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ABSTRACT

There is no unique answer to the question of what an ongoing program costs in medical schools. The estimates of program costs generated by classical methods of cost accounting are unsatisfactory because such accounting cannot deal with the joint production or joint cost problem. Activity analysis models aim at calculating the impact of alternative combinations of school activities. As now practiced, activity analysis yields the incremental cost of an activity given all other school activities, that is, pure program costs. Such analysis is a potentially useful management tool. Input/output analysis is a special form of activity analysis in which some activities provide both final outputs and input into other activities. Following the introduction in Section I, this paper deals with cost analysis in section II and III. Section II discusses cost allocation studies that use the tools of classical cost accounting. Section III analyzes the use of linear regression as a tool for cost allocation, and Section IV examines activity analysis and optimization analysis. (Author/PG)

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ACTIVITY ANALYSIS AND COST ANALYSIS IN MEDICAL SCHOOLS

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and

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ABSTRACT

In circumstances of joint production there is no unique answer to the question of what an ongoing program costs. One can only speak of "pure" and "joint" program costs, the sum of "pure" costs being less than total cost and the sum of "pure" and "joint" costs being more than total cost. This need not be a source of frustration to the policymaker, however. If the policy question is whether a new program is "worth doing" the appropriate cost concept is the sum of "pure" and "joint" costs. If the policy question is whether an ongoing program is "paying for itself" the appropriate cost concept is "pure" cost. It must also be asked whether the institution is "paying for itself," however, for the answer to this question is not implied in the answers to the questions of whether individual programs are "paying for themselves."

A major modification of classical cost accounting procedures is required if appropriate cost estimates are to be obtained. Activity analysis models could provide the basis for such estimates if the models were constructed so as to capture the phenomenon of joint production. The input-output model does not, and hence is unsatisfactory.

ACTIVITY ANALYSIS AND COST ANALYSIS IN MEDICAL SCHOOLS

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I. INTRODUCTION

Management tools for academic health centers have focused on two questions:

1. What inputs will be required to achieve given output targets?
2. How should costs be assigned to a particular process?

The management tools aimed at the first question may be labelled activity analysis; those aimed at the second, cost analysis.

The activities of academic health centers are so complicated and interrelated that predicting the input requirements of output targets may be difficult. Helping to provide answers is the role of activity analysis. How much will it cost to increase M.D. enrollment by 10 percent? How much will total costs fall if direct expenditures on research are cut by 20 percent? The answers to such questions are useful and complicated and depend, among other considerations, on the facilities and faculty now present and how intensively they are being utilized. Will expansion of M.D. enrollment require new beds in the teaching hospital? Is the research to be eliminated closely related to teaching? A variety of such considerations -- specific to a particular school -- will determine the resources required or released by changed output plans. Thus, activity analysis is aimed at predicting the consequences of specific decisions in the detailed context of a particular institution.

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Cost analysis, by contrast, typically attempts to allocate costs to activities without regard to any proposed output change or to information on level of utilization of staff or facilities of various types. Where several activities are carried on jointly -- as teaching, patient service, and research are mingled in a medical school -- a non-arbitrary allocation of costs is impossible and classical cost accounting cannot find the "true" cost of one output. That failing, however, is not as serious as might be expected. Cost allocation useful for decisions can be done once those decisions and their context are specified. The question, "What will it cost, either in terms of money or of real resources, to expand a particular activity or set of activities, given a specified set of resources and levels of output?" can be answered. The question, "What is the true cost of a particular activity?" cannot, in general, be answered.

Sections II and III of this paper deal with cost analysis. Section II discusses cost allocation studies that use the tools of classical cost accounting. Section III analyzes the use of linear regression as a tool for cost allocation. And Section IV examines activity analysis and optimization analysis.

II. COST ALLOCATION STUDIES

The studies considered in this section all have one feature in common. They allocate the costs of certain observable activities of medical centers to the final products of that center, subject to the condition that the sum of the product costs is equal to the total cost of the activities covered. In sharing this characteristic, each of these studies is in some sense a linear descendant of the work on cost accounting methodology in medical schools done by Augustus J. Carroll under the sponsorship of the Association of American Medical Colleges (AAMC).(1,2,3) Most of these studies have in fact explicitly used a methodology developed by the Operation Studies Division of the Department of Planning and Policy Development of the AAMC. These include the seven studies reported by the AAMC in Program Cost Allocation in Seven Medical Centers: A Pilot Study,(4) 17 additional studies organized by the AAMC under the sponsorship of the Bureau of Health Manpower Education (BHME) in 1970-1971, and the set of 38 cost allocation studies sponsored by BHME completed in the summer of 1972. The remaining cost analyses under consideration here -- an investigation of costs and production relationships in the University of Iowa Medical Center(5) and a study in progress at a medical center that we shall call school "X" -- have been carried out somewhat differently, but they share with the AAMC studies the common goal of classical cost accounting: finding a method of allocating total institutional costs across that institution's set of final products in such a way that the sum of product costs equals total cost.

The accounting element on which these studies focus (the so-called cost center) is variously called a program, function, or final product activity. Each of these basic elements corresponds to a final output; each consists of sets of observable actions such as lectures, ward rounds, or laboratory hours. A cost allocation study is thus the mapping of the cost of the various (observable) activities of the resources that a medical center purchases into a set of (nonobservable) processes or programs that result in the final products of that institution. The current AAMC methodology categorizes the operations of a medical center in terms of six instructional functions and separate functions for research, patient services, and public services. In certain studies public services have been further subdivided according to recipient. The Iowa study follows a much more detailed format since cost allocation is only one of its objectives. It summarizes the operations of a medical center in terms of 63 activities whose output may be either final or intermediate product. The allocation of instructional costs by level of instruction is particularly detailed. The program structure of the study at school "X" is relatively simple. There is only one cost center or program in the instructional category.

The major differences among these studies lie not in the set of basic accounting elements or cost centers, however, but rather in the procedures used to define the set of observable activities that make up the process identified with a given cost center. These differences in "mapping" rules arise because many observable activities are functionally related to two or more final products. For example, in the Iowa and school "X" studies, the cost of faculty contact with patients is assigned to the instruction cost center if students were present at the time of contact.[1] In the AAMC studies the faculty respondent is instructed to "use his own good judgment in arriving at a proper percentage of effort in joint (simultaneous) product activities."(6) In this case the cost of faculty contact with patients with students present would be divided between the patient service and instruction cost centers rather than assigned completely to instruction. An analogous difference in mapping procedure appears in the case of simultaneous production of research and instruction. The Iowa and school "X" studies assign the cost of faculty research time to instruction insofar as that research involves student contact. The AAMC studies apportion such a cost between instruction and research.

These studies also differ in the methods used to "observe" the cost dimensions of the "observable" activities that are being mapped into the cost centers. Although a variety of instruments are employed

[1] In the school "X" study the cost of faculty contact with a "teaching" patient is fully allocated to instruction even if the contact was made without a student's being present.

in the AAMC studies, the primary accounting instrument is the faculty effort report. The Iowa study also relies heavily on this device. There are substantial differences, however, in the way these reports are handled. In some cases they are filled out by the individual faculty member; in others they are completed by someone else, usually a department chairman. A large variance can be expected in both the care taken in the preparation of effort reports and the assignment rules used to complete them. The study at school "X" employs professional cost analysts to make intensive interviews of the faculty to establish the dimensions of faculty effort.

These studies differ substantially from one another, indicating that there is no simple answer to the questions of what mapping or assignment procedure is "correct" and what steps must be carried out to estimate with a satisfactory degree of accuracy the costs of the various activities being mapped. The answers given in the AAMC methodology have provoked an extraordinary degree of controversy, and the Iowa and school "X" studies were in large part sparked by this critical response. There is general agreement that more "accurate" information on the costs of medical school outputs is essential both to improved allocative efficiency within medical centers and to better policymaking by government, but there is no agreement as to what kind of procedure would produce satisfactory cost estimates.

The following discussion is an attempt to answer the question of how one might arrive at "satisfactory" or "best feasible" cost estimates for medical school outputs. The answer is divided into two parts. First, what is an appropriate mapping procedure in going from activities to outputs where many activities are simultaneously involved in the production of more than one product? Second, given a mapping or cost assignment procedure, how can reliable cost estimates be obtained? These two areas of discussion correspond to the two main types of criticism levied at the AAMC studies: "They don't really measure what they appear to measure" (or, as a variant, "They attempt the impossible") and "They are based on worthless information."

COST ASSIGNMENT METHODOLOGY

There is a widespread suspicion within the medical-education fraternity that program accounting in medical schools is impossible rather than merely being difficult. A faculty member faced with a AAMC cost allocation questionnaire is likely to complain, "How do you expect me to divide up my time among various functions if I perform them simultaneously." A dean can be expected to look at the final cost assignments and grumble, "There is a lot more involved in medical education than just instruction." He may well conclude that the cost of education is pretty much the same thing as the cost of the medical school, and if told that this is unreasonable given the importance of the school's research and patient service outputs, he would probably think that program accounting in medical centers is impossible. "It just can't be done."

If by "it" he means the unambiguous allocation of institutional costs to the final products of that institution so that the sum of the costs assigned is equal to the total institutional costs, our hypothetical dean is quite correct. It can't be done. The same is true for the complaint of our hypothetical faculty member. There is simply no non-arbitrary way to allocate to individual products the costs of that part of his time spent in activities concerned with the joint production of more than one product if the sum of the allocations must equal the cost of those activities. Only if costs are assigned to products with the understanding that not all costs can be given an unambiguous product assignment (nor should ambiguous assignments be given), and the accounting focus is on joint products as well as individual products, is program accounting both feasible and useful.

In simply pointing out that the root of the controversy over the conceptual validity of medical school cost studies (the validity of the mapping rules) is the "joint cost" problem, the authors do not pretend to offer any new insight. Although the joint cost problem has been widely discussed in this context, the implications of the joint cost phenomenon seem to be generally misunderstood. For this reason it is important to discuss the issue in a general way before proceeding to the complexities of joint production specific to medical centers.

The Joint Cost Problem

A fundamental proposition in the theory of resource allocation is that the concepts of total cost or average total cost of a single product are not meaningful if that product is produced with other products and if the cost of producing the products jointly is less than the sum of the costs of producing them separately. To put this in another way, where the cost of producing a given product is not independent of the level of output of a second product, the two products are said to be joint products, and the total costs of these two products cannot be meaningfully allocated between them. The argument for this proposition is straightforward. The portion of the total cost of producing a set of products that is strictly attributable to a product that is a member of that set is the difference between the cost of producing the entire set and the cost of producing every element of the set except the product in question.[1] Given our definition of the circumstance of joint production, the sum of attributable costs across the set of individual products is thus less than the total cost of production. In circumstances of joint production, the entire cost of production cannot be meaningfully allocated to individual products. If several products can be produced only in fixed proportion they are said to be strictly joint products, and no portion of the total cost of production can be meaningfully allocated to any one of them. In this case all that can be done is to define the sum of these products as a new product and treat this composite as a single product or activity.[2]

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[1]There is no requirement here that the product in question not be produced, simply that it be produced in as small a quantity as is technically compatible with the given levels of production of the other products of the set. This may or may not be zero.

[2]The argument that it is conceptually impossible to allocate joint costs to individual products does not depend on an assumption that the products are never produced separately. In principle, at least, it is possible to use data from non-teaching hospitals to estimate what it would have cost to produce the patient-care product of an academic health center if patient care had been the only activity. This does not mean that the joint cost problem in medical schools is soluble, however. Even if patient care and instruction were the only products of an academic health center the difference between total cost and the estimated cost of patient care in the absence of instruction would be an unambiguous

This may be frustrating, but it is inescapable nonetheless. There is no use looking for a clever cost accountant with a new technique or a sophisticated economist with a new idea. The problem with finding a meaningful way to assign all of the cost of production to individual products in circumstances of joint production is one not of conceptual difficulty but of conceptual impossibility. Indeed, since the joint cost issue is insoluble in terms of ordinary cost accounting, it really is not a problem at all. It is simply a phenomenon to which the cost accountant must adjust.

To see what form this adjustment must take, consider a classic example of joint production in medical schools -- the teaching round. Assume that the cost of a ward round serving both the teaching and patient care functions is 100 resource units and the cost of a ward round providing (the same) patient care services alone is 70 resource units. The additional (marginal) cost of the teaching function given patient care is thus 30. This is the portion of the total activity cost that can unambiguously be assigned to the teaching cost center. But what is the marginal cost of the patient care function? If it is deemed impossible for technological reasons to perform the teaching function without performing exactly the same patient care services that would be carried out if no teaching were to take place, the marginal cost of the patient service resulting from this teaching round is zero. None of the activity cost can unambiguously be assigned to the patient-care cost center, and only 30 of the 100 cost units of the joint activity are assignable to individual products. If the teaching function performed in this teaching round could have been carried out without the full panoply of patient services actually provided -- the

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measure of the cost of instruction only if it could be assumed that the volume of patient care is predetermined and independent of the level of instructional activity. This is a highly doubtful assumption even if the unit of reference is the entire health care system of society. It is patently false if the unit of reference is the individual academic health center. Further, even if it could be argued that patient care activities were "logically prior" to instructional activities, the problem of disentangling the joint costs of research and instruction would remain.

reason for the simultaneous production of both outputs being a matter of efficiency as well as technological necessity -- the marginal cost of patient care in a teaching round given teaching would lie between zero and 70. But as long as some of the actions of the teaching round actually perform more than one function -- as long as there is some element of joint production -- the sum of the costs assignable to individual functions is less than the cost of the teaching round.

In these circumstances the costs of observed activities can be meaningfully mapped into production processes only if a more complex set of cost centers is adopted than the set used in classical (AAMC) cost accounting. In the above teaching-round example, four cost centers are needed: pure teaching, joint production involving teaching, pure patient care, and joint production involving patient care.[1] The part of the cost of an observable activity (for example, teaching rounds) that is the cost of a "pure" process is what is strictly assignable to an individual product -- the difference between (1) the actual cost of the activity and (2) the estimated cost of that activity under the assumption that it has been modified to result in the least possible output of the product in question compatible with maintaining the initial outputs of the remaining products. In our original teaching-round example, the cost of pure teaching is 30 resource units (100-70), and the cost of pure patient care is zero (100-100). The part of the cost of an activity that is the cost of joint production involving a particular product is the difference between (1) the estimated cost of the activity under the assumption that it has been modified to result in the least possible output of the remaining products compatible with maintaining the initial output of the product in question and (2) the part of the cost of the activity that is strictly assignable to that product. In our original teaching-round example the cost of joint production involving teaching

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[1]Strictly speaking, since only two products are involved, only one cost center for joint production processes is needed in this example. We have introduced two cost centers of this type since in the more general case of "n" final products ("n">2) the required number of cost centers for joint production is equal to "n".

is thus 70 resource units (100-30), the same as the cost of joint production involving patient care (70-0).

Note that we have not identified the sum of pure teaching costs and the costs of joint production involving teaching as the cost of teaching. It is not. A more appropriate, although clumsy, definition of this sum is the cost of teaching and such other outputs as are jointly produced with teaching subject to the constraint that these other outputs are produced at the minimum level compatible with the production of teaching. This sum of pure and joint costs is the integral of that marginal cost function of the product defined by the assumption that all other outputs are reduced to the minimum level consistent with the upper bound of the integral (the observed output of the product in question). The cost of pure production is the integral of that marginal cost function of the product defined by the assumption that all other products are produced at the observed levels of output. Both are thus marginal cost concepts. The joint cost "problem" arises because these two integrals do not assume identical values.

The teaching-round example given above is in a way unfortunate because it may lead to the belief that the joint cost "problem" arises only because of constraints on minimum feasible output ratios. That is, joint production takes place because it is necessary to give patient care in order to teach. Minimum feasible output ratios are a major source of joint production phenomena but they are not the only source. Joint production may also arise simply from economies of simultaneous production. If the teaching output of a teaching round could in fact be produced by an activity that did not require patient care (for example, videotaped lectures) the sum of pure teaching costs and the costs of joint production involving teaching would be simply the cost of producing teaching by this alternative method. If the cost of the teaching output of our teaching round would be 50 resource units if it were carried out without patient exposure, the cost of pure teaching would remain at 30 units (100-70), but the cost of pure patient care would increase to 50 units (100-50). The cost of joint production involving patient care would be 20 (70-50), as would the cost of joint production involving teaching (50-30).

Special Problems with Analysis of Joint Costs in Medical Schools

The cost analyst should be prepared to find substantial variation between institutions in perceptions of the dimensions of joint costs in medical school operations for two important reasons. First, the extent of joint production is very much a matter of what kinds of output an institution attempts to produce. For example, there will be considerably more jointness between research and training in an institution heavily committed to the production of medical teachers and researchers than in an institution more oriented to the production of primary care physicians. Note that the driving factor here is future commitment, not the productive history of the institution.

Second, although perceptions of the dimensions of joint costs reflect perceptions of the production functions for medical school outputs -- the technical relationships between inputs of various activities and outputs -- there is relatively little knowledge of or agreement about the nature of these functional relationships. Just as there is great controversy over the question, "What is the best way to train a doctor?" there would be great controversy over the question, "What would the medical education program look like if the simultaneous production of research and patient care were reduced to the minimum levels actually required for educational purposes?" The latter question must be answered if any headway is to be made in unraveling the joint cost problem, yet it is doubtful that many academic physicians have ever seriously addressed it. Given the lack of agreement within the medical profession as to (1) what productive capacity is or should be embodied in a given educational output, and (2) what different educational processes produce in the way of productive capacity, estimates of the dimensions of joint costs can be expected to be highly variable in terms of both magnitude and "quality." We might say that these dimensions will be judged rather than measured.

For these reasons it will be exceedingly difficult to interpret differences among institutions in estimates of either the "pure" or the joint costs of various outputs. They will reflect differences in type of output and differences in perception of the nature of the production function as well as simple differences in efficiency. And this is assuming that each institution has used the same basic cost methodology and has examined the same sets of activities.

The joint costs that we have discussed up to now have arisen from characteristics of the production function -- minimum feasible output ratios or economies of simultaneous production. Joint costs may also derive from the phenomenon of joint factor supply. For example, it may be quite feasible on technological grounds to produce a given educational output without simultaneously producing a particular research output, but if a factor required to produce the educational output will be made available only if it is also allowed to produce that research output, a situation of joint costs has been created.

Although it is obvious enough that this situation can and does arise in medical schools, it is extremely difficult to estimate its dimensions over the entire range of school operations. It is a wise dean indeed who is capable of accurately estimating the minimum amount of research time he would have had to buy if his only objective had been the acquisition of a faculty capable of producing the particular educational output that his school is committed to produce. A much more feasible task is estimating how much more (if any) faculty research (or patient care) time will have to be purchased in order to secure a given increment in faculty time devoted to training.[1]

It is important to point out that the answers to such questions depend on more than the characteristics of the supply function of faculty effort. The competition among medical schools for faculty who are productive in research (a competition largely funded by the federal government) makes it virtually certain that some faculty have salaries

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[1]Strictly speaking, this statement of the problem and the statement of the problem of the preceding sentence are too simple. The problem of our hypothetical dean is to estimate the minimum faculty cost consistent with obtaining the faculty inputs needed to meet educational objectives alone. Since faculty supply is presumably an increasing function of both salary and percentage of effort devoted to research, the actual cost of meeting teaching requirements may exceed the cost allocable to teaching either because research time has to be purchased jointly or because faculty salaries have to be increased to obtain a higher ratio of teaching time to research time.

and teaching load more favorable than would actually be required to keep them from taking employment outside medical schools. As long as the donors of research funds are willing to accept the valuation of faculty time set by the individual medical schools when they (the donors) decide whether or not to support a given project, this excess of "price" over "supply price" is a very real part of the joint costs that a school must pay in order to meet its teaching targets. This part of the joint cost of education arising from joint supply is not "inevitable," however, for it could be eliminated (in principle) if the donors of research funds were to use their monopsony power.

A Conceptually Satisfactory Cost Assignment Methodology

We have already indicated in rough outline the cost assignment procedure that is required under circumstances of joint costs if cost assignments are to be conceptually meaningful. There are two stages to this procedure. The first, aimed at capturing those elements of joint cost that derive from the technology of producing medical school outputs, consists of allocating activity costs by means of observation, interviews, or effort reports to two sorts of cost centers -- "pure" processes (or outputs) and "technologically joint" processes (or outputs). The number of cost centers given over to "pure" processes will be matched by an equal number of cost centers concerned with "technologically joint" processes. The sum of the costs allocated to "pure" cost centers will be less than the total costs of the activities examined. The sum of the cost allocated to all cost centers, "pure" and "technologically joint," will be greater than the total activity cost.

The second stage of this cost assignment procedure aims at capturing those elements of joint costs deriving from considerations of joint supply. It consists of estimation (by some unspecified procedure) of the extent to which the sum of the "pure" and "technologically joint" costs of a particular product is less than the cost of those inputs that must actually be purchased in order to secure that product. The sum of this difference and the "technologically joint" costs is the total joint cost involving that product.

The end result of this two-stage procedure is thus two sets of cost estimates -- a set of "pure" or strictly allocable costs and a set of estimates of "pure" plus "joint" costs. The "pure" cost of a product is the cost of producing it under the assumption that the other products of the system are already being produced at their observed levels. The sum of the "pure" and "joint" costs of a product is the cost of producing that product and such other products as must be produced jointly with it under the assumption that these other products are produced in minimum feasible amounts.

The response to this may well be, "But what then is the unique 'true' cost of producing a given output?". There is no answer to this question, not because no one has discovered a way to find it but because the question has no meaning. The notion that joint costs somehow create a dilemma -- that, as Fein and Weber suggest, there is a "problem" of finding the "theoretically least unsound of technically simple bases for the allocation of joint costs"(7) is misleading. Such a problem exists only if an allocation procedure is sought that has the property of exactly allocating all costs over the set of final products. But there is no reason to attempt to "solve" this "problem." An allocation procedure with those properties does not provide any guidance for management.

The false dilemma of "true cost" can arise only if insufficient attention is paid to the question of why a cost figure is wanted. In examining an ongoing system, such as a medical school, only two kinds of cost questions really have any significance. The first is, "What is the total cost of the system?" The second is, "What part of the cost of that system is strictly allocable to a particular process or product of that system?" An answer to the first question is needed to compare with the answer to the question, "What is the benefit (or revenue) of the total system?" Answers to the second type of question are needed to compare with the answers to the question, "What part of the benefit (or revenue) of the system is strictly allocable to a particular process or product?" It should be noted that the comparison of the answers to the second type of question may be "favorable" for each product of the system while the comparison of the answers to the first type of question is "unfavorable". This may well be the case for many medical schools. Allocable revenues may exceed allocable costs for every product or process even though total revenues are less than total costs. If joint costs are quantitatively important, it may well be that deficits cannot be traced to any particular process or product.[1]

Although it is conceptually feasible to carry out a meaningful cost allocation study of the total operations of a medical school the practical difficulties of doing so are tremendous. It is much simpler to allocate the costs of an incremental change in operations. Further, the cost concept that is generally relevant to policy decisions is the cost of incremental changes. Consider for example, the question that is currently being faced by the staff of the National Institute of Medicine, "What is the cost of training a (particular kind of) doctor?" The practical reason for asking this question is to determine the cost of the resources that must be committed by medical schools in order to secure an increase in the supply of "doctors." This is a separate question from, "How much has it cost to educate doctors?"

Because of the joint cost phenomenon answers given to the last question are inconclusive guides to the answer to the question, "What is the marginal cost of 'doctors'," even if medical education is produced under conditions of constant returns to scale. The major reason for this is uncertainty with respect to the question of whether those products that must be jointly produced with education for technological reasons are currently being produced in sufficient quantity to permit an expansion of educational output without a concomitant expansion of the output of these associated products. An additional reason is uncertainty as to the degree of internal flexibility in the allocation of faculty time between teaching and research and hence how many

[1]There has been considerable criticism of the cost-revenue comparisons contained in the so-called "Financial Distress" study (8) on the grounds that certain of the revenue allocations were arbitrary. Without agreeing or disagreeing with that particular criticism we would like to point out that certain of the cost allocations were improper. The fact that the sum of the cost allocations across products equaled total costs implies that there were no joint products. Yet the authors of the report went to great pains to make clear that they recognized the importance of the joint production phenomenon.

additional resources must be purchased to secure the technologically requisite supply of faculty inputs?

If there is sufficient "slack" in the system, the incremental cost of producing education will approximate the average current cost of those resources strictly allocable to the education process -- the average "pure" costs of education. If there is no slack at all, the incremental cost of education and its joint products will approximate the average (per unit of education produced) current sum of "pure" and "joint" costs of education. If there is slack, but of a degree insufficient to permit the desired expansion of education without some further expansion of the related products, the incremental cost will fall somewhere in between these two measures of the current average "cost" of education.

For these reasons, and for the additional practical reason that many inputs into the educational process are "lumpy" (for example, lecture halls), estimation of the incremental cost of education is more interesting than estimation of current average cost(s). A particularly promising example of this sort of enquiry is the activity analysis model currently being implemented at the Duke University Medical School. We briefly discuss the capabilities of this model in Section IV.

ACCURACY OF MEASUREMENT

Given a satisfactory methodology of cost allocation under conditions of joint production, the problem remains of finding a practical means of applying that methodology. Much of the criticism of AAMC cost accounting has in fact centered on this point rather than on its allocation criteria. In particular, there has been considerable doubt voiced whether a procedure based on the faculty effort report can yield measurements sufficiently accurate to be useful.

There is relatively little one can say about this question. The reliability of retrospective accounting is always suspect. If women cannot give an accurate estimate of the number of live-born babies to which they have given birth in the last year (which demographers assure us they cannot), it is unreasonable to expect that academic physicians can accurately remember all of their varied and complex activities over the same period. If these "memory-errors" in reporting are random, however, and if the population of sample being investigated is fairly large, this sort of criticism of effort-report based cost estimates is considerably weakened. A more disturbing possibility is that effort reports are biased because of a respondent's unwillingness to allocate his time in a fashion that is inconsistent with the sources of his financial support. We suspect that this is a very real problem.

It is also possible that some of the criticism of effort reporting may stem from a dissatisfaction with the cost accounting methodology used in AAMC cost studies rather than dissatisfaction with the effort-report technique itself. Faculty members who ask their secretaries to fill out their effort-report forms may do so because of frustration with the meaning of the questions that those forms ask. The instruction to use one's "good judgment" to allocate joint activities is hardly better than no instruction at all. The respondent has, in fact, been given no criterion to use in preparing his response. He may boggle over the question, "If processes A and B were carried out jointly, how much additional effort was required to perform both A and B than would have been required to perform A (or B) separately?", but he should at least know what the question means.

The plain fact is that no one seems to know just how accurate cost estimates based on the faculty effort report really are. The AAMC is reported to have made an investigation of this problem, but our understanding is that further investigation is considered necessary. Perhaps the studies of the National Institute for Medicine will shed further light on the issue. The problem is both important and researchable. If the effort report does in fact turn out to be as unreliable as the critics maintain, there are many techniques borrowed from industrial engineering that can be used. The experience at both Duke and school "X" suggests that it is possible to obtain information on faculty activity at reasonable cost through the technique of direct interview. It would be very useful, however, to have a better notion of just how much more accuracy these more expensive techniques actually buy.

Another important practical problem of measurement is deciding what set of activities ought to be costed. This is particularly troublesome for medical schools since institutional arrangements between the school and its various teaching hospitals vary enormously. The procedures adopted in existing studies definitely do not capture certain types of costs that are strictly allocable to medical education, costs that result directly from participation in the teaching process such as the increased number of diagnostic studies, increased length of hospital stay (allowing for differences in patient mix), and lowered occupancy rates resulting from the practice of bed assignment by service. Other costs that have generally been overlooked are the opportunity costs of volunteer faculty and building (depreciation) costs. The role of interns and residents in the education of medical undergraduates, interns, and junior residents is also generally neglected.

In a strict sense a complete description of the "cost" of medical education requires allocation of the costs of all activities that are either directly or indirectly (jointly) related to the education process. In many cases this means considering the costs of activities that are neither under the control, nor the responsibility, of the medical school. For example, to the extent that the production function for education requires that patient care be jointly produced with education, even "bed-and-board" costs of patient care are part of the joint costs involving education. From a theoretical point of view it is immaterial whether these activities are self-supporting or even under the financial purview of the medical school. Although not strictly allocable to education, they still contribute to joint costs involving education. The point here is not merely theoretical. An increase in the volume of (technologically required) indigent patients or a rise in the bad-debt ratio applicable to "required" patients can add to the financial woes of a medical center just as surely as an increase in the "pure" cost of education. Although these joint costs are not strictly allocable to education, neither are they strictly allocable to patient care.

In analyzing the costs of existing outputs of education this problem of capturing the full dimension of joint costs involving education can and should be avoided. The only question of interest is how the strictly attributable ("pure") costs of education compare with the benefits or revenues that are strictly attributable to that process. The problem of boundary design is thus simply one of making sure that all "pure" costs are captured. In considering the costs of increased outputs of education there is no short cut, however. All joint costs should be measured. There is no implication here that an organization responsible for the decision to increase the output of education should bear the full sum of the pure and joint costs of that increased education, but if increased education is the only objective sought, the decisionmaker must stand ready to finance that part of total (pure plus joint) cost that cannot be offset by the sale of jointly produced outputs.

III. REGRESSION ANALYSIS OF PROGRAM COSTS

All of the estimates of program costs we have considered so far require substantial effort in data collection. Faculty effort reports, even of the most simplified and shortened form, require considerable investment to provide data on just one school. In order to make estimates of cost by program type for all schools without using such detailed data, Wing and Blumberg resort to regression analysis of gross cost and program data for many schools. (9,10)

THE REGRESSION ANALYSIS MODEL

To estimate equations for operating costs and for space, Wing and Blumberg fit equations of the following form:

$$Y = a + b_1 x_1 + b_2 x_2 + \dots + u,$$

where Y is equal to total non-sponsored expenditures or to non-medical-care floorspace. Independent variables (x) include:

1. number of medical undergraduates
2. number of basic science students
3. number of interns, residents, and clinical fellows
4. number of clinical science degrees granted
5. dollars of sponsored research
6. a dummy variable set equal to one in the case of a state school
7. number of full time faculty
8. number of voluntary faculty
9. a dummy variable set equal to one if the school owns a hospital, zero otherwise.
10. a dummy variable set equal to one if there is a dental school on campus.

Variables 1-6 are used to explain operating costs; variables 1-3 and 6-10 are used to explain floorspace. The "u" is a random error term.

Wing and Blumberg argue that estimates of the fitted coefficients (b_i) provide estimates of the contribution to total cost of one unit of each of the independent variables: For this argument to be true, they note, several strong assumptions are required. "(1) All schools in our regression samples have the same program costs; (2) there are no joint costs among programs; and (3) each of the production processes exhibits constant returns to scale."(9) For their method to be correct, however, a much longer list of assumptions is in fact required -- for example, that salaries and costs of capital are the same for all schools.

Since the crucial point of their argument concerns the precise magnitude of the estimated coefficients, we need to give some care to the criteria by which we evaluate their results. In particular, the R^2, or proportion of the variance of the dependent variable explained by the independent variables, is less important in this case than the standard errors of estimate of the coefficients, whether the band within which we are confident the coefficient lies is broad or narrow. The coefficients, after all, are the object of the exercise -- the estimates of cost per unit.

A principal source of error in the coefficients may arise from specification error. If the form of the estimated linear equation (as distinct from the values of the coefficients) does not accurately represent the structure of behavior in the real world, the coefficients will not be good estimates of the concepts they are intended to represent. Specification is particularly important in this case because of the likelihood of joint costs in the medical school setting. Since there is no way to capture joint costs in their linear model, Wing and Blumberg's coefficients will be biased away from their true values if jointness is, in fact, important.[1] Specification error is hard

[1]A simple joint cost model may be specified as

$$1)\quad Y = b_1 x_1 + (b_2 x_2 - b_3 x_1).$$

If b_1 and b_2 are positive, the cost (Y) of producing x_1 and x_2 together will be lower than the cost of producing them separately. Equation to detect, but it may be revealed in coefficients that seem "unreasonable" or counterintuitive.

REGRESSION ANALYSIS RESULTS

The estimates of operating costs are quite unsatisfactory. Wing and Blumberg break their sample into large and small and state and non-state schools and fit the same equation for each of the resulting four groups and for the sample as a whole. The coefficients in each of the equations are quite different. Most of the variables in the equation for the total sample are significant; in the sub-sample, only the equation for large non-state schools has more than one coefficient significant at the .05 level; that equation has two significant coefficients: sponsored research; and interns, residents, and clinical fellows. The seemingly satisfactory equation for the total sample can therefore be disregarded: The assumption that production processes are homogeneous across schools is obviously violated since the sub-sample equations are quite different.

The estimates of capital costs are more satisfactory. The number of basic science students, number of full time faculty, presence of a dental school on campus, and whether a school owned a hospital or not are all significantly related to the number of net square feet of non-medical-care floorspace. In this estimate as well, however, there appear to be problems of specification and collinearity since the number of medical undergraduates and the number of interns, residents, and clinical fellows are not related to space requirements. Indeed, the coefficient for undergraduates, though insignificant, is negative. This result seems unreasonable and is the sort of outcome one expects from an improper specification with multicollinearity.

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(1) is indistinguishable empirically from

$$2) \quad Y = b_1 x_2 + (b_2 x_1 - b_3 x_2).$$

Fitting the equation, one cannot contend that the coefficient on x_1 is the marginal cost of x_1; it may in fact be some combination of b_1 and $(b_1 - b_3)$. Capturing the effect of joint costs would require a much more complicated functional form, but is not in principle impossible.

In sum, although the work of Wing and Blumberg is an interesting attempt to make bricks without straw -- to estimate costs without detailed data on operations at the level of the individual medical school -- the resulting program cost estimates are unreliable and dubious. Regression analysis of medical school costs may in the future produce useful insights, but will have to rest on more subtle statistical models of school goals and behavior.

IV. ACTIVITY ANALYSIS FOR RESOURCE ALLOCATION

Faculty effort reports and the associated data on program costs have usually been applied to the question, "What is the true cost of producing an M.D.?" That question is a will-o'-the-wisp. Faculty effort data and other cost information are not valueless, however, When organized into an appropriate framework, such data might provide useful insight for the management of school resources. What activities occupy most of the time of the faculty? What will be the bottlenecks encountered if class size is increased by ten percent? How will a ten percent reduction in class sizes affect faculty requirements and space needs? Such questions are meaningful and may be illuminated by the sorts of data described above.

This section discusses two techniques that try to describe the pattern of school resource use by manipulating activity data drawn from effort reports. The first, developed by the Systems Research Group (SRG) is a computer system for aggregating activity data, summarizing resource usages, and systematically projecting the effects of changed policies or levels of activity. The SRG work so far applies only to the educational activities of health science centers. The second technique is the input/output analysis done by Latham, which attempts to describe the operations of a medical school as a whole using a conceptual framework originally designed for general equilibrium analysis of an economy. This work is more ambitious but much more dubious as well.

The SRG work is scattered in a variety of reports and articles.(11,12,13) Health sciences planning work was first done for the University of Toronto Medical School. The study initially produced a system of four models that calculated resource use and funding for various medical school activities.(12) This system of four models has since evolved into the two-model package first applied at Duke.

Latham's work on input/output analysis is reported in the thesis cited above.(5)

ADDING UP ACTIVITIES

A list of all of the educational activities in a health science center would include the various science courses taught; time spent by undergraduates, interns, and residents on different services in teaching hospitals; supervised work on Ph.D. dissertations; and the like. Having defined a complete list of such activities, one can then ask how much each activity consumes of resources of various types: faculty time, materials, classroom space, etc. Each activity could then be matched with the resources it consumes. This matching requires considerable organization of data but no sophisticated computation.[1]

SRG's Educational Activity Analyzer (EAA) performs this set of calculations. Input to the EAA computer program identifies for each activity the number of students enrolled from each education program, the section size, the staff required by department or other unit, the time spent in student contact and in preparation, and the other identifiable resources and space used. The data are gathered from each faculty member. Since courses are often taught by faculty from several departments or by other than strict full time faculty, and since activities themselves may be broad, any one activity may generate a large number of separate input cards, which must then be aggregated.

Symbolically, the object is to calculate x_{ijt}, the utilization by activity i of the jth resource in period t. The EAA allocates the raw input data to the appropriate term in the matrix of the x_{ijt}. The program then produces reports on the utilization of the various resources by period, by department, by program, and so on.

The heart of the program is a procedure for assigning inputs to activities and adding them up in alternative ways. The EAA partly avoids the joint cost problem by dealing with one function at a time and asking for input data in terms of the increment attributable to that function, when all other activities are already being performed. The output data are thus the incremental cost of one activity, given all the other activities of the school; of one course, for example, rather than education as a whole.

[1] This is not to say the program is simple. Carefully editing and checking the input data and producing a variety of well-formatted output reports is a difficult programming task.

ANALYZING POLICY CHANGES

The range of activities and resources that concern medical school management is so broad that simple summary reports on resource usage may be useful by themselves. A still greater payoff, however, will flow from the analysis of program and policy changes. For example, Duke intends to use the SRG system to examine demands for resources implied by curriculum changes or by hypothetical changes in the size of entering classes. These tasks are to be performed by the second half of the SRG package, the Educational Planning Model (EPM), recently implemented at Duke.

Output from the EAA produces a set of planning parameters for each activity: the resources of space, patients, and faculty time required per student in each of the activities. These summaries are in turn put into the EPM together with projected data on the size and structure of enrollment for future periods. Parameters generated by the EAA may be altered so that changed policies or curricula may be investigated. The EPM then calculates the amount of the various resources required. Given requirements of patients, teaching time, and space, the direct requirements are then converted into faculty by type and salary, space is converted to rooms and square feet, and patients are converted to hospital admissions and beds. The program may then compare these resource requirements with exogenously specified resource availabilities. Indirect resource usage is computed according to a formula specified by the user. Fee income from professional services may also be specified. Given the requirements for teaching material and estimates of cost per visit and the fee recovery rate, the income from fees can be estimated and added to estimates of other revenue; these financial requirements and sources are then aggregated and compared.

In general, resources and requirements or expenditures and income need not be equated by the EPM. The discrepancies between sources and uses of resources, however, provide guidance for policy changes that can then be explored in another run of the model.

The EAA and EPM systems together appear to be promising management tools for aiding decisions in health science centers. They will never provide an answer to the questions "What is the average cost of producing an M.D.?" or "What is the marginal cost of producing an M.D.?" The logical structure of the SRG models fails even to address the joint cost issue. The models are useful, nonetheless. They provide information on the incremental cost of educational programs given all other health science center activities and can help provide systematic analysis of program alternatives.

INPUT/OUTPUT SYSTEMS

If there were no problem of mapping activities uniquely and exhaustively into output (that is, if there were no problem of joint costs and interdependent production), and if production relations were well known, then a system of equations relating outputs to activities and thus to usage of resources could be constructed. If some of the activities were, in turn, inputs into still other activities, then the system of equations could be represented as a classic Leontief input/output system. Such a system has been applied to a medical school by Latham.(5)

The logic of such a framework is fairly clear when we are using it to represent the structure of industries in an economy, the application for which it was developed. The production of steel goes partly to other intermediate uses and partly to final uses, such as residential heating. The input/output framework allows economists to capture this pattern of interdependence. Beyond its utility as a descriptive device, however, input/output analysis of an economy allows us to predict how the output of all industries would have to expand in order to produce an increase in the final output of one of them. In order to produce more steel, the economy would have to produce more coal as well as transport services, fuel for operating coal-mining machinery, etc. The input/output matrix represents a set of equations that can be solved for estimates of these direct and indirect requirements or a system that can be optimized.

In order to write this system of equations, one must take the activity and resource data summarized in the matrix of x_{ijt} (utilization of resource j by activity i in period t) and link them to outputs so that the output of activity n in time t is given by:

$$Q_{nt} = a_{111}\, x_{111} + a_{112}\, x_{112} + \cdots\, a_{ijt}\, x_{ijt}$$

In such a simple structure, any output simply requires specified inputs of the activities, represented by the coefficients, a_{ijt}, times the activities, x_{ijt}. Summing across time (say an academic year) the t subscripts can be eliminated:

$$Q_1 = a_{11}\, x_{11} + a_{12}\, x_{12} + \cdots\, a_{ij}\, x_{ij}$$

$$\vdots$$

$$Q_n = a_{n1}\, x_{n1} + a_{n2}\, x_{n2} + \cdots\, a_{nj}\, x_{nj}.$$

If some outputs, Q_1, are partly or totally used as inputs in another process, then

$$Q_1 = \alpha_{11}Q_1 + \alpha_{12}Q_2 + \ldots + a_{11}\, x_{11} + a_{12}\, x_{12} + \ldots$$

$$\vdots$$

$$Q_n = \alpha_n Q_1 + \alpha_{n2}Q_2 + \ldots + a_{n1}\, x_{n1} + a_{n2}\, x_{n2} \ldots$$

Outputs are thus divided into amounts used as inputs in the production of other outputs (intermediate output) and outputs that go to other uses (final output). More important, the production of a given quantity of any one output requires an exactly specified input of other outputs and primary inputs. Since the relation is linear, doubling the rate of final production of an output requires that its inputs, both primary and intermediate, be doubled.

The set of equations is usually written as a matrix or table. In Latham's table, an entry represents a flow from the activity shown on the side of the table to the activity shown along the top. For example, an X in the General Administration row, Medical Courses column, indicates that there is a flow of administrative services required for the production of Medical Courses. Cells with value zero represent combinations of supplying and using activity that are not permitted in the conceptual framework or not observed in practice.

Input/output equations permit various potentially useful computations: What inputs are required to produce a specified set of final outputs? Given valuations of the different outputs, what is the most highly valued combination of final outputs that can be produced? How would the optimal output combination be changed if constraints (for example, class size, research/teaching ratios) were changed?

Even in the economic applications for which it was designed, input/output analysis has been less useful than its inventors hoped. As a tool for the analysis of health science centers, its utility is even more doubtful. In viewing the usefulness of the approach, we will first consider the analytical framework itself: Does input/output analysis clarify the operations of a medical school and help make useful predictions? Then we will examine the optimization exercises performed by Latham and try to evaluate their usefulness.

IS INPUT/OUTPUT USEFUL?

Input/output analysis of an economy was developed in response to the observation that many transactions involve not sales by an industry to final consumers but sales by one industry to another. Representation of such sales together with final demands requires a system of simultaneous equations. Simultaneous equation systems are tractable only if they are linear, therefore these equations are assumed to be linear. If the equations for an input/output system must be linear then constant returns to scale, no substitution of one kind of input for another, and independence of production processes must be assumed. These assumptions are part of the cost of fitting analysis into the input/output framework. These costs are offset by the importance of the intermediate or "interindustry" flows the assumptions permit us to describe. If we divide a medical school into a set of activities that seem fairly natural, is there a relatively large flow of transactions among the activities? In Latham's framework, with the exception of flows needed simply for accounting, the answer is no.

If we eliminated the rows corresponding to the need to add up courses into years and degrees, eliminated the row for the miscellaneous Other Programs, and allocated General Administration to each activity as an overhead item, little would be left in the way of "interindustry" flows. Latham's complete matrix contains 63 "industries" and 3,969 cells. Fewer than five percent of these cells have non-zero entries. Half of the non-zero entries correspond merely to the flow of students through courses, that is, to simple accounting needs. The bulk of the non-zero entries remaining refer to general administration and use of the library. No more than 40 represent "interindustry" flows in any essential sense, and the magnitude of these is small relative to the direct use of primary inputs.

If the interindustry relations are weak, then the system could just as well be represented by relations between primary inputs and outputs, with the "indirect" requirements imputed to outputs, much like the SRG model.

The machinery of input/output seems unnecessary. That in itself is not a severe criticism of the study. Much more serious is the effect on the results of the assumptions that must be made to use the input/output framework. The most important example of this is reflected in Latham's estimates of the costs of doubling the output of M.D. degrees. Substituting a doubled value for the output of M.D.s into his solved equations indicates that only quite small increments in most intermediate inputs would be required: about 15 percent more patient service, about seven percent more research. Faculty would increase less than 15 percent. The small size of these increases reflects several considerations, but the most important is the assumption -- which must be made in the input/output analysis -- that the various final outputs are absolutely independent of each other: that one can increase the rate of production of M.D.s without simultaneously increasing the final output of care or research. Unless that assumption is absolutely true, the input requirements predicted for any given increase in final output will be in serious error. In the authors' view the need for this assumption casts serious doubt on the usefulness of the input/output framework on the medical school setting.

OPTIMIZING MEDICAL SCHOOL OUTPUTS

So far the analyses we have discussed are all descriptive; they represent attempts to discover and organize the costs of medical education or predict the implications of changed policies. They do not attempt to determine how schools should behave or how their resources should be allocated. Even the SRG model, which is the closest to being a real management tool of any of the work we have considered, does not attempt to produce optimum resource allocations.

With the machinery of Latham's input/output analysis in place, however, the question, "What should be the pattern of school activities be?" can now be posed. In order to answer that question we must place prices on each of the school outputs. The price of each output times its quantity, summed over all outputs gives the total value of school outputs. The optimal pattern of school outputs is simply defined as the highest value that can be achieved given the constraints faced by the school: the input/output relations and restrictions on the total staff, space, and budget available. Which particular set of constraints is chosen may, of course, make a large difference in the optimal outcome. Choice of different prices for the outputs may also make an important difference. For the maximizing to be possible, all the other assumptions of the input/output framework must be met as well. That is, there must be no joint production, average and marginal costs must be equal, and outputs must be independent.

The linear programming technique is nothing more than a systematic way of defining all the possible combinations of output levels given the constraints, choosing a subset of these combinations, and evaluating them according to the prices assigned to each output. The program then finds the particular combination of outputs that produces the highest attainable value of the objective function given the constraints.

The results of the exercise are typical of linear programming problems: As the price at which M.D. degrees are evaluated rises, the optimal rate of production of M.D.s rises and the production of other outputs falls; if "quality" constraints requiring a minimum amount of research per student or patient care are removed, output of M.D.s can rise sharply; if the college were constrained only by space, budget, and minimum limits on research and patient care per student, output of M.D.s could quintuple while other final outputs remained the same. (5)

The possible quintupling of output captures the basic flaw in the input/output-linear programming method. It seems unlikely that, in any meaningful sense, the character of the training provided in a school would remain constant in the face of such an increase in the number of students unaccompanied by major increases in the output of research and care. The reductio ad absurdum, however, flows directly from essential features and assumptions of the input/output framework.

V. SUMMARY

The literature on tools for the overall management of health science centers divides into four types: (1) classic cost finding studies, (2) cost estimation with regression analysis, (3) simulation of school activities, and (4) input/output analysis. The first two categories aim at finding the true cost of education or some other medical school output. The last two categories focus on the resource use implications of alternative medical school programs.

The estimates of program costs generated by classical methods of cost accounting are unsatisfactory because such accounting cannot deal with the joint production or joint cost problem. There is no unique answer to the question of what an ongoing program costs in circumstances of joint production. This need not be a source of frustration to the policymaker, however. The question of whether ongoing programs are "paying for themselves" is still meaningful. "Pure" program cost is appropriate to this question, but it must also be asked whether the institution is "paying for itself," for the answer to the first question does not necessarily imply an answer to the second. If the policy question is whether a new program is "worth doing," the appropriate cost concept is the sum of "pure" and joint costs.

Activity analysis models aim at calculating the impact of alternative combinations of school activities. An activity consumes a well-defined set of inputs (teaching hours, classroom, materials, etc.) and furnishes services to a specified group of users. Given a set of activities and information on how many users must be served, such a model calculates the real and financial resources required by a specified program. As now practiced, activity analysis yields the incremental cost of an activity given all other school activities, that is, "pure" program costs. Such analysis is a potentially useful management tool.

Input/output analysis is a special form of activity analysis in which some activities provide both final outputs and input into other activities. This framework requires that the various final outputs be perfectly independent, that there be no joint production, and that all processes show constant returns to scale. The benefits of input/output analysis are small in this application because interesting flows among activities are small and the rigidity of the linear framework leads to questionable projections of resource requirements.

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