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OR PRACTICE

POLICY DECISION MODELING OF THE COSTS AND OUTPUTS OF EDUCATION IN MEDICAL SCHOOLS

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This paper presents the results of a project designed to develop a methodology to aid policy decision making in statewide medical education systems. The methodology requires the development of quantitative models that project the state's future investment in medical education, as well as the effects of potential policy proposals on the costs of medical education, on state costs, and on physician manpower supply. To build these models, we collected and analyzed extensive data from one statewide medical education system. We discuss the development of our methodology, its application in the strategic planning by the state's educational leaders, its significance in the policy formulation process, and we offer guidelines for future research.

State-supported academic health centers are an essential component of our nation's health care system. They are the setting for undergraduate and graduate education, research, and patient care, and they shoulder a complex mix of societal mandates and community responsibilities. Over the past several decades, however, the mission and scope of these centers have changed radically. With today's restrictive financial environment, many of these centers and their state legislatures are facing difficult resource allocation decisions.

In the 1960s, physician shortage was one of the nation's leading health policy issues. Federal and state

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governments responded by enacting a number of resource allocation measures directed at expanding the medical education system. However, they seldom examined the long-term implications of these policies. The result is that the shortages of the '60s have evolved into the surpluses of the '80s, which in turn are projected to extend into the twenty-first century.

After a decade of increasing federal financial support for medical education, the government has drastically changed its position (Association for Academic Health Centers 1982), and the financial stability of schools of medicine is now threatened by funding reductions.

As federal support has diminished, a greater portion of the costs of educating health professionals has shifted to state governments. These governing bodies are faced, however, with the problems of containing increases in tuition, fees, and the overall cost of medical education, of meeting the financial needs of low-income students, and of addressing the manpower needs of the state, especially in medically underserved areas. It is likely that there will be cutbacks in state

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commitments as medical education is forced to compete with other essential services such as other areas of higher education, primary and secondary education, community development, social programs, and highways for a portion of the state's limited budget (for a detailed discussion of the relationship between the state and medical education, see Lewin and Derzon 1982 and Schramm 1983).

Confronted with the growing recognition of scarce resources, society must have a comprehensive understanding of the relationship between medical education costs, available physician resources, and the health needs of the population. The intent of this paper is to present a planning methodology that has been developed and used to help decision makers to understand the impact of changes in medical school policies on both the costs of medical education and physician supply. The methodology attempts to provide information to policy makers so they may better assess trade-offs associated with specific policy decisions.

Specifically, the major objectives of the study were to

- (1) develop a planning and policy tool for use by the appropriate educational leaders to assess the implications of various policy alternatives for medical education; and
- (2) identify and analyze the costs of the four basic program areas of medical education (medical student training, resident and other student training, research, and patient care), and other data to be used as inputs to the planning tools developed.

These objectives were pursued through a detailed analysis of one statewide system of medical education. We studied three schools in the state, labeled Schools A, B, and C.

The state in which the study was conducted has made a substantial economic and political commitment to medical training as a means of assuring an adequate supply of physician manpower for its residents. Its legislature has become concerned, however, that resources may no longer be available to sustain current policies, and has raised the question of whether the state can increase the cost effectiveness of its dollars and/or find a means of offsetting public funds.

The analysis in this study provided a factual base from which to assess both the effects of the state's current investment in medical resources, and the impact of various potential policy proposals on the total costs of medical education, on state costs, and on the state's supply of physician manpower. The analysis is

heavily dependent upon the evaluation of policies that were developed by the research team in concert with the educational leaders in the state. While the ultimate choices remain political, the results of this type of research can provide an important tool to guide policy deliberations affecting schools of medical education. They can thus be an aid in a state's search for allocations that will best achieve its medical training goals and its general health objectives yet remain within its budgetary constraints.

This paper is organized as follows. Section 1 gives a brief overview of past efforts in medical education system planning studies; Section 2 describes our approach, which has two components: the Strategy Development and Evaluation Process (SDEP) and an associated Decision Support System (DSS). Section 3 briefly outlines the models developed for the Decision Support System, and Section 4 describes the major data collection and analysis efforts. In Section 5 we discuss the application of the planning process and, in Section 6, present the implementation of the process and its results. We conclude the paper in Section 7 with directions for future research.

1. Review of Prior Research

Most of the past studies on models for the policy analysis of medical education systems concentrate on either the costs or the outputs of medical education without integrating the two in a policy evaluation framework. Earlier work by A. Carroll for the Association of American Medical Colleges (see AAMC 1965, Carroll and Darley 1967, and Carroll 1969) emphasized the importance of accumulating data on program costs, difficulties in identifying costs, and the usefulness of cost information. Instead of collecting data on faculty effort based on individual judgment or judgments of medical school deans, Hilles (1973) suggested that faculty activity rather than effort would be a better basis for obtaining less biased information. Koehler and Slighton (1973) provided a concise overview of the fundamental concepts of the nature of cost analysis, the distinction between pure and joint costs, and the types of management questions and financial decisions that can be based on different types of information. Their objective was to provide an efficient means of activity analysis and to project the effects of changes in policy or activity on the health science center as a whole. Other work on activity or effort analysis of faculty includes Kutina (1973).

AAMC (1974) has thoroughly studied and reported the elements, costs and objectives of undergraduate medical education. The analysis included data from

twelve medical schools and a model for the allocation of faculty costs. Another study by the Institute of Medicine (IOM) (National Academy of Sciences 1974), the most comprehensive examination to date, investigated varied components of educational costs and sources of revenue in a detailed and systematic fashion.

The studies described in the preceding paragraph have focused on detailed analysis of the time and costs of medical faculty in the education of medical doctors. Most of them are thus descriptive in nature, and do not provide a modeling capability to predict cost impacts when the environment underlying the medical education system changes, or when policy interventions are to be evaluated. There have been some works that address this latter objective. Latham (1971) modeled the medical education system as a classic Leontief input/output system. The outputs of the system can be predicted, given a set of inputs, through the use of the model. The major shortcoming of such a framework is the possible nonlinear nature of the "production" function of medical schools. Another method, known as the Systems Research Group (SRG) method, summarizes resource usages for each aggregated activity in medical education, and systematically projects the effects of changed policy on levels of activity (see Judy 1971, Mowbray and Levine 1971, SRG 1969, and University of Toronto 1970). Our approach, as described in this paper, is similar in spirit to the SRG's.

The outputs of the medical education system have also been actively researched. Most of the studies, again, are descriptive in nature. They usually focus on two issues: the physicians' choice of location upon finishing their education (undergraduate, residency, and/or fellowship), and their choice of specialty or subspecialty. Yett and Sloan (1974), working from extensive data on physicians' first practices, suggested that increasing the number and recency of contacts with a state, whether by subsidization or by other means, should increase the likelihood of the physicians' locating their practices in the state. Hadley (1975) and Wilensky (1979) supported this observation. Mason (1971) and Wilensky suggested that the establishment of loan programs, with the provision that the loan could be forgiven if the physician chose to practice in the state, could be an effective means of increasing the likelihood that the physician will select the state as the location of his or her practice. As we shall see later, our planning model analyzes this policy.

Models of the choice of specialty by physicians have also included the disaggregated models (Hadley 1979) and the decision tree type (Steinwachs et al. 1982).

With a comprehensive historical data set, researchers made projections of the number of physicians in different specialty groups for the whole country, and suggested policies to change undesirable trends (Steinwachs 1982). Some recent studies include similar projections at the state level (Bonsanac, Petersen and Wyant 1982).

Descriptive studies enhance our understanding of the processes underlying the flow of the medical education system. However, the current crisis demands more powerful decision models that have the capability of analyzing the cost and benefit of varying policy strategies. Computerized simulation models have been developed (see Forsyth et al. 1974; Forsyth, Lavery and Herbert 1975; Kutina and Bruss 1979; and Milch and Bhatia 1976). These simulation models, again, concentrate on estimating the changes in resource requirements when certain key inputs to the system are changed, for example, increasing the number of students, and varying the mix of interns, residents, and medical students. Kutina and Lee (1973) described a program-planning model that considered both the resource side of medical education and the outputs of the program. The model is highly aggregated: for example, it does not consider location and specialty factors. Moreover, it deals with a single educational institution. To be used for statewide planning purposes, it would have to be expanded.

We close this section by noting that there have been significant advances in the development of planning decision support systems for colleges and universities (see Weathersby and Weinstein 1970; Wagner and Weathersby 1971; and Hopkins and Massy 1981). To our knowledge, however, our model appears to be the first attempt to develop a comprehensive planning methodology for state-wide medical education systems.

2. The Strategy Development and Evaluation Process

The methodology we developed to aid policy planning of medical education consists of a Strategy Development and Evaluation Process (SDEP) associated with a Decision Support System (DSS). The Strategy Development and Education Process forms the overarching framework that links all phases of the project (see Figure 1). The policymakers specify the goals that in turn guide both the development and subsequent evaluation of policy options or potential future states. For each policy, school and/or system, variables and parameters must be specified under different assumptions. These specifications include the number of

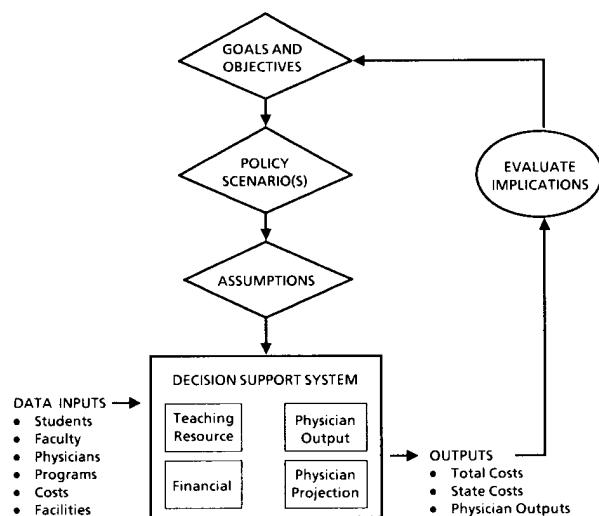


Figure 1. Strategy development and evaluation process.

students in the class; the definition of urban and rural regions; the retention rates for the schools, which are defined as the percentage of medical school graduates who remain to practice in the state; the level of state funding support; the tuition levels; the impact of increased tuition on the size and composition of entering classes; the impact of student loan burden on specialty choice and practice location; the size of and criteria for a state loan program; assumptions regarding the economy, and so forth.

The specification of these parameters or variables may depend on informed judgment or experience generalized from other settings. It may be appropriate to conduct sensitivity analysis to study the effects of a range of values for a certain variable, especially when insufficient historical or experiential data are available to establish a reasonable value for the variable.

The Decision Support System consists of a set of quantitative models that use the specifications of the policies and scenarios to project the policy impacts on resources (costs) and outputs. These impacts can, in turn, be used as a basis for generating new policy options. It comprises four models that are based on an extensive data set. The Financial and Teaching Resource Models estimate the resources required to educate a specified number of medical students. The Physician Output and Physician Supply Projection Models estimate, by location and specialty group, the number of physicians who will practice in the state.

The remaining step in the SDEP is the evaluation of the implications of a proposed policy. This evaluation is pursued in two ways. First, the output of each policy option is assessed in terms of its impact on

system variables and stakeholders. Second, these outputs are compared with the goals set by policymakers.

3. Models in the Decision Support System

3.1. The Teaching Resource Model

The Teaching Resource Model deals with the resources needed to provide in-class education of medical students. Typically, in-class education is required only in the first and second years of the curriculum. Hence, the model uses, as inputs, a given number of first- and second-year medical school students, and gives, as outputs, the costs of the direct resources necessary to support such teaching requirements.

Stored in the Teaching Resource Model is information about every medical school course offered to first- and second-year students at the various schools in the state, including the various lecture, audit, examination, seminar, and laboratory hour requirements.

A major constraint in teaching a larger number of medical students is capacity. Although lecture rooms for the various departments in the medical schools are usually large enough for modest increase in class sizes, the most severe capacity limitation lies in seminar and laboratory requirements for teaching. Seminars and lab work require personalized attention. Therefore, increased class sizes require more sections for seminars and laboratory sessions, resulting in increased manpower needs for these purposes. The Teaching Resource Model collects and stores a comprehensive data set describing the availability and capacity of classrooms, seminar rooms, and laboratories for each department at each school.

The basic assumptions for the Teaching Resource Model are that faculty in-class lectures, audit, and examination hours are independent of the number of students in the class, and that faculty seminar and lab hours are proportional to the numbers of seminar and lab sections required to teach the course. The same assumptions are made for graduate assistants and technicians. As the class size changes, the demand for faculty time also changes. It is important to identify the portions of faculty time that are related to course teaching. For this purpose, we designed a log diary that we used as a vehicle to collect data. The next section presents a detailed description and analysis of the log diary data.

Each school records the number of in-class teaching hours for nonmedical basic science and continuing education students; we subtract those hours from total teaching hours so as not to attribute them to medical student teaching hours and costs. In order to disaggre-

gate other teaching hours by student type, we applied ratios obtained in the IOM study (National Academy of Sciences 1974), which is a large-scale log diary effort, to the log diary teaching activity data collected in this study. Given the project's time frame and cost constraints, we deemed this method the best available for disaggregating first-degree students' teaching hours and costs from resident teaching hours and costs.

Changes in the number of seminar and lab sections affect not only faculty hours, but the numbers of graduate assistants and lab technicians required to assist in these classes. The Teaching Resource Model also estimates these changes. Appendix A gives a detailed description of the Teaching Resource Model.

3.2. The Financial Model

The Financial Model takes as inputs the outputs of the Teaching Resource Model, i.e., the resources in terms of person-hours necessary to provide teaching support for a given number of medical students. It then determines the number of faculty, graduate students and laboratory technicians corresponding to those numbers of resource person-hours, from which the direct and indirect costs for the basic and clinical science departments at each school can be estimated. The model can operate under varying assumptions to calculate changes in the size of the school's faculty, its current expenses, its other staff costs, and the like, due to variations in the school's scale or level of operation.

Central to estimating resource requirements is determining faculty size and makeup. To calculate changes in the composition of the faculty, we obtained, from the Teaching Resource Model, the total person-hours for the teaching activities of first and second year medical students. Since the first and second years of teaching consist of basic science subjects, the Teaching Resource Model essentially gives the teaching hours requirement for the basic science departments.

A school's current faculty hours are disaggregated into four components: medical school teaching, resident/other student teaching, research, and patient care hours. Total teaching hours include fixed hours, hours that vary indirectly with the number of medical students at the school, and hours that vary directly with medical students. These three categories can be used to calculate the net change in total teaching hours if the size of the school changes.

Given the net change in total teaching hours, we can calculate the net change in faculty only by making additional assumptions. A change in faculty teaching hours can be met in a number of ways. The Financial Model assumes that changes in teaching hours are met

by varying the number of faculty rather than changing the proportions of time each faculty member spends teaching, doing research, and providing patient care. In other words, we assume that the proportions of time each faculty spends in teaching, research and patient care remain fixed. As mentioned before, we obtain these proportions through a comprehensive analysis of the log diary data. We made this assumption because we believe that the quality of both the faculty and the students' education would be adversely affected by significant forced changes in the faculty's allocation of its time. Hence, when faculty size changes, we assume that the faculty's teaching, research, and patient care activities are maintained in the same proportion as before the change. Using this assumption, we obtained the net change in faculty by dividing the net change in teaching hours by the average faculty teaching load.

The Financial Model also calculates other personal service, current expense, and repair and alteration cost estimates for teaching, research, and patient care activities. While we assume the repair and alteration figures to be fixed, we assume the other accounts to vary according to the percentage change in faculty at the school. The model can also calculate the indirect costs of the schools. When the schools are freestanding, this calculation is made directly from the indirect cost data collected at the schools. However, cost determination is complicated when the medical school is a unit in a larger university. In the latter instance, university-wide costs must be allocated back to the medical school.

The next section describes an extensive effort to collect and compile cost account data for the medical schools in the state modeled in the Financial Model. Appendix B presents further documentation of the Financial Model.

3.3. The Physician Output Model

The Physician Output Model focuses on each single medical school class and computes the number of students who will remain to practice in the state after they finish their in-state medical training. It models the flow of a single medical school class as an extremely large network. Figure 2 describes such a network. The model is designed both to describe current practice patterns and to be used as a planning tool that will allow administrators to evaluate the impact of policy changes on physician outputs. Given a specified number of entering students, it calculates the number who will remain in the state to practice, and subdivides that figure by specialty group into the number practicing in urban and rural areas.

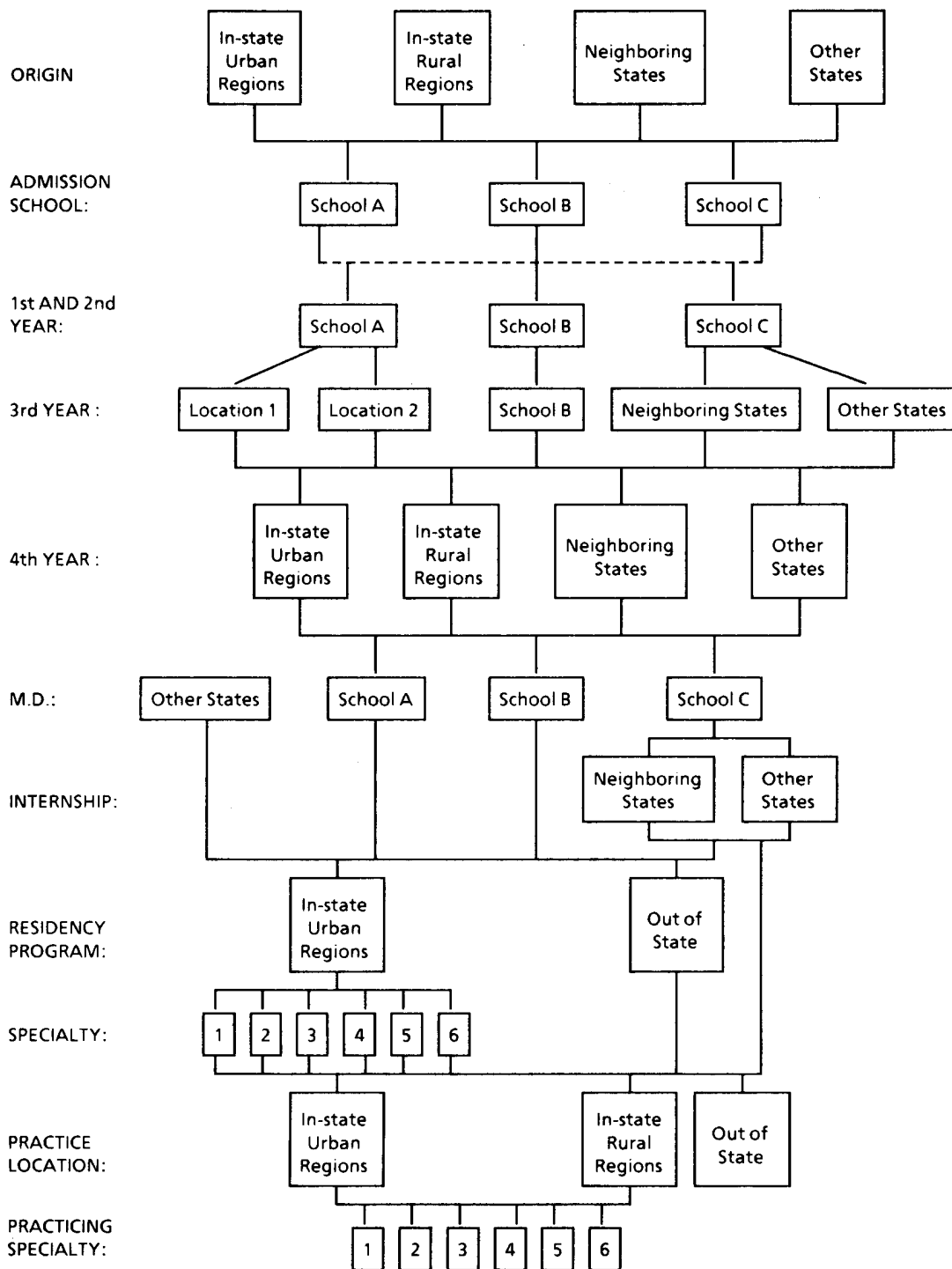


Figure 2. Flow of students in the physician output model.

The model treats the educational process as a large input-output system. It forecasts the flow of students through a collection of intermediate levels defined by the student's year of education, as well as by the school

he or she attends, and predicts the outputs of the system and the student's eventual practice location and specialty group. It takes as data the likelihood of student movements from one level (educational year

and school) to another, and given these likelihoods, computes the expected number of students in each level. We now discuss two important variables in the model, student origin and specialty groups.

(1) *Student Origin.* Historical analysis of the state's medical student data indicates that student origin is one of the most important factors affecting the volume and direction of flows through the various stages of medical education. Consequently, all medical students have been classified into four groups, according to their origin: (a) in-state urban regions, (b) in-state rural regions, (c) neighboring states, and (d) other states. For this analysis, an urban student is defined as one who, prior to enrollment, resides inside the state in an incorporated area with 10,000 or more inhabitants. A rural student is one who, prior to enrollment, resides in an in-state region that is not an urban area.

(2) *Specialty Groupings.* Students may choose to specialize in one of 53 different areas of medical practice, ranging from general internal medicine to public health (see GMENAC 1980). To facilitate discussion of graduating students' specialty choices, we grouped these 53 specialty areas into six categories of medical practice: three specialty categories of primary care (general internal medicine, family and general practice, and pediatrics) and three non-primary care categories (specialties that frequently involve early or initial patient contact, specialties that normally involve care on a consultant or referral basis, and specialties that normally do not include direct patient contact).

We used historical flow data to estimate the likelihoods of the flows in the network. Appendix C presents the mathematical description of the Physician Output Model.

3.4. Practicing Physician Supply Projection Model

The Practicing Physician Supply Projection Model uses the output of the Physician Output Model, along with in- and out-migration trend data, to determine, over a planning horizon, the total number of physicians practicing in the state. It tracks the movement of doctors into and out of the state by class of graduation, specialty group, and urban-rural practice location. It projects the physician supply in the state through the year 2000, and can thus provide administrators with information about how proposed changes in policy will affect physician supply in the state.

The movement of physicians into and out of the state by class of graduation, specialty group, and urban/rural practice has been traced between 1979 and 1982 from physician licensure data tapes supplied

by the state health department. The number of state graduates who enter practice in the state in any 3-year period is derived from the Physician Output Model and varies for each policy option. We believe that the number of out-of-state graduates who entered practice in the state between 1979 and 1982 is typical of any other 3-year period; thus, we assumed their migration into the state to remain constant through 1999.

The key limitations to the model's projections stem from the representativeness of the data base obtained from the state and the risks inherent in long-term projections. First, we used state data for the two most recent periods (1979 and 1982) (we disregarded earlier data because we believed that practice patterns reflected in these data no longer represent the future). However, if the 1979 and 1982 data are not representative or the rates of migration are in flux, biased estimates of physician supply could result. Second, projections of long-term trends in physician supply are extremely complex. Numerous factors affect physician supply and migration rates, including health care reimbursement policies; local, regional, and national economies; and the organization of health care delivery. The current set of models does not account for these variables. Nevertheless, the model's results can be used to provide the general trends of the projected physician supply. In addition, the models are designed so that they can account for additional longitudinal data and can incorporate new variables. Thus, the models can be updated to reflect the best information available.

4. Data Collection and Analysis

Extensive empirical data are required to estimate the parameters of the four models just described. Figure 3 illustrates the different sources of data for this effort. The capacity data for the space constraints of the medical schools, and the course data for the specified number of teaching hours for in-class, seminar and lab teaching for the courses, are straightforward to obtain. Historical student flow data, residency data, and practicing physician data are also readily available on record. The major tasks for data collection and analysis are establishing and maintaining a log diary to conduct faculty activity analysis, and acquiring cost accounting data in order to conduct direct and indirect cost analysis for the medical schools.

4.1. Faculty Activity Analysis

The analysis of how faculty spend their time during an average work week is essential to estimating the

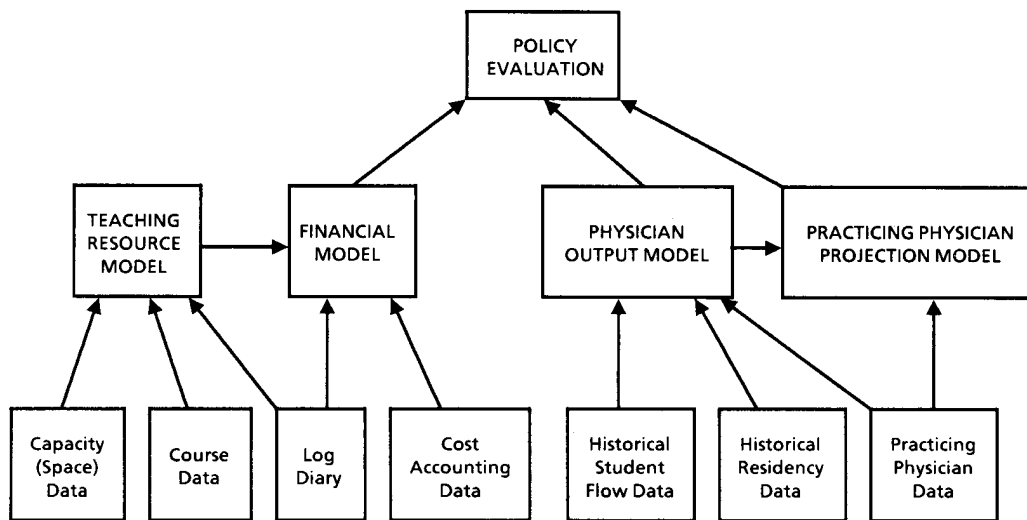


Figure 3. Data support of models.

costs of medical training. To obtain estimates of faculty activity, we asked faculty members at each medical school to keep a daily record of their professional activities for a 1-week period during the fall semester and again during the spring semester of 1981–1982. The data collection instrument was a log diary using the Institute of Medicine's activity categories (National Academy of Sciences 1974).

We used faculty responses to the log diary instrument to assign faculty hours (and costs) to the various medical programs. We aggregated hours into four categories: medical teaching, resident and other teaching, research, and patient care. This aggregation process, however, was complicated by the fact that teaching, research, and patient care are often interrelated, and that faculty often produce simultaneous or joint concepts. We adopted two allocation schemes similar to those used by the IOM study. The instructional hours scheme allots a percentage of joint teaching/patient care hours to patient care, with the remaining hours included in teaching. The educational hours scheme, on the other hand, elects to allocate all joint product costs to teaching.

Another, more difficult issue arises from the fact that both medical students and residents may accompany faculty members when the latter are conducting research or providing patient care. In this case, how do we distinguish the time devoted to medical students versus that given to residents? For this analysis, we used, for joint teaching activities, an arbitrary 50:50 allocation for medical teaching and residency training, and used ratios from the 1976 IOM study (National Academy of Sciences 1976) to separate

the pure teaching times of medical students and residents/fellows.

The log diary response rate from all schools was 91% for the fall and 84% for the spring.

4.2. Cost Analysis

We collected comprehensive cost accounting data for the medical schools. The data can be represented in several different ways. The instructional cost concept views the cost of medical education narrowly, and considers only those costs directly involving medical student contact. The educational cost concept accounts for the costs of other support programs necessary to maintain a quality medical education effort. The total costs concept more fully expands the notion of educational costs by including all of the medical school faculty's other activities: the teaching of residents and other students, research, and patient care conducted independently of students. However, it is unclear whether all of these costs, especially those of resident training, should be attributed to the total cost of medical student education. In response to this problem, the allocated educational total costs concepts allocate total costs to medical student training and to resident/other student training.

The issue of joint products poses problems for calculating medical training costs. Traditional cost accounting assigns joint costs to individual products based on allocation methods that are judged most appropriate for a given study design. These often include ratios of direct cost or of effort. Many members of the medical educational community disagree with attempts to allocate these joint costs, arguing that

in medical schools it is virtually impossible to assign costs to specific programs (Koehler and Slighton). However, if we wish to evaluate the costs of medical education, we must account for joint activities such as teaching and patient care, and teaching and research.

In addition to the problems arising from joint products, the problems of multiple and interrelated products and nonreimbursable costs also create difficulties in capturing the costs of running academic health centers. The following two categories illustrate these difficulties.

- *Multiple and Interrelated Products.* Medicine is not taught solely by members of the faculty; although residents are still in training, they also teach students. Ideally, we would calculate the amount of time residents spend teaching medical students and add the cost of this time to the cost of instructing medical students. At present, the former cost is borne by the hospitals' residency programs. Similarly, the faculty costs of educating residents are borne by the medical schools.
- *Nonreimbursable Costs.* Some resources cannot be defined in terms of reimbursable costs. Volunteer faculty (attending non-faculty physicians), whose services represent a substantial investment of time, contribute in important ways to the educational experience. At the same time, however, these faculty receive unpaid services for their patients from the students and residents whom they teach. An accurate picture of total costs would reflect the difference in the value of the teaching provided and the patient care received by these faculty. For the purposes of this study, we assumed that the volunteer faculty received economic or intrinsic value equal to the value of their teaching services. Also, we did not account for costs of using other resources such as veterans' and other community hospitals and staff, for reasons similar to those involved in assessing the costs and benefits of volunteer faculty. Finally, we did not account for depreciation of physical plant because it is separately budgeted in the state university/medical school budgets: for the short run (several years), these sunk costs are fixed unless there is a need to rebuild portions of the physical plant.

5. Application of the Strategic Planning Methodology

The appropriate educational leaders have used our strategic planning methodology to assess the implications of various policy alternatives for the financing of medical education in the state. Our approach also

assists policymakers in formulating strategies for realizing particular system goals. The computer models that constitute the Decision Support System facilitate the examination of the effects of hypothetical strategies or events on the costs and outputs of the medical education system. We used assumptions concerning economic and physician supply trends to develop baseline financial and practicing physician profiles from 1981–1982 through 1999–2000. We formulated several hypothetical futures from a set of policy options suggested by the state Board of Regents and the leaders of the schools of medicine. Using the established data base and the computer models, we calculated the resulting costs and outputs of physicians in each of the futures. We then compared these with the baseline data to determine the net differences between the scenarios.

5.1. System Goals: Nominal Group Technique

Prior to identifying the policy issues to be addressed in the study, we asked the health affairs committee of the Board of Regents to specify the goals of the state's medical education programs. Using a structured group process called the nominal group technique to aggregate group judgment in a meeting setting, we recorded the group's ideas in a round-robin fashion and created a list of specific goals. Each idea was discussed and clarified, and then ranked by group balloting according to priority. In this way, individual judgments were combined into group consensus.

The goals emphasized the following themes:

1. Develop an organized strategy for providing medical education in the state that is responsive to state needs.
2. Provide quality medical education within available resources.
3. Provide quality medical education in an efficient and effective manner.
4. Emphasize primary care training.
5. Provide a reasonable opportunity for state residents to obtain quality medical education.
6. Provide the appropriate number and type of physicians needed in the state, and encourage an appropriate demographic distribution of physicians.
7. Increase cooperation of M.D.s and D.O.s in education and services.
8. Improve the health of state residents.

We used these goals to evaluate each of the policy options that we analyzed and to determine the positive features of the various policies that should be

considered in developing future policies. As for goals 2 and 3, Binder, Solnick and Carr (1983) of the Leonard Davis Institute found that universally accepted quality measures for medical education do not exist. Hence, the models are not capable of evaluating the quality implication of policy options, and so evaluating policy options for these two goals would have to be subjective.

5.2. Evaluative Framework

We use two different methods to evaluate the implications of each policy option. The first method analyzes each option in terms of its impacts on stakeholders. The stakeholders include the state, the region, the institutions, the faculty, students, and the population at large. The dimensions along which these impacts are measured include: political and social, psychological and economic, health care delivery and quality of medical education. While most of these dimensions must be measured subjectively, DSS models can be used to address the economic and health care delivery dimensions.

The second evaluation method compares the outputs of each policy option with the goals specified by the health affairs committee of the Board of Regents. Each option is scored positively, neutrally, or negatively against each goal. Composite scores for each scenario suggest the overall priority of a policy recommendation. The scores also may suggest possible modifications in the policies that allow them to better meet a particular goal. These scores can be summarized in a matrix form.

5.3. Illustration of a Policy Evaluation

For illustrative purposes, we consider a policy that increases medical school tuition and at the same time establishes a state revolving-loan program that helps needy students cope with the increases in tuition, with the feature that the loan can be forgiven for some students. This policy recognizes that the tuition increases may be prohibitive for many students in the state. The purpose of the loan forgiveness program is to encourage graduates of the state schools of medical education to practice in the state in primary care specialties and in rural communities. Using the models from the DSS, we found the 10-year cumulative savings from variations of this policy to range from \$21.5 million to \$34.4 million, while the outputs (physician supply) in the state improve slightly.

We now discuss the implications of this program.

- *Medical Education.* Addition of a revolving-loan program to tuition increases should reduce the impact that the tuition increase is likely to have on the

character of the undergraduate medical student body. The loan program also is likely to make tuition for state residents manageable; by deferring payment of the cost of education until the students enter practice, it overcomes the financial barriers to medical training.

- *Health Care Delivery.* While it is unlikely that the loan program itself can reduce the effect tuition increases may have on location and specialty choice, these problems may be more than offset by a loan forgiveness program. Thus, combining tuition increases and loan forgiveness may result in improved access to care in areas that are currently underserved.
- *Economic Interests.* Both the economic advantages and disadvantages of the tuition increase plan are softened by the loan program. Both state costs and out-of-pocket expenses incurred by students and their families are not as high as they would be without the loan program.
- *Political Dimension.* The political resistance to the tuition increase program should be lessened with the introduction of a loan forgiveness program; however, this reduction will likely be balanced by increased difficulties in settling the resource allocation problem.

6. Implementation and Results

The project team worked with the Board of Regents in implementing the methodology so as to arrive at an effective policy for the state's medical education system.

Using the Decision Support System, we rigorously evaluated the policy of maintaining the status quo. The models projected that, without changes in the system of medical education, there would be both a surplus of physicians and continued fiscal stress. Maintenance of the status quo would also force the state legislature to make significant cuts in other program areas. This assessment resulted in an imminent need for the Board of Regents to initiate alternative policy options, evaluate their cost and benefits, and present a recommendation to the legislature.

The Board of Regents and the project team began by identifying several dozen policy options as possibilities for policy changes. Eight pure strategies were examined prior to the selection of the specific policy options analyzed in this study. They included: (1) merging programs from different schools; (2) reducing their size; (3-5) changing their products (programs), prices, or revenue sources; (6) having the schools enter new markets; (7) having the state divest itself of the school(s); and (8) maintaining the status

quo. The specific policy options analyzed in this study were:

- (i) Increase tuition levels for each of the medical schools to reduce state funding by 10% or 20%.
- (ii) Increase tuition and establish a state revolving-loan program without loan forgiveness.
- (iii) Increase tuition and establish a state revolving-loan program with loan forgiveness.
- (iv) Reduce enrollment at each school by 10%, 20%, or 30%.

We then used the DSS model to project the costs and physician supply based on these different policy options. They provided quantitative estimates of the impacts of these policy changes on the medical education system. Next, we assessed the responsiveness of the policies to the goals and objectives of the education system, and we tabulated a policy assessment matrix for the four selected mixed strategies (Table I).

The model outputs from the DSS and the assessment matrix showed that the combination of tuition increases and a loan fund with forgiveness feature was the most attractive policy. The tuition increase policy reduces both state costs and the need to make resource trade-offs; however, it achieves these benefits by limiting the medical opportunities for state residents.

A tuition increase is likely to have minor negative effects on the availability of physicians by location and specialty; there is no reason to expect it to have any impact on the physicians' cooperation. The enrollment reduction policy saves dollars by reducing the number of students who enter the state's medical schools. Educational opportunities are therefore affected negatively. According to the adjusted

GMENAC (1980) figures, it appears that the state will have a surplus of physicians in the year 2000; thus, the reduction in the numbers of physicians educated may contribute positively to the system's overall strategy. However, this policy does not address the problem of maldistribution of physicians in urban/rural areas, and in the various specialties. The two policies with combinations of tuition increases and a loan fund satisfy the goal of having a systems strategy to meet the state's educational needs, which was ranked as the first priority by the Board of Regents. Both plans have significant amounts of state funds and help state residents overcome the financial barriers created by a tuition increase. The loan program without forgiveness saves more state dollars than does the one with forgiveness. However, the forgiveness feature provides the state with a means of addressing the current patterns of maldistribution of physicians, thus making it possible to increase the availability of care to underserved segments of the population. Neither option is thought to affect the cooperation of physicians.

With the projected impacts estimated by the decision models, the Board of Regents was then able to refine its policies, and to develop additional mixed strategies. The project team then analyzed these policy options again. In particular, they analyzed in great detail, the policy of tuition increase and a loan program with forgiveness feature, with different variations in the specification of the size of the loans, the terms of forgiveness of the loans, and so forth. This second round of analysis was considered essential in order for the Regents to make recommendations to the state legislature concerning the future of medical education in the state.

Table I
Policy Assessment Matrix^a

Policies	Goals						
	1. Systems Strategy to Meet Educational Needs	2. Quality Education within Resources	3. Effectiveness/Efficiency	4. Primary Care Training 6. Numbers and Kinds of Physicians and Location	5. Educational Opportunity	7. M.D./D.O. Cooperation	8. Improvement in Health Status
Increase tuition	+	+	0	-	0	+	
Increase tuition with revolving-loan fund, with loan forgiveness	+	+	+	+	0	+	
Increase tuition with revolving-loan fund, no loan forgiveness	+	+	0	+	0	+	
Reduce enrollment	+	+	0	-	0	+	

^a +, positive; 0, neutral; -, negative.

The detailed analysis using the Strategy Development and Evaluation process and the associated DSS indicated that the policy of tuition increase and a loan program with forgiveness feature would be by far the most desirable and effective strategy for the state to enact. The report from the project team was presented to the Board of Regents, who then presented the findings and recommendations to the legislature. During the legislative session following the delivery of the report, a broad fiscal crisis dominated the attention of the legislators. At the time, the legislature enacted a stop-gap measure to raise tuition, and did not establish a loan fund and further tuition increases. However, promises were made that the issues would be taken up again later.

The Board of Regents subsequently developed a broad proposal for establishing a loan fund and further tuition increases that would shift a further portion of the burden of financing medical education onto the recipients of the presumed advantage and off the taxpayers. The models developed by the project team were useful in this regard. However, because of pervasive political pressures, the model could be applied only to those limited alternatives that were politically viable; it could not be extended further. A new policy was then reintroduced to the legislature during a politically highly divisive period. The proposal of the Board of Regents included quantified financial impacts of the new policy on the medical education system, the state, and in comparison with other public medical schools in the region. It also included discussions of the impact of the policy on the stakeholders, as well as the board's assessment of the policy relative to the goals of the medical system in the state.

Debates on the proposal were intense. The question of who benefits and who pays came up again and again. The methodology of policy modeling, however, provided broad answers to some of the issues at stake. On April 8, 1985, the state legislature amended the state code. These amendments established a medical education fee and a revolving student loan program fund with provisions for loan forgiveness in certain instances. The Board of Regents plans to increase the education fee annually until the tuition and fees approximate the median value for medical schools in their region of the country. The legislation parallels the third policy presented to the Board of Regents by the Leonard Davis Institute research team: increased tuition, with a revolving loan fund. This policy had achieved the highest rating in the scenario assessment matrix developed for the project.

It is gratifying to see that the Fiscal Note of the State Legislature to House Bill 1820 outlines three policy

issues addressed by the legislation: "rising state cost of medical education, continued access to medical care by [state residents] who demonstrate financial need, and geographic and specialty maldistribution of physicians." These policy issues correspond to three of the goals and objectives identified by the Board of Regents for the project (listed in Section 5.1): develop an organized strategy for providing medical education in the state that is responsive to state needs; provide a reasonable opportunity for state residents to obtain quality medical education; and provide the appropriate number and type of physicians needed in the state, and encourage an appropriate demographic distribution of physicians.

7. Future Directions

The current project has components that are unique to the state under review, as well as some that are more general. The goal of cost-effective education of physicians is a universal one. However, the specific strategies pursued by a state or an individual institution must be tailored to its idiosyncratic system variables and stakeholders. The Teaching Resource, Financial, Physician Output, and Physician Projection models that constitute the Decision Support System and the Strategy Development and Evaluation Process are generic methodologies that can be applied to other settings with differing data bases and alternate priorities.

Our future work will focus on this latter, generalizable method and will proceed in two related directions: we will (1) refine the models, and (2) apply them to other states and institutions with comparable problems. We hope that these additional applications will lead to further improvements in our resource allocation instrument, and that this improved tool will assist decision makers in the current era of "physician surplus." We hope that, with the twenty-first century rapidly approaching, widespread use of such models will reduce the likelihood of an overreaction to physician surplus similar to the response that characterized the physician shortages of the 1960s and 1970s.

Appendix A: The Teaching Resource Model

For each department j in a school, let

f_{ij} = average % of time spent on teaching combined with patient care (with students or residents present) and teaching combined with research (with students or residents present) per faculty;

- f_{2j} = average % of time spent on in-class teaching per faculty;
- f_{3j} = average % of time spent on course preparation;
- f_{4j} = average % of time spent on curriculum development and evaluation, and school and other administration per faculty;
- f_{5j} = average % of time spent on other teaching activities, such as proportions of the times for professional development, general service, writing and reviewing journal articles or textbooks, and so forth, per faculty.

Define

$$R_j = \frac{f_{4j}}{f_{1j} + f_{2j} + f_{3j} + f_{4j} + f_{5j}},$$

$$T_j = \frac{f_{1j}}{f_{2j}},$$

and

$$P_j = \frac{f_{3j}}{f_{2j}}.$$

For a particular course i , let

- $C_{ij}(X_i)$ be the total number of faculty hours from department j in lecture + audit + examination, given X_i students in the course;
- $S_{ij}(X_i)$ be the total number of faculty hours in seminars, given X_i students in the course;
- $L_{ij}(X_i)$ be the total number of faculty hours in laboratories, given X_i students in the course;
- $N_i^s(X_i)$ be the number of seminar sections, given X_i students in course i ;
- $N_i^l(X_i)$ be the number of laboratory sections, given X_i students in course i ;
- M_i^s be the maximum number allowed in each seminar section of course i ;
- M_i^l be the maximum number allowed in each laboratory section of course i ;
- X_i^0 be the current number of students taking course i ;
- X^0 be the current class size;
- $T_{ij}(X_i)$ be the total number of faculty hours from department j in the instruction of course i , given X_i students in the course;
- $P_{ij}(X_i)$ be the total number of faculty hours from department j in the preparation of course i , given X_i students in the course;
- $G_{ij}^s(X_i)$ and $G_{ij}^l(X_i)$ be the total number of graduate assistant hours from department j for course i in seminars and laboratories, respectively, given that there are X_i students in the course;

- $E_{ij}(X_i)$ be the total number of laboratory technician hours from department j for course i in laboratories, given that there are X_i students in the course;
- V_j be the variable faculty teaching time (per student) for department j .

Assumptions.

1. R_j and C_{ij} are constants independent of class sizes, i.e., $C_{ij}(X) = C_{ij}(X_i^0) = C_{ij}$.
2. The faculty time spent in seminars and laboratories is proportional to the number of seminar sections and laboratory sections, respectively.
3. The teaching time net of total instruction, preparation and school administration (R) is a variable time proportional to the class size.
4. For a number of students $X_i \neq X_i^0$, the number of sections for seminar or for laboratory is given by the smallest number that can accommodate these X_i students and yet meet the constraint as specified by the maximum number per section.
5. When the total number of students changes, the number of students in each course i changes in the same proportion to that of the total number of students.
6. The numbers of graduate assistant hours in seminars and laboratories are proportional to the number of seminar and laboratory sections, respectively.
7. The number of laboratory technician hours is proportional to the number of laboratory sections.

We first note that $C_{ij}(X_i^0)$, $S_{ij}(X_i^0)$, $L_{ij}(X_i^0)$, $N_i^s(X_i^0)$, and $N_i^l(X_i^0)$, M_i^s and M_i^l can be obtained from course data.

From assumption 1, we have

$$T_{ij}(X_i^0) = [C_{ij} + S_{ij}(X_i^0) + L_{ij}(X_i^0)] \cdot T_j,$$

$$P_{ij}(X_i^0) = [C_{ij} + S_{ij}(X_i^0) + L_{ij}(X_i^0)] \cdot P_j.$$

From assumptions 2 and 3, we have

$$V_j = \frac{(\sum_{k=1}^6 f_{kj}) + (1 - R_j) - \sum_i [T_{ij}(X_i^0) + P_{ij}(X_i^0)]}{X^0}.$$

From assumption 4, we have

$$N_i^s(X_i) = \left\lceil \left(\frac{X_i}{M_i^s} \right) \right\rceil,$$

and

$$N_i^l(X_i) = \left\lceil \left(\frac{X_i}{M_i^l} \right) \right\rceil,$$

where $\lceil y \rceil$ denotes the smallest integer greater than or equal to y .

Moreover,

$$S_{ij}(X_i) = \frac{S_{ij}(X_i^0)N_i^s(X_i)}{N_i^s(X_i^0)},$$

and

$$L_{ij}(X_i) = \frac{L_{ij}(X_i^0)N_i^L(X_i)}{N_i^L(X_i^0)}.$$

Based on assumption 5, given a new level of class size X , the new number of students in course i is given by

$$X_i = X_i^0 \left(\frac{X}{X_0} \right).$$

Now with X_i , the new T_{ij} and P_{ij} 's are given by

$$T_{ij}(X_i) = [C_{ij} + S_{ij}(X_i) + L_{ij}(X_i)]T_j,$$

$$P_{ij}(X_i) = [C_{ij} + S_{ij}(X_i) + L_{ij}(X_i)]P_j,$$

where $S_{ij}(X_i)$ and $L_{ij}(X_i)$ are computed as above.

The total number of faculty teaching hours for department j is then given by

$$R_j + \left\{ \sum_i [T_{ij}(X_i) + P_{ij}(X_i)] \right\} + V_j \left(\frac{X}{X_0} \right).$$

For graduate assistants and laboratory technicians, since their main activities are in seminars and laboratories, respectively, the time required can be determined once we have $N_i^s(X_i)$ and $N_i^L(X_i)$:

$$G_{ij}^s(X_i) = \frac{G_{ij}^s(X_i^0)N_i^s(X_i)}{N_i^s(X_i^0)},$$

$$G_{ij}^L(X_i) = \frac{G_{ij}^L(X_i^0)N_i^L(X_i)}{N_i^L(X_i^0)}.$$

Hence, total graduate assistant hours from department j is given by

$$\sum_i [G_{ij}^s(X_i) + G_{ij}^L(X_i)],$$

and the total laboratory technician hours from department j is given by

$$\sum_i E_{ij}(X_i).$$

Appendix B: The Financial Model

Calculation of a school's faculty hours requirements depends on the collection of seven data items per department. Four of these are average hours a faculty member in department i spends weekly teaching medical students (M_i), teaching residents and other students (S_i), doing research (R_i), and providing patient care (P_i). The other three departmental data items include: (1) the number of faculty in the department (F_i); (2) the total medical student classroom hours per

department per year (C_i), which are calculated by the Teaching Resource Model; and (3) the ratio of an average faculty member's teaching hours to his or her curriculum development and school administration hours. We collect these seven variables at the school under study, and they define the faculty resource requirements of the school at its reference size or scale of operation (the size at which it was operating when the data were collected). This reference size is arbitrarily defined as a scale of 1.

Changes in the scale of operation may lead to changes in the resource requirements of the school. To simplify the problem, we assume that, as faculty resource requirements change, the ratio between a faculty member's teaching ($M_i + S_i$), research, and patient care hours remains fixed. Given this assumption, it is possible to focus on teaching hours as a means of calculating the new faculty resource requirements. Let $TPR_i = (M_i + S_i)/(M_i + S_i + R_i + P_i)$.

Total departmental teaching hours (TT_i) is defined as:

$$TT_i = (M_i + S_i) \times F_i \times 45,$$

where 45 is the number of weeks the average faculty member works exclusive of vacation and sick leave.

TT_i can be subdivided into fixed hours, hours that vary indirectly with the number of students at the school, and hours that vary directly with the number of students at the school. Fixed hours equal resident and other student teaching hours plus that share of medical student teaching hours that the faculties devote to curriculum development and school administration:

$$FT_i = [S_i + (TPR_i \times M_i)] \times F_i \times 45.$$

Hours that vary indirectly with the number of students at the school (VIT_i) equal C_i . Finally, hours that vary directly with the number of students at the school (VDT_i) equal the difference between total teaching hours and these other two categories:

$$VDT_i = TT_i - (FT_i + VIT_i).$$

Revised departmental total teaching hours (RTI_i) are defined as:

$$RTI_i = FT_i + RC_i + [VDT_i \times (1 + \alpha)],$$

where RC_i is the revised classroom hours (derived from the Teaching Resource Model for a school with a percentage change of α in class size).

The net change in teaching hours (NTT_i) is defined as the difference between the revised total teaching hours and the total teaching hours:

$$NTT_i = RTT_i - TT_i.$$

The number of faculty that can be released or that must be hired (NF_i) is:

$$NF_i = \frac{NTT_i}{(M_i + S_i) \times 45}$$

Notice that the net change in teaching hours is divided by a faculty member's weekly teaching hours ($M_i + S_i$) times 45 weeks per year. Though the net change in hours includes no time attributable to residents or other nonmedical students, these additional hours must be divided by a faculty member's full complement of teaching hours. This is because we have assumed that research and patient care are a fixed portion of a faculty member's time as is teaching time.

Once the net change in faculty has been found, it is possible to determine the net change in faculty research (NR_i) and patient care (NP_i) hours:

$$NR_i = R_i \times NF_i \times 45;$$

$$NP_i = P_i \times NF_i \times 45.$$

Appendix C: The Physician Output Model

Let

l, k be the index for location (for example, 1 for in-state urban region; 2 for in-state rural region; 3 for neighboring states; 4 for other states, including foreign);

i be the index for the medical school in the state;
 N_k^i = the number of incoming students from origin k to school i ;

a_{ij} = the proportion of first- and second-year students from school i who are assigned to take first- and second-year courses at school j ; $\sum_j a_{ij} = 1$;

b_{ij} = the proportion of third-year students from school i who spent their third year at location j ; $\sum_j b_{ij} = 1$;

p_{kl}^i = proportion of students from school i whose origins are k and who spend their fourth year in location l ; and

n_m^j = average number of students taking courses at school j in the m th year.

We assume that students taking first-year courses at one location will take their second-year courses at the same location. Hence, $n_1^i = n_2^i$. We then have

$$n_1^i = \sum_j a_{ij} \left(\sum_k N_k^i \right),$$

$$n_3^i = \sum_j b_{ij} \left(\sum_k N_k^i \right).$$

Then the number of student-equivalents who spend their fourth year at location l is

$$n_4^l = \sum_i \sum_k p_{kl}^i N_k^i.$$

After students graduate, they go on to residency programs or to internship programs, depending on the institution (see Figure 3).

(i) Graduates of Schools A and B

Let q_{kl}^i be the probability that graduates of school i whose origin is k will do residency in location l .

Then the expected total number of graduates of school i whose origin is k and who will do residency in location l is $q_{kl}^i N_k^i$; $i = 1, 2$.

Now let r_{ilu}^i be the probability that graduates of school i whose origin is k and who did residency in location l will come back to an in-state urban region, and let r_{klr}^i be the corresponding probability that they will come back and practice in an in-state rural region.

Let $S_{klu}^i(g)$ and $S_{klr}^i(g)$ be the probability that this group of graduates will eventually practice in specialty group g .

Then the total number of school i graduates who practice in an in-state urban region in specialty group g is given by

$$\sum_k \sum_l S_{klu}^i(g) \cdot r_{klu}^i q_{kl}^i N_k^i; \quad i = 1, 2.$$

The corresponding number who practice in an in-state rural region is

$$\sum_k \sum_l S_{klr}^i(g) \cdot r_{klr}^i q_{kl}^i N_k^i; \quad i = 1, 2.$$

(ii) Graduates of School C

Let h_{km}^3 be the probability that graduates of School C whose origin is k will do internship in location m . Then the expected total number of graduates of School C whose origin is k and who will do internship in location m is $h_{km}^3 N_k^3$.

For those graduates who practice immediately after internship, the probabilities that they will come back to in-state urban and rural regions to practice are r_{kmu}^3 and r_{kmr}^3 , respectively. For specialty choices, $S_{kmu}^3(g)$ and $S_{kmr}^3(g)$ are similarly defined.

The probability that graduates of School C will continue for residency programs in l after internship is given by f_{kml}^3 , given that the student is from origin k and does internship at m .

Hence, the total number of School C graduates who practice in an in-state urban region in specialty group g is given by

$$\sum_k \sum_m S_{kmu}^3(g) \cdot r_{kmu}^3 h_{km}^3 N_k^3,$$

and for an in-state rural region it is

$$\sum_k \sum_l S_{kmr}^3(g) \cdot r_{kmr}^3 h_{km}^3 N_k^3.$$

The total number of School C graduates who practice in an in-state urban region after residency is

$$\sum_k \sum_l \sum_m S_{klu}^3(g) r_{klu}^3 f_{kml}^3 h_{km}^3 N_k^3,$$

and for an in-state rural region it is

$$\sum_k \sum_l \sum_m S_{klr}^3(g) r_{klr}^3 f_{kml}^3 h_{km}^3 N_k^3.$$

The total number of graduates of the state's medical education system who leave the system for practice is

$$\begin{aligned} & \sum_{i=1,2} \sum_k \sum_l (1 - r_{klu}^i - r_{klr}^i) q_{kl}^i N_k^i \\ & + \sum_k \sum_m \left\{ 1 - r_{kmu}^3 - r_{kmr}^3 \right. \\ & \quad \left. - \left[\sum_l f_{kml}^3 (f_{klu}^3 + r_{klr}^3) \right] \right\} h_{km}^3 N_k^3. \end{aligned}$$

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