, a number of foreign medical school graduates are not foreign citizens, but are U.S. citizens trained abroad.*

Given these difficulties, and lack of data on gross flows, we adopted the approach of estimating the net increment to the stock and distributing the new increment across specialties and activities by a constant matrix of percentages.† This matrix was a simple average of the percentage distribution of the existing stock of FMGs in 1970 and the estimated percentage distributions of the new increment of FMGs made by Butter.‡

Table 1 presents marginal distributions of the supply of MDs projected to 1980. It is apparent that proportionately more of the foreign-trained MDs are either house staff (interns or residents) or are engaged in hospital-based practice. Furthermore, simulations of this submodel show that the most critical factor influencing the supply of MDs in the short run is the net migration rate of foreign medical school graduates. High and low projections for domestic graduates in 1980 were 14,314 and 13,579 respectively, a difference of less than 1,000 MDs per year. By contrast, the assumption of a continuation of the recent historical net immigration rate of 9 percent versus projection of no net growth in the number of FMGs yielded a difference of 80,000 in the projected total stock of MDs by 1980.

2.4. *Physician Services Submodel*

The physician services submodel treats the interactions between consumers and physicians and, accordingly, provides the linkage between the population of individuals and population of physicians. It consists of three components treating: (1) the demand for outpatient physician visits; (2) the supply of such visits, and the derived demand for full-time equivalent RNs, LPNs, technicians, and other office aides; and (3) the market interactions of supply and demand for services via price adjustment.

2.4.1. *Demand for outpatient physician services.* Several alternative approaches to formulating and estimating the demand for physician services were considered. One was to assume that the elasticity of demand is constant across all consumer subpopulations and types of services and estimate a single demand equation. The other extreme of those considered was to allow the elasticities to vary across each stratum, requiring the estimation of a separate demand equation for each population groups and service type. In order to implement our prototype model a combination of both approaches was used. Price elasticities of demand were obtained by "site" (which corresponds approximately to a doctor's specialty)

* For example, of the total FMG population in the U.S. as of December 31, 1970, 5,972 (10.4 percent) were born in the United States. See: American Medical Association (1971).

Also, of the 12,072 FMGs who entered the U.S. during 1966–1968, 2,100 (17.4 percent) entered without visa and most of these were U.S. natives and naturalized citizens. See Butter (1971).

† Our current procedure is admittedly arbitrary and high priority is assigned to revising it. This may be done by having a high fraction of the new arrivals go into residency and internship, then eventually having many of these leave the U.S. and others transfer to patient care and other professional activities. Our treatment of FMGs would then parallel that of U.S. graduates.

‡ See: Butter (1971).

via a single regression over all individuals who reported a doctor visit in the previous two weeks in the 1967 Health Interview Survey (HIS). The intercepts of the demand equations for each population group were then adjusted to predict the corresponding annual rate of doctor visits per person observed in 1969.

The demand equations may be expressed formally as follows:

$$\text{(1)} \qquad \text{DOCVIS}^{d}_{ijklmt} = \alpha_{ijklm}[(\text{PDOC}_{mt})(\text{CRDOC}_{it})]^{\beta_m},$$

where DOCVIS^d is the quantity of visits demanded per person in year t, PDOC is the price per visit, CRDOC is the coinsurance rate (or the fraction of the price paid out-of-pocket), α represents the intercept adjusted to fit the mean rates of utilization in 1969 and β is the elasticity of demand. The subscripts are: age i, sex j, race k, income l, site m, and year t.

Prices vary by sites and year. Health insurance is represented by exogenous coinsurance rates that vary by age and year.

The subpopulations of consumers by which the demands vary are based on the following attribute subdivisions:

Age		*Sex*	*Race*	*Family Income*
0–5	6–16	Male	White	Under \$5,000
17–24	25–34	Female	Other	\$5,000–\$10,000
35–44	45–54			Over \$10,000
55–64	65–74			
75+				

The demands for physician visits at specified sites are as follows:

Office Visits and Inhospital Visits by Physicians in Private Practice

General Practice (GP)
Internal Medicine (IM)
Pediatrics (PED)
Other Medical (O. MED)
General Surgery (GS)
Obstetrics/Gynecology (OBG)
Other Surgical (O. SUR)
Other Specialists (O. PHY)

Hospital Based Clinics and Other Sources

Hospital clinics (HOSCLI)
Hospital emergency rooms (HOSEMER)
Telephone, home, other (TELHOM)

The estimates of the elasticity of demand with respect to price, β_m were obtained from regression analysis using the following linear specification:

$$\text{DOCVIS}^{d}_{m} = f\,(\text{Price, Income, Age, Sex, Condition}),$$

where $DOCVIS^d_m$ is the number of patient visits demanded per year from site m, Price is the cost of the most recent visit to the physician at site m, Income is the annual income of the person's household, Age is the person's age in years, Sex is a binary variable which takes the value 1 if the person is female and 0 otherwise. Each of the four condition binary variables takes the value 1 if the person has at least one chronic condition and has some activity limitation, and is 0 otherwise. Multiple variables are included to measure the severity of the condition in terms of activity limitation.

Table 2 presents the regression results for site 1 (i.e., visits to general practice physicians). The three sets of estimates it contains illustrate the importance of including condition in demand equations for medical services. Set C shows that the condition variables alone have a significant positive influence on demand. It is apparent from Set A that price has the expected negative effect on demand, while income has the expected positive effect. Set B shows that deleting the conditions variables results in a negative income elasticity. The results also show that while age is a proxy for conditions, it is much better to directly represent conditions.

TABLE 2

DEMAND FOR PHYSICIAN OFFICE VISITS TO GENERAL PRACTICE PHYSICIANS

	Specification							
	Set A			Set B			Set C	
	All Variables			No Conditions			Conditions Only	
	Coef	t-Ratio	Elas	Coef	t-Ratio	Elas	Coef	t-Ratio
Age	0.004	1.23	0.021	0.046	16.73	0.246		
Sex	1.036	8.21		0.851	6.58			
Price	−0.023	−1.31	−0.020	−0.028	−1.52	−0.024		
Income	0.017	1.21	0.018	−0.018	−1.28	−0.019		
Condition 2*	2.230	14.36					2.379	16.68
Condition 3	4.314	14.16					4.544	15.63
Condition 4	4.459	18.96					4.703	22.77
Condition 5	7.012	18.27					6.843	19.41
Constant		3.835			4.838			4.473
R-Squared		0.1146			0.0461			0.1061
F Statistic		118.20730			88.24892			216.72010
Standard Error		5.23891			5.43649			5.26282
Number of Observations		7312.0			7312.0			7312.0

* Condition 2 = 1 if 1+ chronic conditions, but no limitation of activity, 0 otherwise.
Condition 3 = 1 if 1+ chronic conditions, with limitation but not in major activity, 0 otherwise.
Condition 4 = 1 if 1+ chronic conditions, with limitation in amount or kind of major activity, 0 otherwise.
Condition 5 = 1 if 1+ chronic conditions, and unable to carry on major activity, 0 otherwise.

Our initial estimates of the price elasticity are quite low, ranging from −0.02 to −0.20. This may be due, in part, to the use of gross prices rather than prices net of health insurance benefits, and the fact that the price data pertains to the most recent visit. Nevertheless, our estimates correspond closely to those reported by other investigators.*

* See Newhouse and Phelps (1974).

Table 3 provides an example of output generated by the model. Since space limitations do not permit us to present the joint distribution of physician services demands, it gives a marginal distribution by income and site for 1970.

2.4.2. *Supply of physician services and the derived demand for ancillary personnel.* The aggregate supply of physician visits by specialty is the product of the number of such physicians in office-based practice times the productivity of the average physician in each specialty. Productivity depends first on whether the physician is in group or non-group practice.* There are 14 specialties and the group-solo distinction, giving 28 types of physicians for which separate functions are maintained to treat the supply of services and the demand for aides.

Given mode of practice, productivity for a given type of specialist depends on average annual hours of physician input and average number of nurses, technicians, and other aides employed. The output of visits is related to the inputs of physician hours and the three types of aides by estimated production functions. Physician hours are currently exogenous.† The number of each type of aide demanded depends on wages, prices, and visits. Since aides demanded and visits supplied are endogenous, this gives a system of four simultaneous structural equations for each specialty determining the quantities demanded for three types of aides and the quantity of visits supplied. The reduced form equations therefore yield nurses demanded, technicians demanded, secretaries demanded, and visits supplied, as linear functions of the product wages (i.e., wages relative to output price) of nurses, technicians, and secretaries, and hours of physician input.

$$(2) \qquad N^d_{ijk} = \alpha_{ijk} + \sum_{i=1}^{4} \beta_{ijk} \cdot \mathrm{WAGE}_i/\mathrm{PDOC}_{jk} + \gamma_{ijk} \cdot \mathrm{DOCHOUR}_{jk},$$

where N^d is aides demanded (or visits supplied), WAGE is the wage rate in dollars per week, and DOCHOUR is the number of physician hours devoted to medical practice. The subscripts are: manpower type i, specialty j, and practice type k.

The development of the current version of the supply of physician services sector has drawn heavily upon work on another study of the economics of private medical practice—including, *inter alia*, the comparison of group and solo forms of practice.‡ The equations expressing the demand for aides were derived from estimates by Intriligator and Kehrer (1973). The production function estimates were adapted from estimates by Kimbell and Lorant (1972). These two sources of estimates were used to synthesize our current version.

2.4.3. *Price adjustment procedures.* The basic assumption underlying our price adjustment procedures is that physician services markets are typically in a

* The non-group physician classification is dominated by solo physicians, and hereafter will be described as "solo" for brevity; logically the set contains two-man partnerships and "informal associations."

† Annual surveys of physician hours and incomes by Medical Economics, Inc. have shown remarkably stable hours. However, as Sloan (1974) has recently shown, it will be feasible to make physician hours endogenous in future versions of the model.

‡ This project was conducted jointly by the Human Resources Research Center of the University of Southern California and the Center for Health Services Research and Development of the American Medical Association, pursuant to Contract No. HSM 110-70-354 with the Health Services and Mental Health Administration, U.S. Department of Health, Education and Welfare.

TABLE 3

OUTPATIENT PHYSICIAN VISITS DURING 1970 BY INCOME OF PATIENT AND SITE OF VISIT (IN THOUSANDS)

Income	GP	IM	Ped	O. Med	GS	OBG	O. Sur	O. Phy	Hoscli	Hosemer	Telhom	Total
< $5000	98906.	16428.	5196.	13676.	15716.	6523.	21628.	44792.	44061.	14686.	41336.	322949.
$5–10000	129752.	25060.	31515.	19357.	22799.	25812.	35943.	48486.	40785.	20386.	63887.	463784.
$10000+	117957.	48086.	45321.	28133.	24485.	30547.	51740.	68142.	41080.	19832.	81696.	557019.
Total	346615.	89575.	82032.	61167.	63000.	62882.	109311.	161420.	125926.	54904.	186920.	1343749.

Row Percentage Table

Income	GP	IM	Ped	O. Med	GS	OBG	O. Sur	O. Phy	Hoscli	Hosemer	Telhom	Total
< $5000	30.6	5.1	1.6	4.2	4.9	2.0	6.7	13.9	13.6	4.5	12.8	100.0
$5–10000	28.0	5.4	6.8	4.2	4.9	5.6	7.8	10.5	8.8	4.4	13.8	100.0
$10000+	21.2	8.6	8.1	5.1	4.4	5.5	9.3	12.2	7.4	3.6	14.7	100.0
Total	25.8	6.7	6.1	4.6	4.7	4.7	8.1	12.0	9.4	4.1	13.9	100.0

Column Percentage Table

Income	GP	IM	Ped	O. Med	GS	OBG	O. Sur	O. Phy	Hoscli	Hosemer	Telhom	Total
< $5000	28.5	18.3	6.3	22.4	24.9	10.4	19.8	27.7	35.0	26.7	22.1	24.0
$5–10000	37.4	28.0	38.4	31.6	36.2	41.0	32.9	30.0	32.4	37.1	34.2	34.5
$10000+	34.0	53.7	55.2	46.0	38.9	48.6	47.3	42.2	32.6	36.1	43.7	41.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Visit Rates per 100 Persons

Income	GP	IM	Ped	O. Med	GS	OBG	O. Sur	O. Phy	Hoscli	Hosemer	Telhom	Total	Population
< $5000	199.0	33.1	10.5	27.5	31.6	13.1	43.5	90.1	88.7	29.6	83.2	649.8	49697.
$5–10000	160.7	31.0	39.0	24.0	28.2	32.0	44.5	60.0	50.5	25.2	79.1	574.3	80753.
$10000+	160.5	65.4	61.7	38.3	33.3	41.6	70.4	92.7	55.9	27.0	111.2	757.9	73491.
Total	170.0	43.9	40.2	30.0	30.9	30.8	53.6	79.2	61.7	26.9	91.7	658.9	203941.

state of disequilibrium, with gradual adjustments in fees in the direction of equilibrium.* When there is growth in the quantities of visits demanded relative to quantities supplied, there will be an acceleration in the inflation of fees. When there is a slower growth in visits demanded than in visits supplied, there will be a retardation in the rate of price inflation.

The basic form of the price adjustment equations for the first seven aggregate types of specialists is:†

$$\text{(3)} \qquad \text{PDOC}_{m,t+1} = \alpha_m \cdot \text{PDOC}_{mt} + \beta(\text{DOCVIS}^d_{mt} - \text{DOCVIS}^s_{mt}),$$

where PDOC_{mt} is the price charged by specialty m in year t, DOCVIS^d_{mt} is the aggregate quantity of visits demanded from specialty m in year t, DOCVIS^s_{mt} is the aggregate quantity of visits supplied by specialty m in year t, $\alpha_m - 1$ is the fractional rate at which fees will grow when equilibrium obtains, and β is the adjustment factor which governs the speed of fee adjustment during periods of disequilibrium.

The α_m's were estimated from the mean rate of change observed in the physician fee component of the Consumer Price Index over the period 1960–1970. The speed adjustment coefficient, β, was specified at alternative values and sensitivity studies were performed to find the best calibration.‡

2.4.4. *Linkages between the physician services submodel and the rest of the HRRC model.* The physician services submodel is linked to the rest of the HRRC microsimulation model by six channels: (1) the population of individuals generated by the consumer submodel drives the demographic variables in the demand for physician office visits; (2) the physician submodel provides the numbers of office-based physicians by specialty, which influences the supply of physician visits; (3) inhospital visits by physicians in office-based practice are taken from inpatient days generated in the hospital services submodel; (4) outpatient visits to hospital clinics and emergency rooms are generated in the physician services submodel for input to the hospital services submodel; (5) wages of RNs, LPNs, technicians and secretaries enter the physician services submodel from the health manpower submodel; and (6) the physician office demands for these aides, generated in the physician services submodel, are inputs to the health manpower submodel.

* Our data did not permit us to exploit recently developed techniques for estimating price adjustments in markets assumed to be in disequilibria, although additional work to generate time series may permit us to do so. See Goldfeld and Quandt (1973) and Fair and Jaffee (1972).

† The remaining category of private practitioners includes psychiatrists, radiologists, pathologists and anesthesiologists. They are of either peripheral interest (viz., psychiatrists), or provide services with poorly defined patient visits. No fee adjustment is therefore simulated; instead the exogenous trends in fees currently determine supply and demand behavior. Eventually, these types will be treated differently. Hospital clinics and emergency rooms use comparatively small amounts of total hospital manpower and other resources. Accordingly, we assume that the pricing policies of these outpatient sources of care are determined largely on the basis of the overall hospital financial condition. The aggregate demands for outpatient visits from these sources therefore determine the amounts transacted with exogenously set prices (i.e., chronic excess demand can persist in this sector without fee increases). This may need revision for long-run projections but is deemed adequate for the current prototype version of the model.

‡ The speed adjustment coefficients are the only parameters in the model which are not estimated by classical techniques, and they constitute fewer than one-tenth of one percent of all parameters in the model.

2.5. *Hospital Services Submodel*

The hospital services submodel, which treats the interactions between consumers and hospitals, consists of three components: (1) the demand for inpatient days; (2) the supply of such services, and the derived demands for full-time equivalent RNs, LPNs, allied health professionals, and non-professional personnel; and (3) the resulting price and capacity adjustments over time.

2.5.1. *Demand for hospital services.* The procedure for estimating the hospital services demand equations is similar to that presented above for outpatient physician services, with the exception that separate equations are employed to predict admissions rates and the mean lengths of stay.

That is, demands depend on the price of hospital care and health insurance coverage. The price of hospital care (total charges per day) varies by type of hospital and year. Health insurance is represented by coinsurance rates that vary by age, type of hospital, and year. The product of the (gross) price and the coinsurance rate yields net prices, which vary by age, type of hospital, and year. The demand for hospital admissions in year t is:

$$\text{ADM}^d_{ijkcsmt} = \alpha_{ijkcsm}[(\text{PHOS}_{mt})(\text{CRHOS}_{it})]^{\beta}, \tag{4}$$

where ADM^d is the quantity demanded, PHOS is the gross price, CRHOS is the coinsurance rate, α represents the intercept adjusted to fit the base rate of utilization, and β is elasticity of demand. The subscripts are: age i, sex j, race k, condition c, surgical treatment s, hospital type m, and year t. The mean length of stay per hospital admission involves a similar relationship:

$$\text{ALS}^d_{ijkcsmt} = \alpha_{ijkcsm}[(\text{PHOS}_{mt})(\text{CRHOS}_{it})]^{\beta}{}_{ijc}, \tag{5}$$

where the elasticity of demand β is specific to age, sex, and condition. The expected number of patient days per person per year is given by the product of admissions and length of stay.

The relevant attribute subdivisions of the population of consumers are:

Age	*Sex*	*Race*	*Condition*		*Surgery*
0–5	Male	White	INFEC	(infections and parasitic diseases)	Yes
6–16	Female	Other			No
17–24			MALIG	(neoplasms and diseases of the nervous system)	
25–34					
35–44			HEART	(circulatory, respiratory and digestive disorders)	
45–54					
55–64			BIRTH	(pregnancies and complications due to pregnancy)	
65–74					
75+			BONES	(musculoskeletal injuries and diseases)	
			OTHER	(all other conditions)	

The sites providing inpatient hospital care are:

Short-term	*Long-term*
State and Local Gov't	General and Chronic Disease
< 100 beds	Psychiatric
100–199 beds	Skilled Nursing Homes
200–499 beds	
500+ beds	
Voluntary	
< 100 beds	
100–199 beds	
200–499 beds	
500+ beds	
Proprietary	
< 100 beds	
100–199 beds	
200–299 beds	
300+ beds	
Federal	

An extensive regression study was performed on the 1967 Health Interview Survey (HIS) hospital file in order to estimate demand equations for the length of stay of patients in short-term hospitals. While the HIS hospital file contains over 12,000 useable responses, stratifications according to the full joint distribution of demographic characteristics, conditions, etc., would yield many cells with very few observations. Consequently, it was decided to divide the sample into 60 groups according to the attributes age (5), sex (2), and condition (6), and to estimate the following demand equation for each group:

$$\text{ALS} = f\,(\text{Net Price, Income, Surgery}),$$

where ALS is the average length of stay in days, Net Price is the price per day of hospital care net of insurance benefits, and Surgery is a binary variable which takes the value 1 if the hospital episode involved one or more surgical operations (zero otherwise). Table 4 presents the net price elasticities obtained using 1967 HIS data. All 51 elasticities were negative—an exceedingly unlikely event if the true distribution were centered on zero.

The coinsurance rates employed are based on extraneous estimates of how they have varied with age over time. This means primarily that those persons age 65 and over paid a substantially lower coinsurance rate after Medicare was introduced. Recall that in simulation the net price is calculated by multiplying the price charged by hospitals by the coinsurance rate for each age group.

TABLE 4

ESTIMATED NET PRICE ELASTICITIES OF DEMAND FOR LENGTH OF STAY IN SHORT-TERM HOSPITALS

Rank	Condition, Age, Sex	Elasticities
1	Other, 65+, Female	−0.018
2	Malig, 65+, Female	−0.029
3	Infec, 5–14, Female	−0.030
4	Bones, 15–44, Female	−0.040
5	Malig, 15–44, Female	−0.046
6	Heart, 0–5, Male	−0.051
7	Other, 15–44, Female	−0.058
8	Malig, 44–64, Female	−0.059
9	Bones, 44–64, Male	−0.062
10	Bones, 15–44, Male	−0.062
11	Malig, 65+, Male	−0.063
12	Heart, 5–14, Female	−0.063
13	Heart, 15–44, Male	−0.066
14	Heart, 65+, Female	−0.067
15	Heart, 15–44, Female	−0.070
16	Infec, 65+, Male	−0.070
17	Heart, 0–5, Female	−0.070
18	Other, 15–44, Male	−0.071
19	Heart, 65+, Male	−0.073
20	Bones, 44–64, Female	−0.075
21	Malig, 5–14, Male	−0.076
22	Heart, 44–64, Female	−0.080
23	Infec, 0–5, Male	−0.085
24	Malig, 44–64, Male	−0.085
25	Infec. 15–44, Female	−0.085
26	Malig, 0–5, Female	−0.089
27	Heart, 44–64, Male	−0.089
28	Other, 44–64, Female	−0.092
29	Infec, 44–64, Female	−0.092
30	Heart, 5–14, Male	−0.094
31	Other, 0–5, Female	−0.099
32	Bones, 65+, Female	−0.099
33	Bones, 5–14, Male	−0.101
34	Bones, 0–5, Female	−0.103
35	Other, 5–14, Male	−0.104
36	Bones, 0–5, Male	−0.105
37	Infec, 65+, Female	−0.108
38	Pooled Regression	−0.110
39	Other, 0–5, Male	−0.116
40	Birth, 15–44, Female	−0.117
41	Malig, 0–5, Male	−0.119
42	Other, 65+, Male	−0.122
43	Other, 5–14, Female	−0.127
44	Bones, 5–14, Female	−0.137
45	Malig, 15–44, Male	−0.139
46	Other, 44–64, Male	−0.160
47	Infec, 5–14, Male	−0.203
48	Malig, 5–14, Female	−0.235
49	Bones, 65+, Male	−0.237
50	Infec, 44–64, Male	−0.258
51	Infec, 15–44, Male	−0.258

Estimates of the price elasticity of demand for short-term hospital admissions* are difficult to obtain from micro data for two reasons. First, only those individuals with specific diseases or conditions are likely to require hospital care, and conditions are not well established for individuals who do not receive treatment. Second, data are not collected on the net price of hospital care facing individuals who are not hospitalized. Accordingly, we employed -0.46, one value obtained by M. Feldstein from an analysis of aggregate time series data, as the estimated price elasticity of admissions in equation set (4).†

Tables 5–7 present marginal distributions by age of the admissions, average length of stay, and total patient days in state and local, voluntary, proprietary, and federal short-term hospitals predicted by the prototype model for 1970. The demand for short-term hospital services is strongly related to the age structure of the population. With few exceptions, hospital utilization increases almost monotonically with age. The aged have higher admission rates (i.e., the probability of at least one hospital episode increases with age). The likelihood of experiencing multiple episodes also increases with age. Moreover, the average length of stay per episode increases substantially with age.

2.5.2. *Supply of hospital services and the derived demand for manpower.* In the short run variations in the demand for hospital services are reflected through changes in the occupancy rate of hospitals. For example, occupancy increased in response to Medicare and Medicaid, and later decreased in the recession of 1970. Accordingly, we have structured the hospital submodel so that quantity of patient days (PD) is determined by demand for any given year. Hospital occupancy (OCC) is computed as the ratio of average patient days demanded to the predetermined number of hospital beds (BEDS). During the following year adjustments take place in both the price of hospital services and the capacity of hospital facilities.

The demands for four types of hospital manpower are derived from the demand for hospital services. The categories RN's and LPN's are well defined, while allied health personnel constitute an aggregation of heterogeneous occupations with varying amounts of professional training. Other personnel have skills which are not specific to the health care system (e.g., clerical personnel) or have less than one year of formal training (e.g., nurses aides). The manpower demand

* The basic data sources employed in the estimation of hospital demand do not contain information on the demand for long-term facilities. In view of this difficulty, one approach would have been to omit long-term care entirely from our prototype model. While the number of patients in psychiatric, long-term general and chronic disease hospitals, and skilled nursing homes is large, manpower intensity is considerably lower in such facilities than in short-term hospitals. On the other hand, the rapid changes in this sector over the past decade argues in favor of including it in the prototype model—even though it could not be afforded the same treatment as the short-term hospital sector. Accordingly, although this sector was treated as exogenous, historical data were employed on the number of patient days provided by psychiatric, long-term general and chronic disease hospitals, and skilled nursing homes. Projected trends of these variables were used in simulations beyond the period for which historical data are available. This approach allows the changing utilization of long-term care facilities to have an impact on the demand for health manpower in experiments conducted with the model. However, we plan to explore various avenues for incoprorating behavioral content into specifications of the demand for the different forms of long-term care.

† See: Feldstein (1971).

TABLE 5

ADMISSIONS TO SHORT TERM HOSPITALS DURING 1970 (IN TEN THOUSANDS)

Age of Patient by Ownership of Hospital

Age	Govt	Vol	Prop	Fed	Total
0–5	75.0	220.9	13.9	12.6	322.4
6–16	60.9	239.6	18.5	12.9	331.9
17–24	102.1	250.3	22.7	27.8	402.8
25–34	99.1	336.1	26.9	22.0	484.1
35–44	82.1	248.8	27.9	16.0	374.8
45–54	87.8	291.6	27.5	30.0	437.0
55–64	72.0	260.3	25.8	15.9	374.0
65–74	82.4	247.3	26.5	8.7	364.9
75+	63.3	230.7	26.4	11.0	331.4
Total	724.8	2325.7	216.0	156.9	3423.4

Row Percentage Table

Age	Govt	Vol	Prop	Fed	Total
0–5	23.3	68.5	4.3	3.9	100.0
6–16	18.3	72.2	5.6	3.9	100.0
17–24	25.4	62.1	5.6	6.9	100.0
25–34	20.5	69.4	5.6	4.5	100.0
35–44	21.9	66.4	7.4	4.3	100.0
45–54	20.1	66.7	6.3	6.9	100.0
55–64	19.3	69.6	6.9	4.3	100.0
65–74	22.6	67.8	7.3	2.4	100.0
75+	19.1	69.6	8.0	3.3	100.0
Total	21.2	67.9	6.3	4.6	100.0

Column Percentage Table

Age	Govt	Vol	Prop	Fed	Total
0–5	10.3	9.5	6.4	8.0	9.4
6–16	8.4	10.3	8.6	8.2	9.7
17–24	14.1	10.8	10.5	17.7	11.8
25–34	13.7	14.5	12.5	14.0	14.1
35–44	11.3	10.7	12.9	10.2	10.9
45–54	12.1	12.5	12.7	19.1	12.8
55–64	9.9	11.2	11.9	10.1	10.9
65–74	11.4	10.6	12.3	5.5	10.7
75+	8.7	9.9	12.2	7.0	9.7
Total	100.0	100.0	100.0	100.0	100.0

Rates per 100 Persons

Age	Govt	Vol	Prop	Fed	Total	Population
0–5	3.5	10.2	0.6	0.6	14.9	21697.
6–16	1.4	5.3	0.4	0.3	7.4	45039.
17–24	3.7	9.0	0.8	1.0	14.4	27952.
25–34	4.1	13.9	1.1	0.9	20.0	24179.
35–44	3.6	10.9	1.2	0.7	16.5	22733.
45–54	3.8	12.5	1.2	1.3	18.7	23370.
55–64	3.8	13.9	1.4	0.8	19.9	18765.
65–74	6.6	19.9	2.1	0.7	29.4	12417.
75+	8.1	29.6	3.4	1.4	42.5	7789.
Total	3.6	11.4	1.1	0.8	16.8	203941.

TABLE 6

AVERAGE LENGTH OF STAY IN SHORT TERM HOSPITALS DURING 1970

Age	Age of Patient by Ownership of Hospital Govt	Vol	Prop	Fed
0–5	6.9	5.2	3.4	3.9
6–16	7.5	4.2	3.4	6.2
17–24	4.7	4.8	4.5	12.0
25–34	6.0	5.6	4.3	17.8
35–44	7.7	7.6	6.4	21.2
45–54	9.2	8.8	6.8	19.2
55–64	11.5	11.3	9.4	25.9
65–74	12.2	14.1	12.6	27.9
75+	17.6	14.9	10.8	21.6

equations take the following form:

$$(6)\quad \frac{N_i^d}{\mathrm{PD}} = \alpha + \beta \cdot \frac{\mathrm{OPV}}{\mathrm{PD}} + \gamma \cdot \frac{\mathrm{BIRTHS}}{\mathrm{PD}} + \delta \cdot \frac{\mathrm{SURG}}{\mathrm{PD}} + \sum \varepsilon_i \cdot \mathrm{WAGE}_i + \tau \cdot \mathrm{TIME}$$

where N_i^d represents the number of full-time equivalent personnel in each category demanded by the hospital, PD is the amount of patient days produced per year, OPV is the number of outpatient visits, BIRTHS is the number of new born patients, SURG is the number of surgical operations performed, WAGE_i represent indices of the wages paid to each category of hospital personnel, and TIME is a time trend to take account of variations in manpower demand not already explained by wages and casemix measures. It should be emphasized the coefficients ε_i represents both the "own" and "cross" wage elasticities (e.g., for the first category of health manpower ε_1 corresponds to the own wage and $\varepsilon_2, \varepsilon_3, \varepsilon_4$ refer to wages paid to other types of manpower).

Once manpower demand has been determined, the cost of providing hospital care is calculated from labor and nonlabor costs. An identity is used to calculate labor costs per patient day (ALC):

$$(7)\quad \mathrm{ALC} = \frac{\sum N_i^d \cdot \mathrm{WAGE}_i}{\mathrm{PD}}$$

and nonlabor costs per patient day (ANLC) are computed from the following equation:

$$(8)\quad \mathrm{ANLC} = \alpha + \beta \cdot \mathrm{OCC} + \gamma \cdot \frac{\sum N_i}{\mathrm{BEDS}} + \delta \cdot \overline{W} + \varepsilon \cdot \frac{\mathrm{ASSETS}}{\mathrm{BEDS}} + \rho \cdot \frac{\mathrm{SURG}}{\mathrm{PD}} + \pi \cdot \frac{\mathrm{BIRTHS}}{\mathrm{ADM}} + \sigma \cdot \frac{\mathrm{OPV}}{\mathrm{PD}}$$

where $\sum N_i$/BEDS is the number of personnel per bed (i.e., manpower intensity), the average wage paid to hospital employees ($\overline{W}$) and ASSETS/BEDS is the value of capital assets (plant and equipment) per hospital bed. Average cost per patient day (AC) is the sum of ALC and ANLC.

TABLE 7

PATIENT DAYS AT SHORT TERM HOSPITALS DURING 1970 (IN TEN THOUSANDS)

Age of Patient by Ownership of Hospital

Age	Govt	Vol	Prop	Fed	Total
0–5	518.9	1141.4	47.9	48.6	1756.9
6–16	456.3	1010.3	63.0	80.4	1610.0
17–24	475.9	1201.4	103.1	332.2	2112.7
25–34	595.9	1885.5	116.1	390.4	2987.9
35–44	630.9	1884.3	178.7	338.6	3032.6
45–54	809.0	2579.8	187.3	577.9	4153.9
55–64	827.9	2951.1	242.7	412.5	4434.1
65–74	1008.1	3499.4	334.8	243.1	5085.4
75+	1114.4	3437.9	285.5	238.6	5076.3
Total	6437.4	19591.1	1559.0	2662.3	30249.7

Row Percentage Table

Age	Govt	Vol	Prop	Fed	Total
0–5	29.5	65.0	2.7	2.8	100.0
6–16	28.3	62.8	3.9	5.0	100.0
17–24	22.5	56.9	4.9	15.7	100.0
25–34	19.9	63.1	3.9	13.1	100.0
35–44	20.8	62.1	5.9	11.2	100.0
45–54	19.5	62.1	4.5	13.9	100.0
55–64	18.7	66.6	5.5	9.3	100.0
65–74	19.8	68.8	6.6	4.8	100.0
75+	22.0	67.7	5.6	4.7	100.0
Total	21.3	64.8	5.2	8.8	100.0

Column Percentage Table

Age	Govt	Vol	Prop	Fed	Total
0–5	8.1	5.8	3.1	1.8	5.8
6–16	7.1	5.2	4.0	3.0	5.3
17–24	7.4	6.1	6.6	12.5	7.0
25–34	9.3	9.6	7.4	14.7	9.9
35–44	9.8	9.6	11.5	12.7	10.0
45–54	12.6	13.2	12.0	21.7	13.7
55–64	12.9	15.1	15.6	15.5	14.7
65–74	15.7	17.9	21.5	9.1	16.8
75+	17.3	17.5	18.3	9.0	16.8
Total	100.0	100.0	100.0	100.0	100.0

Rates per 100 Persons

Age	Govt	Vol.		Fed	Total	Population
0–5	23.9	52.6	2.2	2.2	81.0	21697.
6–16	10.1	22.4	1.4	1.8	35.7	45039.
17–24	17.0	43.0	3.7	11.9	75.6	27952.
25–34	24.6	78.0	4.8	16.1	123.6	24179.
35–44	27.8	82.9	7.9	14.9	133.4	22733.
45–54	34.6	110.4	8.0	24.7	177.7	23370.
55–64	44.1	157.3	12.9	22.0	236.3	18765.
65–74	81.2	281.8	27.0	19.6	409.6	12417.
75+	143.1	441.4	36.7	30.6	651.7	7789.
Total	31.6	96.1	7.6	13.1	148.3	203941.

The average price charged for inpatient hospital care per day (PHOS) is represented as a markup over average total cost, with adjustments for the fact outpatient services account for a portion of hospital costs:

$$\text{PHOS} = \alpha + \beta \cdot \text{OCC} + \gamma \cdot \text{AC} + \delta \cdot \frac{\text{OPV}}{\text{PD}} \tag{9}$$

The occupancy rate is included to explain variations in hospital prices which have not already been taken into account through average cost. That is, as capacity is approached the markup of prices over average cost will grow.

The number of hospital beds in the next period (year) is determined by:

$$\text{BEDS}_{t+1} = \alpha + \beta \cdot \text{PD}_t \tag{10}$$

which implies that each type of hospital has a desired occupancy rate. If patient days exceed that rate, additional capacity will be forthcoming in succeeding years.

2.6. *The Non-Physician Manpower Submodel*

As described above, the model calculates the quantities of RNs, LPNs, allied health professionals, and other personnel demanded by 28 types of physician practices and 16 types of hospitals. The sum over these types of providers yields the aggregate demands for the 4 categories of health manpower. These aggregate demands are then ready for input into the markets for health manpower. The interaction of the demand and supply for each type of manpower results in changes in wage rates, which, in turn, affect labor force participation rates.*

2.6.1. *Supply of non-physician manpower*. The population of RNs is updated in a similar manner to the procedures described above for the populations of consumers and physicians. Mortality decreases the stock of trained RNs, while new graduates and the net immigration of foreign nurses increase the stock. In the prototype the number of graduates from schools of nursing in the U.S. is an exogenous policy variable which can be set at various levels to simulate the consequences of achieving a particular manpower goal.

Participation rate equations were estimated from annual time-series on RNs aggregated into six age groups. The equations were taken from another HRRC study involving the specification, estimation, and simulation of an econometric model of the nurse market.†

Considerable attention was devoted to the supply of physicians and nurses in developing the prototype model. However—owing primarily to data limitations—it was not possible to perform detailed analyses of the supply of other health professionals. Nevertheless, there are no technical reasons why the methodology used to generate the supplies of physicians and nurses could not be applied to other health manpower occupations. Moreover, the 1970 Census provides a more recent data base for further research in this area. The current procedure used to estimate the number of active LPNs and allied health professionals available

* As in the case of physicians, the prototype model does not yet contain equations which relate wages to the demand for training. However, in view of the high proportion of inactive working-age females in these occupations, it does not ignore the link between wages and labor force participation.

† See Deane and Yett (1973), and for a detailed explanation of this specification, see Deane (1973).

for employment by the institutions included in the model involves subtracting individuals employed by other institutions (e.g., public health agencies) from the estimated total employment figures over the historical period and from projections of the expected supply in future years.

The model also contains a category, "other personnel," which is composed of individuals who have skills that are not specific to the health care system (e.g., clerical personnel). The health service institutions included in the model account for only a small fraction of the total employment of such personnel. Consequently, the wage rates paid to these individuals are treated as exogenous to the health care system. Actual values of the wage rates are used over the historical period, and extrapolation of previous trends generates projected values.

2.6.2. *Wage adjustment procedures.* The basic assumption underlying the wage adjustment procedures is that the markets for RNs, LPNs, and allied health professionals and technicians are typically in a state of disequilibrium, with gradual adjustments in wages in the direction of equilibrium. When there is growth in the quantities of manpower demanded relative to quantities supplied, there will be an acceleration in the inflation of wages rates.

The basic form of the wage adjustment equations for RNs, LPNs, and allied health professionals is:

$$\text{WAGE}_{i,t+1} = \alpha_i \cdot \text{WAGE}_{i,t} + \beta \cdot (N^D_{i,t} - N^S_{i,t}) \tag{12}$$

where $\text{WAGE}_{i,t}$ is the wage paid to the ith type of manpower in year t, $N^D_{i,t}$ is the aggregate quantity of full-time equivalent personnel demanded by physicians offices and hospitals, $N^S_{i,t}$ is the aggregate quantity supplied by each manpower cohort of type i, $\alpha_i - 1$ is the fractional rate at which wage rates will grow if equilibrium is reached, and β is the adjustment factor which governs the speed of wage adjustments during periods of disequilibrium.

The α's were estimated from the mean rate of change observed in the wage rates paid to personnel over the period 1960–1970. For RNs, LPNs, and allied health professionals, it is assumed that the wages paid to hospital personnel are an approximate index of the average earnings of individuals in the occupation. Given the fact that hospitals account for more than half of the total employment, this assumption is at least a reasonable first approximation. The speed of adjustment coefficient, β, was specified at alternative values, and sensitivity studies were performed to find the best calibration.

3. Simulation of the Model and Plans for Further Research

Although the prototype model is fully operational it has not yet been subjected to a detailed program of experimentation and critical evaluation. Such a series of tests will no doubt lead to further revisions in estimated parameters and alternative specifications of some of the structural relationships.

One useful test of the performance of such a model is whether it produces the behavior of the system over an historical period. We have performed such a test on our prototype model by beginning the simulation in 1960 and examining the predictions to 1970. Table 8 presents the results for several key variables generated by the hospital services submodel in this run.*

* For a more detailed summary of the results see Yett, Drabek, Intriligator and Kimbell (forthcoming).

TABLE 8

HOSPITAL MANPOWER AND HOSPITAL COSTS FOR 1966 AND 1968*

Variable	State and Local Governmental		Voluntary		Proprietary		Federal	
	Model Predicted	Historical Estimates	Model Predicted	Historical Estimates	Model Predicted	Historical Estimates	Model Predicted	Historical Estimates
Registered Nurses (1968)	70	61	259	248	15	16	29	24
Licensed Practical Nurses (1968)	31	37	87	100	8	10	12	7
Total Personnel (1966)	375	352	1130	1104	76	77	149	155
Labor Cost Per Patient Day (1966)	30.69	29.41	33.78	29.89	28.41	23.30	28.58	30.07
Non-labor Cost Per Patient Day (1966)	22.35	16.69	23.61	19.05	28.49	23.30	13.79	6.55
Average Cost Per Patient Day (1966)	53.10	46.10	57.40	48.94	57.06	46.60	42.41	37.62
Price Per Patient Day (1966)	32.87	—	46.67	47.42	53.26	49.09	—	—

* Historical estimates for RNs and LPNs are derived from the published data from the 1968 Survey of Nursing Personnel in Hospitals. See U.S. Bureau of Health Manpower Education (1970). The estimates for 1966 are taken from the AHA Annual Survey of Hospitals. See: American Hospital Association (August, 1967). Manpower data are expressed in thousands while cost and price data are in dollars.

With respect to hospital manpower demand, the model projected an increase in demand for all types of personnel—the largest being for LPNs and non-medical personnel. The model apparently overstates hospital employment in 1960, and, consequently, it understates the growth in such employment—especially in the later years of that decade.

As indicated by the historical data, the increase in hospital utilization accounts for only a small fraction of increase in the demand for hospital manpower (i.e., substantial increases have been observed in personnel per patient day). Also, the composition of the hospital patient population shows offsetting effects among the various casemix categories. An increase in out-patient visits per patient day leads to increased demand for personnel, while a decrease in surgical operations per patient day reduces the demand for personnel.† Consequently, attempts to improve the model's ability to forecast hospital manpower demands should probably focus upon new specifications with regard to the relationship between hospital personnel wage rates and changes in the price of hospital care.

As shown in Table 8, the labor and non-labor cost equations perform well, yielding accurate predictions of hospital costs. Further improvements in the manpower demand relationships should lead to even better results in the future.

The performance of the price adjustment relationships varies by type of hospital. The equations for governmental and proprietary hospitals perform

† The elderly have a relatively low surgery rate as compared with the younger population.

best in the post-Medicare period, while those for voluntary hospitals track the pre-Medicare period, but understate the rise in hospital prices in later years. These equations are dependent on the hospital cost equations discussed above, and future improvements in the prediction of hospital costs will yield better prediction of hospital prices.

One problem we repeatedly encountered in seeking to evaluate the "historical" run is that consistent time-series data are not available for several variables at the degree of disaggregation contained in the model.* In some cases surveys have not been taken except in a few years. In other cases, variable definitions and sampling procedures have changed. Consequently, only an assessment of the overall performance of the model is possible at this time since it is difficult to separate errors in prediction from the variations which are attributable to data limitations.

After we are satisfied that the prototype model performs well, we plan to use it to perform three types of experiments. (1) The first type will involve conditional forecasts of the implications of alternative assumptions about future values of exogenous variables not subject to significant influence by decision makers, but which impact substantially on the health care system (e.g., birth rates). These experiments are needed to help decision makers anticipate future developments far enough in advance in order to avoid remedial actions that might be necessary if they fail to foresee these developments (e.g., correcting for excess hospital maternity care facilities). (2) The second type of experiment will involve policy alternatives that can be influenced directly, and substantially, by health care decision makers (e.g., alternative National Health Insurance proposals). These experiments can assist in the design of more efficient and more equitable health care provision for the nation. (3) The final type of experiment will relate to the sensitivity of the model's forecasts to alternative assumptions about major behavioral hypotheses represented in its estimated parameters. These sensitivity studies can readily offer conditional forecasts based on parameters other than those we have programmed.

Numerous potential improvements of our prototype model have already been identified, and will be implemented readily.† Indeed, it is the low marginal cost of revision that leads model building efforts generally to display, almost universally, an evolutionary pattern of development that is not as often observed with other approaches.

4. Some Preliminary Conclusions

Five preliminary conclusions emerge from the development thus far of the HRRC Microsimulation Model.

First, demographic information and prices alone are not nearly as effective in explaining demand for health services as the combination of demographic information, prices and health conditions. Health conditions play a major role in determining demand for health services, and this role must be represented in

* The situation is in sharp contrast to the experience in simulation microeconometric models of the U.S. economy, such as the Brookings model which relies on quarterly time-series data sets beginning in 1952.

† In addition to those described above, see the more detailed listing given in Yett, Drabek, Intriligator, and Kimbell (forthcoming).

the model. Most other analytic studies of the health system, however, do not treat the health status of the population, and hence omit a major driving force for the system.

The second conclusion of the HRRC Microsimulation Model is the importance of the distribution of the population for the composition of health services provided. Thus, for example, a "bulge" in the number of women of child-bearing age has a significant effect on demands for the services of pediatricians and obstetricians, two of the physician specialties explicitly treated in the HRRC model.

The third conclusion of the HRRC model is the importance of the foreign medical graduates (FMGs), based on a simulation study which exploited the capability of the model to track separately domestically trained and foreign trained physicians. The FMGs are important components of the health care system, especially for hospital staffs, and the number of FMGs is more susceptible to short-run policy choices than the numbers of domestically trained physicians. In fact, the most critical factor influencing the supply of physicians in the short-run is the net migration rate of FMGs. A more liberal policy toward FMGs could play a significant role in meeting the demands created by National Health Insurance.

The fourth conclusion of the HRRC model is the fundamental importance to National Health Insurance outcomes of the productivity of physicians and other labor inputs in producing outpatient and inpatient services.

The fifth major conclusion of the HRRC model is the importance of organizational factors. Changing the mix of practice settings (e.g., shifts from solo to group practices), and changing the mix of institutions (e.g., types of hospitals), can be of considerable significance in evaluating the impact of National Health Insurance. Several of the National Health Insurance proposals have taken cognizance of this fact by including specific programs for organizational changes (e.g., use of Health Maintenance Organizations) which can be treated in the HRRC model.

These preliminary conclusions are based upon work to date in the development of the HRRC Microsimulation Model. Further conclusions, such as more specific conclusions regarding the outcomes of National Health Insurance will be based upon the further development and application of the model.

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