Articles

Teaching Hospital Costs: The Effects of Medical Staff Characteristics

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This article examines the effect of medical staff behavior on the cost of hospital-based care and graduate medical education, and shows its implications for estimation of hospital costs. The empirical work brings a unique new data source for these characteristics to the estimation process. Our results indicate that there are important economies of scale and scope in hospital production, both for inpatient stays and for residency training. Controlling for medical staff characteristics significantly reduces the estimated costs of residency training. Staff characteristics may be capturing aspects of the quality of inpatient care and residency training provided by the hospital.

The structure of teaching hospital costs has been an important concern for policymakers and researchers for more than 20 years. During that same period, researchers have been investigating hospital behavior and the relationship between hospitals and their medical staffs. However, the relationship between medical staff characteristics and the structure of teaching hospital costs has not been fully explored. This article examines the effect of medical staff behavior on the cost of hospital-based care in a model including graduate medical education, and shows its implications for estimating hospital costs. In particular, we

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demonstrate the importance of medical staff characteristics. The empirical work brings a unique new data source for these characteristics to the estimation process. We are able to identify some new aspects of the cost structure for hospital-based care, and to estimate the marginal costs of residency training.

Our results indicate that there are important economies of scale and scope in hospital production, both for inpatient stays and for residency training. Hence, large hospitals, and large teaching hospitals in particular, are likely to benefit from flat-rate payment formulas. In addition, controlling for medical staff characteristics reduces the estimated costs of residency training significantly. To some extent, staff characteristics may be capturing aspects of the quality of inpatient care and residency training provided by the hospital. The implications of these findings are relevant to the hospital cost literature in general and to those who make policy concerning hospital reimbursement.

BACKGROUND

A number of authors have identified the team production aspects of hospital-based care. Pauly and Redisch (1973), for example, hypothesized that, because physicians manage the production of health care using their own and hospital inputs, hospital behavior could best be understood if the hospital were modeled as a physicians' cooperative. Harris (1977) described the hospital as two separate firms. One firm, controlled by the hospital administrator, supplies inputs—ancillary services—to the other firm. The second firm is controlled by the medical staff; this firm combines the inputs from the first firm with physician inputs to produce health care. Custer et al. (1990) extend this analysis and show that unless hospitals and their medical staffs cooperate to maximize some joint objective function, they are unlikely to employ the cost-minimizing mix of hospital and physician inputs in the production of health care. The general consensus is that hospital-based care is not produced by a perfectly competitive, cost-minimizing, single firm.

The appropriate behavioral model for teaching hospitals and their costs is of particular importance. Current Medicare reimbursement policy separates "direct" teaching costs, for example, resident stipends and faculty salaries, from more difficult-to-measure "indirect" teaching costs. Indirect teaching costs represent various cost-increasing aspects of teaching hospitals, which may include unmeasured differences in case mix and severity as well as less efficient provision of care by residents. While a pro rata share of direct costs is paid by Medicare, indirect costs are reimbursed by adding an average of 7.65 percent for each 0.1 resident per bed to the usual diagnosis-related group (DRG)-based payment for hospital services for fiscal years 1989 to 1995. This factor is a result, after some political adjustment, of empirical research into teaching hospital costs by the Health Care Financing Administration (HCFA), described by Anderson and Lave (1986). Since its introduction in 1983, this factor adjustment has been revised each year, and there has been continuing study of its appropriate size. In 1987, the indirect costs of teaching paid by Medicare totaled well over $1 billion. In this context the modeling and estimation of hospital costs have direct budgetary consequences.

The theoretical research into hospital production directly suggests that physician inputs are relevant to hospital costs and therefore to cost function estimation. Although cost functions employ input prices (and outputs) to explain costs, the majority of medical staff inputs are not costly inputs to the hospital (most staff physicians are not employed by the hospital). Thus, use of their prices, that is, the physician's wage, is not appropriate, while control for the input characteristics or for the inputs themselves, or for both, would be more consistent with hedonic and hybrid cost functions that control for nonprice cost shifters.

A second implication of the theoretical discussions is more subtle. Outputs of hospital-physician production are actually health care and graduate medical training, neither of which is easily measured. While residents might be considered inputs in the production of medical training, in the spirit of Lee and Hadley (1985), inpatient days and discharges are similarly inputs in the production of health care. Nevertheless, it is standard to use inpatient days and discharges as measures of hospital output in cost function estimation. The use of residents as a measure of output follows similar logic. More perfect output measures would be preferable, but in lieu of that we believe that residents can usefully represent the output of graduate medical training.

Recent work on hospital costs and production have recognized some of these issues. A number of authors have included some measure of the size of the medical staff as an input to production. Pauly (1980) and Jensen and Morrisey (1986a) also differentiated staff size by specialty, finding that certain specialties have higher marginal products for admissions than other specialties (their results disagree in many cases). Grannemann, Brown, and Pauly (1986) found that a higher percentage of staff physicians under age 45 reduced costs, although that was the only physician characteristic variable they included. None of these studies paid special attention to teaching hospitals. Jensen and Morrisey (1986b) looked at teaching hospital production of case mix-adjusted admissions using the number of physicians and the number of residents as separate inputs, and estimated the marginal product of residents to be very nearly zero.

Some studies have focused more directly on teaching hospital costs. Sloan, Feldman, and Steinwald (1983) estimated cost equations for pathology and radiology departments that included physician expenses (payments to physicians that passed through the hospital) in some of their cost measures, and found that teaching results in higher costs. However, they included only dummies for teaching status, and their basic estimating equation was a reduced-form rather than a structural model. Hosek and Palmer (1983), in estimating the effect of teaching as an output on radiology department costs in Veterans Administration hospitals, provided a much clearer theoretical framework. They found that teaching reduces costs for most radiology procedures, probably due to substitution of resident time for staff physician time. The original HCFA work was a mixed model, neither a structural nor a reduced form. It used Medicare operating cost per case as the dependent variable, with residency training represented by a resident-to-bed ratio, and found that teaching added significantly to hospital costs.

Among these studies and others (see Cowing and Holtmann 1983; and Eakin and Knieser 1988), only Hosek and Palmer (1983) attempted to incorporate residency training as an output in a theoretically based cost function. However, their use of VA radiology departments avoided the principal problems of unmeasured physician costs and independent medical staff behavior that are more typical of teaching hospitals. The fact that radiology departments produce more ancillary services than admissions also limits the applicability of their results.

Another aspect of the teaching hospital cost problem is the fact that residency training is produced jointly with other products. Thus, in addition to economies of scale there may exist economies of scope, wherein different products can be produced more efficiently together than separately. If resident training helps produce patient care, saving on the cost of other hospital inputs, the marginal cost of care will be reduced even if physician costs are not part of total costs (mere substitution of resident time for physician time would not produce this result). Grannemann, Brown, and Pauly (1986) are among the few who recognize economies of scope in hospital production, but they examine outputs across departments rather than the influence of teaching activities.

Our article addresses each of these issues. We specify a framework for estimating the structure of observed hospital costs when the medical staff can act independently of hospital interests. Hospital costs are a result of hospital inputs to production of health care rather than a direct result of this production. Physician costs are separate factors that can be represented by physician time inputs and other characteristics. We employ a rich data set on physician practice activities to control for medical staff inputs and characteristics, and find that they explain significant variation in hospital costs. We also obtain estimates of marginal cost, economies of scope, and product-specific economies of scale.

The following section presents a basic theoretical model of hospital and medical staff behavior that serves to illustrate the nature of the problem and suggests a solution. We then discuss the empirical model to be employed and the data used to estimate it. The fourth section presents and discusses the empirical results and is followed by concluding observations.

CONCEPTUAL FRAMEWORK

The amount of education produced in a teaching hospital is modeled simply as a function of the number of cases seen and the number of residents. The production of inpatient health care is a function of hospital inputs, physician inputs, and resident inputs. We model education and inpatient health care as having separate production functions, as opposed to a transformation function, to capture the on-the-job training aspect of graduate medical education (Marder and Hough 1983). Increasing the amount of inpatient health care produced increases the amount of education produced if the number of residents is unchanged.

The cost-minimizing combination of hospital and physician inputs in the joint production of inpatient health care and graduate medical education is given by the solution to:

$$\min_{z,t,r} C(N,E) = c(z) + w(t) + s(r) \tag{1}$$

$$\text{subject to: } \begin{aligned} N &= N(z,t,r) \\ E &= E(N,r) \end{aligned}$$

where

C = total costs;

N = inpatient health care ($N_i > 0$, $N_{ii} < 0$, for $i = z,t,r$; $N_{zr}, N_{tz}, N_{tr} < 0$);
E = education ($E_j > 0$, $E_{jj} < 0$; for $j = N,r$);
z,t,r = hospital, physician, and resident inputs, respectively;
c = hospital costs (c', $c'' > 0$);
w = physician costs (w', $w'' > 0$);
s = resident costs (s', $s'' > 0$).

The solution to Equation 1 implies:

$$c'/Nz = w'/N_t = (s'/N_r) - \lambda(E_r/N_r) \tag{2}$$

where primes denote the first derivative, subscripts denote the partial derivatives, and λ is the Lagrange multiplier. Equation 2 is the familiar result that the ratio of the marginal factor cost to the marginal product of each input is equal across inputs with the exception of residents. For residents, the ratio of marginal factor cost to marginal product exceeds that ratio for hospital and physician inputs by the shadow cost of education times the ratio of the marginal product of residents in education and inpatient care, respectively. The addition of education as an output implies that inpatient care is not produced using the cost-minimizing input mix.

Moreover, the organization of production of health care in the hospital suggests that the joint production of inpatient care and graduate medical education is not efficient. Physicians and hospitals are reimbursed separately for their joint production of inpatient care. Custer et al. (1990) show that, if hospitals and their medical staffs maximize separate objective functions, the resulting input mix to the production of health care need not be cost-minimizing. In that case, Equation 2 will not hold. Neither the production of inpatient care nor graduate medical education will necessarily be cost-minimizing.

The empirical problem is to estimate the relationship between hospital costs, inpatient care, and graduate medical education. Medical staff inputs to the production of inpatient care are an important factor in the relationship. The structure of this relationship reflects both the organization of production of inpatient care and the inefficiency in its production due to the demands of graduate medical education.

EMPIRICAL SPECIFICATION

In the current analysis, the use of the strict translog cost function with input share equations and cross-equation restrictions does not carry its usual advantages of adherence to the production-cost duality and increased efficiency of estimation. Because there is strong reason to believe that hospital costs are not minimized, duality-based cross-equation restrictions are not appropriate. Furthermore, zero output levels are not permissible in the strict translog form.

Among the alternative functional forms, the hybrid cost function employed by Grannemann, Brown, and Pauly (1986) is most easily adapted to the current problem. These investigators use actual output levels instead of logged levels, do not estimate share equations, and allow other cost-shifters, but otherwise they maintain a polynomial structure of outputs similar to that used in the translog cost function. In specifying outputs we begin with the suggestions of Breyer (1987) and include the number of discharges, the number of inpatient days, and the number of outpatient visits. As Joskow (1980) and Breyer argue, excess capacity, as measured by the average percentage of beds unoccupied, should also be considered an output; we include it here. Finally, the number of residents is the best available measure of the teaching output of the hospital.

Our full specification is:

$$\ln c = \sum_{i=1}^{5} \alpha_{1i} Y_i + \sum_{i=1}^{5} \alpha_{2i} Y_i^2 + \sum_{i=1}^{5} \alpha_{3i} Y_i^3 + \sum_{i>j}\sum \beta_{ij} Y_i Y_j + \upsilon_0 M$$
$$+ \sum_{i=1}^{5} u_i Y_i M + \delta_0 t + \sum_{i=1}^{5} \delta_i Y_i t + \sum_{k=1}^{m} \varepsilon_k X_k + \sum_{l=1}^{n} \rho_l S_l + u \quad (3)$$

where $Y_1, \ldots, Y_5$ represent the five outputs delineated above, M is the Medicare case-mix index, and t is a measure of physicians' time input (discussed in more detail further on). Because of their particular importance, M as a measure of the type or quality of output and t as a measure of free (to the hospital) inputs to production, they are interacted with each output. $X_1, \ldots, X_m$ are hospital characteristics hypothesized to affect cost level: ownership type, Medicare and Medicaid share of discharges, membership in the Council of Teaching Hospitals (COTH), the Medicare index of prevailing charges for physicians, census region, and metro area size. $S_1, \ldots, S_n$ are medical staff characteristics: specialty shares; proportion female; proportion foreign medical graduates; average years practice experience and experience squared; the percentages of total work hours spent in administrative, teaching, and research activities; and the percentages of time not employed by the hospital spent in various other practice types. Greek letters represent parameters to be estimated, and u is a random error term.

We do not impose linear homogeneity with respect to input prices. This is due in part to poor price measures in our data. In most cost estimation problems, however, it is difficult to obtain a complete set of input prices, so imposition of linear homogeneity relies on the assumption that those prices observed are representative of all input prices. In our case we use the Medicare prevailing charge index, and a nursing wage index to represent general price levels for health care inputs; these are useful regression controls but are not presumed to represent all inputs to hospital care.

The dependent variable is the log of total hospital expenses. Grannemann, Brown, and Pauly argue that the price of capital is included in this variable and, therefore, that this functional form is a long-run total cost function. The hospital ownership variables, which include multihospital system affiliation, could affect the hospital's access to capital markets.

DATA

Part of the contribution of this study is the application of a unique data set on physician activities to the problem of hospital costs. The American Medical Association Physicians' Professional Activities (PPA) Census has, in recent years, been conducted every four years, the last in 1985. This mail survey is sent to all physicians listed in the AMA Physician Masterfile, which is an ongoing enumeration of all U.S. physicians. Because the Masterfile begins tracking physicians through medical schools and licensing boards, its coverage of U.S. physicians, including residents, is virtually 100 percent, although there can be a lag in updating the activity status of physicians (particularly retirements). Thus, the sampling base of the PPA is the entire physician population. Extensive efforts are made to obtain as high a response rate as possible.

The 1985 PPA file contains data for 78.9 percent of active physicians. Response rates were higher among AMA members (87.2 percent) than nonmembers (71.8 percent), and fell from about 90 percent for young physicians to 74 percent for prime-age physicians, and back to 80 percent for senior physicians. U.S. medical graduates (USMGs) were somewhat more likely to respond (80.6 percent) than foreign medical graduates (72.7 percent), and males (79.0 percent) and females (78.5 percent) were about equally likely to respond, as were board-certified physicians (79.3 percent) and noncertified ones (78.3 percent). Response rates varied somewhat among office-based physicians (78.7 percent), hospital-based physicians (73.7 percent), administrative physicians (82.0 percent), and medical teachers (75.9 percent), but less among specialties (from 77.0 percent for anesthesiologists and pathologists to 80.8 percent for surgeons). While there is always some potential for response bias, it does not appear to be too large here.

The PPA asks a set of questions about the physician's practice activities in a typical week of practice. In particular, it asks the physician to divide the number of hours worked in a typical week in two ways. First, hours are classified by type of activity. They are divided among postgraduate training, direct patient care, management and administration, medical teaching, medical research, and other medical activities. Another question directly asks how many hours were spent in a hospital or in an office in a hospital. Second, hours are divided among employers or employment arrangements. These categories are: self-employed solo practice, two-physician partnership, group practice, nongovernment hospital, city/county/state hospital and nonhospital, U.S. government and other federal agency hospital and nonhospital, other patient care employment, and other nonpatient care employment (e.g., insurance carriers, medical societies).

A crucial feature of the PPA is that it asks the physicians to identify their principal hospital affiliation. We were thus able to group physicians by their primary hospital affiliation, recreating the "staff" of the hospital. Aggregate or mean characteristics of the staff were then calculated, as appropriate, creating a single observation for each hospital. These observations were then merged with teaching hospital data.

Data for teaching hospitals were taken from the American Hospital Association (AHA) 1986 Annual Survey of Hospitals. The AHA annual survey is an ongoing survey of all U.S. hospitals; for purposes of the AHA survey, a hospital is defined as the organization or corporate entity registered as a hospital by the state to provide diagnostic and therapeutic patient services for a variety of patient conditions, including both surgical and nonsurgical services. For this study, we defined a teaching hospital as a hospital with at least one full-time resident. Although this is a rather broad definition, in our estimations we controlled for major teaching hospital status (i.e., Council of Teaching Hospitals membership). The purpose of this definition was to capture a set of hospitals with a large range of patient and education outputs to facilitate meaningful calculation of economies of scope.

In order to construct a nursing wage index we used the AHA 1984 Annual Survey of Hospitals, which reported payroll expenses for nurses separately from other employees. The total payroll expenses for nurses and the total number of registered nurses (RNs) and of licensed practical nurses (LPNs) employed by hospitals were summed over the urban and rural areas of each state. The aggregate total payroll expenses were then divided by the aggregate total of nurses employed to provide a nurses' wage index for the urban and rural areas of each state.

The Medicare case-mix index for the hospital is based on the data published in the *Federal Register*. The Medicare case mix has been shown to be a useful representation of the hospital's overall case mix (Jensen and Morrisey 1986b). The Medicare prevailing charge index and other county-level data (metro size variables) were taken from the 1987 Area Resources File.

The final data set contained data on all variables for 564 hospitals. The AHA 1986 Annual Survey of Hospitals classified 971 hospitals as short-term acute care or obstetrics/gynecology hospitals with at least one full-time resident. From that set of hospitals 157 were eliminated because the cost data were estimated rather than reported; 138 were eliminated because no case-mix match was made; and 112 were eliminated because the PPA file contained information on fewer than 10 percent of the medical staff.

Average total expenses at these hospitals were $84.4 million, with an average of 87.3 full-time equivalent residents (49,210 total FTE residents), 15,587 discharges, 119,816 inpatient days (average length of stay: 7.7 days), and 130,803 outpatient visits per hospital. Complete sample statistics are shown in Appendix Table A1.

An important statistic is the percentage of the total medical staff of the hospital captured in the PPA data. These 564 hospitals have an average of 325 physicians, while they have an average of 116.4 physicians from the PPA data who claim their primary affiliation with that hospital. Physicians at teaching hospitals have approximately 2.2 hospital affiliations, and admit approximately 75 percent of their patients to the hospital of primary affiliation. Using these numbers, approximately 46 percent of the physicians at a hospital, or an average of 149 physicians, will have their primary affiliations at these hospitals. The 116.4 responding physicians per hospital make up 77.9 percent of that, which is in general agreement with the PPA response rate. Furthermore, about 19 percent of responding physicians, or 22 physicians per hospital, are hospital employees. The AHA data report 27 full-time physician employees per hospital in this sample, which puts our coverage of hospital employee physicians at 81 percent. Thus, it appears that PPA respondents constitute a clear majority of physicians with their primary affiliations at these teaching hospitals, and should be representative of those physicians and of the physician inputs to hospital production.

We create a variable, PERCOVER, that is the ratio of PPA respondents at a hospital to the total medical staff in order to capture possible effects of limited response. However, we also expect that this variable may have another, more structural effect. The larger the percentage of the medical staff that considers the hospital as primary, which may also be represented by PERCOVER, the easier it will be for the hospital and the medical staff to form implicit and explicit agreements on the proper input mix—and the more efficient the production of health care. If this is true, its coefficient in the cost estimation should be negative.

From these data we construct several important physician input variables mentioned briefly earlier. In addition to variables representing staff characteristics, we have some that directly represent physician activities. We control for the percentages of total work time (summed over the staff) spent in administrative, research, and teaching activities. These percentages measure characteristics of inputs, but should not directly measure the scale of costly inputs to the hospital. Second, we control for the percent of total work time that is spent outside the employment of a hospital. This variable is important in distinguishing between hospital care overseen by a hospital employee physician, who may be more sympathetic to the cost-minimizing needs of the hospital, and that overseen by a self-employed physician, who has greater incentive to overutilize hospital inputs, including residents, in order to minimize his/her own costs. Because of their potential to represent costly hospital inputs (employee physician time), even though they are free of scale effects, we estimate our cost curves with and without the variables measuring physician activities. As a reference point, we also estimate the cost curve with no staff characteristics included at all.

EMPIRICAL RESULTS

Regression results for the three cost curve specifications are shown in full in Appendix Table A2. In all three specifications all outputs (except for reserve ratio) have cost structures of the expected cubic polynomial form—increasing (in the linear term), decreasing (in the quadratic term), and then increasing (in the cubic term)—which is consistent with a U-shaped average cost curve. This is qualified by the fact that the cubic terms are insignificant for residents and outpatient visits (and the cubic term for residents is in fact insignificantly negative in the third specification); thus, marginal costs do not clearly begin to increase again at higher levels of these outputs.

Hospitals with higher Medicare discharge shares, for-profit hospitals, and those with COTH membership have higher costs, all else equal, in each specification. Hospitals in the Northeast, South, North Central and West census divisions are, respectively, least to most costly. Hospitals in rural counties, in counties of standard metropolitan statistical areas (SMSAs) with population under 1 million, in counties that are suburbs of SMSAs of over 1 million population, and in counties including the central cities of SMSAs of over 1 million, are least to most costly, in that order. While there is as much as a 24 percent cost differential from the least to most expensive census region, and an 18 percent cost differential from the least to most expensive county type, these are probably the result of input price differences that are not fully controlled. Although the sizes and patterns of these geographic differences are different from those of previous studies, the differences in price variables limit comparisons here.

Differences in medical staff composition can have important effects on costs. Higher percentages of internists, radiologists, psychiatrists, and "other" specialists increase costs significantly, as do higher percentages of board-certified physicians, USMGs, and female physicians. With respect to the latter three effects, the argument can be made that they represent differences in the quality of care, although to our knowledge there is no direct evidence that USMGs and females provide a higher quality of care. However, it has been documented that female physicians spend more time per patient visit, which can be construed either as higher-quality or less efficient care (or neither). Finally, physicians with more years of practice experience are significantly more costly. These cost differences are generally much larger than expected salary differentials across physician characteristics (Langwell 1982) and are not completely consistent with them, particularly in the case of females. Thus, the pay of employee physicians cannot be entirely responsible for this result. It is possible that physicians with higher time costs are more likely to substitute hospital inputs for their own.

The coefficient of the PERCOVER variable is negative, as predicted, and is strongly significant, suggesting that the greater the percentage of physicians on staff whose primary affiliation is with that hospital, the more efficient the use of inputs in production will be.

When physician activities are controlled, we find that higher percentages of time in administrative or research activities, relative to teaching or patient care activities, increase hospital costs. The effect of research time here is particularly strong. While this is quite possibly the direct effect of research activities, many research activities involve care of particularly interesting or difficult cases. Conversely, those involved in research may be those most frequently sought out to treat the most difficult (and costly) cases.

The second set of practice activity variables measures the proportions of staff time not in the employment of a hospital (the denominator) that are spent in partnership, group, medical school, and other practices (the numerators), with solo practice as the reference group. Only medical school employment is significantly different from the other types, and is associated with lower costs. They may have less incentive to overutilize hospital inputs relative to their own, either because of a close relationship between the medical school and the hospital or simply because they are not self-employed.

Finally, the set of variables involving the proportion of total time spent outside of hospital employment has a net negative and significant effect on cost. This was expected in that, as the proportion of non-employee time falls, the proportion of costly employee time rises.

Using these regression results, some cost measures for outputs can be calculated. The marginal cost of an output is simply the first derivative of the cost curve with respect to that output. Following Baumol, Panzer, and Willig (1982), the multiproduct analog of average cost is average incremental cost, defined as:

$$AIC(Y_1) = [C(Y_1, Y_2, Y_3, Y_4, Y_5) - C(0, Y_2 Y_3, Y_4 Y_5)]/Y_1$$

Product-specific economies of scale SCL_i are then defined as:

$$SCL_i = AIC_i / MC_i, \; i = 1, \ldots, 5$$

Product-specific returns to scale for output i are increasing if the value of SCL_i is greater than one, constant if it is equal to one, and decreasing if it is less than one. The final measure is economies of scope. Economies of scope occur if the cost function is subadditive, that is, if the sum of the cost of producing sets of outputs separately is greater than the cost of producing the sum of the outputs jointly. For example, for Y_1, the measure of economies of scope, SCP_1, is calculated:

$$SCP_1 = \frac{C(0, Y_2, Y_3, Y_4, Y_5) + C(Y_1, 0, 0, 0, 0) - C(Y_1, Y_2, Y_3, Y_4, Y_5)}{C(Y_1, Y_2, Y_3, Y_4, Y_5)}$$

These measures will be greater than zero if there are economies of scope and less than zero if there are diseconomies of scope. The whole-set measure of scope compares the sum of the costs of producing each output separately to the cost of producing them all jointly.

These cost measures can be computed at any point ($Y_1, \ldots, Y_5$) on the cost surface. Lowest variance estimates occur at sample means. In Table 1 we present these four cost measures for each output at the sample means for each of the three cost specifications estimated. It contains several noteworthy findings.

Table 1: Cost Measures for Hospital Outputs at Sample Means

	(1) No Staff Variables	*(2) Limited Staff Variables*	*(3) Complete Staff Variables*
Marginal Costs			
Discharges	$ 1,978	$ 2,506	$ 2,624
Inpatient Days	246	196	200
Outpatient Visits	45	45	35
Residents	118,455	72,589	54,516
Reserve Ratio	195,468	157,999	191,538
Average Incremental Costs			
Discharges	2,466	2,742	3,122
Inpatient Days	290	256	298
Outpatient Visits	44	47	38
Residents	132,967	86,639	60,951
Reserve Ratio	286,356	282,464	60,583
Product-Specific Economies of Scale			
Discharges	1.25	1.11	1.19
Inpatient days	1.18	1.30	1.49
Outpatient visits	0.97	1.07	1.09
Residents	1.12	1.19	1.12
Reserve ratio	1.46	1.91	0.32
Product-specific Economies of Scope			
Discharges	-0.125	-0.199	-0.163
Inpatient days	-0.193	-0.131	-0.277
Outpatient visits	0.117	0.119	0.166
Residents	0.040	0.099	0.165
Reserve ratio	0.042	0.060	0.148
Whole-Set Economies of Scope	0.330	0.357	0.456

First, inclusion of medical staff variables has significant effects on output costs, particularly on the costs of residents. With no staff variables, the marginal yearly cost of a resident at sample means is $118,455. Including some staff characteristics but no activity measures reduces the estimated marginal cost by approximately 39 percent to $72,589, while the inclusion of activity measures reduces it to less than half its original value, $54,516. Clearly, the presence of residents is correlated with the presence of a more costly medical staff and more costly staff activities.

Costs of other outputs also change across specifications, but to a lesser degree. The marginal cost of a discharge and the overall marginal cost of an inpatient episode increase when staff variables are included. They range from $1,978 per discharge, $246 per inpatient day, and $3,872 per episode (average length of stay is 7.7 days) when no staff variables are included, to $2,624 per discharge, $200 per day, and $4,164 per episode in the full specification. The marginal cost of a 1 percent increase in the reserve ratio, which represents 4.4 additional excess beds at sample means, is $150,000–$200,000; the marginal cost of an excess bed is thus $34,000–$45,000.

Grannemann, Brown, and Pauly also provide estimates of marginal costs for high-volume hospitals, which they define as hospitals with 13,000 discharges, somewhat lower than our sample mean for teaching hospitals. Their marginal cost of a discharge is about 30–50 percent lower than our own estimates (after adjustment for inflation). However, their estimate of the marginal cost of an inpatient day is in the same range as our estimates. Our estimates of the marginal cost of outpatient visits are less than half of what Grannemann, Brown, and Pauly found, although they controlled separately for emergency room visits.

Average incremental costs of the outputs are generally higher than their marginal costs at sample means, indicating the presence of some product-specific economies of scale. For residents, the average incremental cost of a resident in the middle specification is $86,639, and results in a reasonably strong 1.19 value for economies of scale. There are also strong economies of scale here for discharges and inpatient days, and near-constant returns to scale for outpatient visits.

Product-specific economies of scope for discharges and inpatient days are negative, but producing discharges without inpatient days and vice versa is meaningless. However, the relatively more separable resident and outpatient visit outputs exhibit positive economies of scope, as does reserve ratio. Whole-set economies of scope are highest at .456 when all staff variables are included in the specification.

DISCUSSION

The results of this exercise can be used to evaluate the current Medicare indirect graduate medical education reimbursement formula. The standard DRG payment for Medicare patients is adjusted for teaching hospitals to compensate them for the indirect costs of medical education. These indirect costs include the less efficient care provided by residents, the increased administrative burden, and the higher staffing ratios. The direct costs of medical education, such as resident and faculty salaries, are reimbursed separately. HCFA originally estimated that a 10 percent increase in one plus the resident-to-bed ratio increased Medicare cost per case by 5.795 percent. Congress doubled that figure to 11.59 percent to compensate hospitals with a disproportionate share of low-income patients. The adjustment factor has been reduced to 7.65 percent for fiscal years 1989–1995.

In our data there are just under 0.2 residents per bed at sample means, which would result in an increase of approximately 14 percent to the standard DRG payment for a Medicare inpatient stay. Of the average incremental cost of $86,639 per resident, pay and fringe benefits average $26,198, which is reimbursed directly, leaving $60,441. With 87.25 residents and 15,587 discharges, the average cost of residents per discharge is $338. This figure may still include some faculty salary costs, so it should be considered an upper bound. The average cost of an inpatient stay can be calculated by adding the average incremental cost of a discharge to the product of the average incremental cost of an inpatient day and the average length of stay, 7.7 days. The average cost per case is $4,763, but the estimation results indicate that if all cases were Medicare, average costs would rise to $6,429 per case. Of this, the resident cost per case is about 5.3 percent at sample means, or 2.7 percent per 0.1 resident per bed, meaning that reimbursement under the current formula is more than two times larger than warranted. This calculation more or less agrees with the results of Thorpe (1988) and the U.S. General Accounting Office (GAO) (1989).

Several points are relevant here, however. First, HCFA's original research, and subsequent analysis such as the GAO's, do not include medical staff characteristics in their estimates of Medicare costs per case. Using the average incremental costs from the specification without medical staff characteristics, resident costs per case add 4.6 percent per 0.1 resident per bed to the Medicare cost per case, somewhat below HCFA's original estimate of 5.795. Medical staff characteristics in our model may be capturing some quality differences that would be appropriately reimbursed as part of the cost per case. The indirect costs of medical education may include the hospital's costs of attracting and retaining high-quality physicians on its medical staff.

Another consideration is that teaching hospitals differ from other hospitals in the proportion of the medical staff that is employed directly by the hospital. Hospitals with a higher proportion of employee physicians are likely to have higher costs per case, all else equal, because not all physician services are billed separately (e.g., under Part B in the case of Medicare). Having more employed physicians can facilitate supervision of residents, but it also tends to be correlated with higher indigent caseloads. In those studies that control for the percentage of low-income patients cared for by the hospital, costs attributable to residents per bed tend to fall compared to when the hospital's "disproportionate share" is not included in the estimation (U.S. General Accounting Office 1989). The hospital's "disproportionate share" is thought to control for the greater severity of illness of indigent patients, but may also capture differences in the hospital's employment of physicians.

Our third specification includes some controls for employed physicians. The percentage of total staff time spent outside of hospital employment is interacted with each of the five outputs. As expected, a decrease in time spent outside the employment of the hospital increases the costs of inpatient care. However, the results indicate that the cost of residents falls when the proportion of the staff employed increases, which is consistent with the notion that residents are more efficiently incorporated into hospital production when overseen by full-time staff physicians.

Thus, the estimated cost of residency training decreases markedly as increasingly greater detail about the medical staff is included in the estimation. It would appear that the cost of residency training is actually relatively low. Studies that find higher costs associated with teaching hospitals may be confounding the costs of residency training with other factors that are correlated with residency training. It may be, however, that these other factors, the presence of employed physicians, medical research, and physicians with greater experience, for example, may be necessary and desirable features of teaching hospitals. If more detailed adjustments to hospital reimbursement are not feasible, or would result in unintended or undesirable incentives for teaching hospitals to alter their behavior, the higher adjustments for indirect graduate medical education costs, based on simpler cost specifications, may be useful public policy.

Finally, these calculations are appropriate at the sample means.

Table 2: Marginal and Average Incremental Costs for Selected Hospital Outputs Using Limited Staff Variable Specification at Selected Mean Output Levels

	Residents	Discharges	Inpatient Days
Alternative Resident-to-Bed Ratios			
1. 45 residents, other outputs at sample means (.1 residents per bed):			
Marginal cost	$91,072	$2,527	$188
Average incremental cost	97,986	2,775	251
2. 180 residents, other outputs at sample means (.4 residents per bed):			
Marginal cost	$35,021	$2,459	$214
Average incremental cost	65,612	2,775	265
Alternative Scales			
3. Residents, discharges and inpatient days at 50% below sample means:			
Marginal cost	$81,160	$4,451	$348
Average incremental cost	88,481	4,178	365
4. Residents, discharges and inpatient days at 50% above sample means:			
Marginal cost	$64,932	$1,339	$106
Average incremental cost	85,069	2,031	188

Average costs change as the number of residents and cases increases or decreases, so the appropriate reimbursement may be different between larger and smaller hospitals. We can comment on this better after exploring differences in costs across the output space in more detail.

Table 2 reports marginal and average incremental costs for residents, discharges, and inpatient days at four different points in the output space. First, we vary residents while holding other outputs at sample means. We choose 45 residents and 180 residents to represent about 0.1 and 0.4 residents per bed in this sample. Next, we vary residents, discharges, and inpatient days by the same proportion, essentially expanding hospital size along a ray that keeps residents per bed, average length of stay, and reserve ratio constant. Here we calculate marginal costs at 50 percent above and 50 percent below sample means. All four points are within one standard deviation of the sample means. We use the results of the second specification in these calculations.

These calculations show that economies of scale manifest themselves in somewhat different ways for residents versus inpatient care. With other outputs held at sample means, the marginal cost of residents falls by more than half when the number of residents rises from 0.1 residents per bed to 0.4 residents per bed. At the latter number, with 180 residents in a hospital of about 450 beds, the marginal cost of a resident is only $35,021. However, when the whole scale of the hospital is varied, as in the third and fourth lines of Table 2, the marginal cost of residents does not change by nearly as large a margin (even adjusting for the smaller percentage increase in residents for 3 versus 4 than in 1 versus 2). The more dramatic changes are in the marginal costs of discharges and inpatient days, which fall by a factor of three. Average incremental costs do not fall quite as sharply, but still are cut in half. (The cubic nature of costs of these outputs results in minimum marginal costs at about twice sample means, or for a hospital of about 900 beds.)

CONCLUSION

This study has investigated two related problems in teaching hospital cost function estimation. First, the literature on hospital-physician behavior suggests that the cost of health care produced in the hospital will rely on physician inputs not entirely under the hospital's control. Hence, total health care costs may not be minimized, and will be affected by characteristics and activities of the medical staff. We present a theoretical model of hospital production of health care and residents, and show where we expect inefficiencies to occur. Second, most of the empirical work used to make policy regarding reimbursement for the costs of graduate medical education has failed to account for the full complexities of the structure of production and cost in teaching hospitals.

Utilizing rich data on hospital medical staff characteristics and a hybrid functional form for the cost function modeled after that of Grannemann, Brown, and Pauly (1986), we provide estimates of the determinants of teaching hospital costs under alternative specifications. We find that medical staff characteristics and activities significantly affect hospital costs, generally in the expected ways. Including medical staff variables results in large reductions in the estimated marginal and average incremental costs of graduate medical training, and reinforces previous research suggesting that the current Medicare reimbursement formula for indirect graduate medical education costs is above the costs of resident training. In terms of public policy this conclusion must be qualified by the fact that medical staff characteristics may represent quality of care, medical research, or other cost factors that are appropriate for reimbursement.

Further, we find significant economies of scale and scope in teaching hospital production, at least for hospitals within one standard deviation of sample means. This results in large variations in marginal and average incremental costs of not only residents but also of discharges and inpatient days as the scale and the resident-to-bed ratio of the hospital change.

APPENDIX

Table A1: Sample Statistics

Variable	*Mean*	*Standard Deviation*
Hospital Variables		
Hospital expenses	$84,360,498.83	58,004,766.58
Log of expenses	18.06	0.68
Discharges	15,587.21	7,822.62
Outpatient visits	130,803.43	142,775.96
Inpatient days	119,816.41	68,221.18
Full-time equivalent residents	87.25	114.24
Reserve ratio	28.02%	11.69
Case-mix index	1.11	0.09
1984 Medicare prevailing charges	29,164.30	6195.41
Private nonprofit hospital	81%	0.39
For-profit hospital	2%	0.15
Member of multihospital system	36%	0.48
Obstetrics hospital	0.2%	0.04
Council of Teaching Hospitals (COTH) member	47%	0.50
Percent of discharges who are Medicare patients	31%	0.09
Percent of discharges who are Medicaid patients	14%	0.11
Total beds	443.38	220.83
Total payroll expenses	$41,206,963.95	29,451,444.12
Employee benefit expenses	$7,753,147.53	6,223,022.57
Resident payroll expenses	$1,923,865.79	2,515,326.47
Total medical staff	324.59	247.91
Full-time equivalent physician employees	26.90	61.41

Continued

Table A1: Continued

Variable	*Mean*	*Standard Deviation*
Hospital Location		
North Central census region	26%	0.44
South census region	21%	0.41
West census region	14%	0.35
Suburban county of large SMSA	15%	0.36
SMSA population between 50,000 and 1,000,000	35%	0.48
Non-SMSA county	7%	0.25
Nurses wage index	$23,550.13	2069.50
Medical Staff Variables		
Percent female	11%	0.07
Percent foreign medical school graduates	22%	0.17
Medical staff's average years of experience	20.29	3.24
Years experience squared	422.23	135.61
Percent of staff with primary affiliation (PERCOVER)	39%	0.14
Percent of staff board certified	30%	0.12
Percent of Medical Staff Time in		
Administrative work	7%	0.03
Teaching	9%	0.05
Research	3%	0.05
Non-hospital group practice	32%	0.19
Non-hospital medical school	15%	0.24
Non-hospital partnership practice	12%	0.08
Other non-hospital employment	4%	0.02
Total work not in hospital employment	81%	0.14
Percent of Medical Staff Whose Specialty Is:		
Internal medicine	33%	0.13
Surgery	26%	0.09
Pediatrics	9%	0.07
Obstetrics/Gynecology	9%	0.06
Radiology	4%	0.03
Psychiatry	7%	0.07
Anesthesiology	5%	0.03
Pathology	3%	0.02
Other	12%	0.07

Table A2: Hospital Cost Regression Results

Dependent Variable = Log of Total Hospital Expenses

Independent Variable	Regression Coefficients (t-Statistic) 1	2	3
Hospital Variables			
Discharges	1.149E-04	1.033E-04	8.012E-05
	(2.962)	(2.781)	(2.182)
Outpatient visits	2.650E-06	2.610E-06	3.368E-06
	(1.994)	(2.080)	(2.588)
Inpatient days	8.162E-06	8.218E-06	1.4757E-05
	(1.778)	(1.851)	(3.273)
Full-time equivalent residents	4.520E-03	2.710E-03	1.449E-03
	(3.480)	(2.162)	(1.098)
Reserve ratio	0.020	0.009	0.002
	(1.736)	(0.819)	(0.162)
Discharges squared	-2.591E-09	-2.817E-09	-3.787E-09
	(-3.233)	(-3.661)	(-4.964)
Outpatient visits squared	-1.147E-13	-6.819E-13	-6.349E-13
	(-0.135)	(-0.837)	(-0.806)
Inpatient days squared	-3.336E-11	-2.766E-11	-3.739E-11
	(2.966)	(2.561)	(3.396)
Residents squared	-4.912E-06	-3.447E-06	-1.300E-06
	(-2.085)	(-1.505)	(-0.556)
Reserve ratio squared	1.339E-06	-1.437E-04	1.335E-04
	(0.007)	(-0.718)	(0.665)
Discharges cubed	3.309E-14	3.139E-14	3.506E-14
	(2.969)	(2.978)	(3.404)
Outpatient visits cubed	1.057E-19	3.554E-19	3.998E-19
	(0.285)	(0.997)	(1.159)
Inpatient days cubed	5.704E-17	4.174E-17	4.257E-17
	(3.531)	(2.702)	(2.817)
Residents cubed	1.772E-09	1.175E-09	-1.186E-09
	(0.622)	(0.432)	(-0.432)
Reserve ratio cubed	-1.046E-06	1.139E-06	-1.165E-06
	(-0.634)	(0.651)	(-0.672)
Inpatient days * residents	5.119E-09	2.811E-09	4.345E-09
	(1.412)	(0.814)	(1.237)
Inpatient days * discharges	-7.912E-11	-1.778E-11	1.469E-10
	(1.208)	(0.278)	(1.931)
Inpatient days * outpatient visits	-5.382E-12	-3.751E-12	-7.304E-12
	(-1.905)	(-1.400)	(-2.731)
Inpatient days * reserve ratio	6.800E-08	1.913E-08	1.027E-07
	(1.498)	(0.437)	(2.330)
Residents * discharges	-2.571E-08	-7.369E-09	-2.728E-08
	(-0.838)	(-0.253)	(-0.890)

Continued

Table A2: Continued

Dependent Variable = Log of Total Hospital Expenses

Independent Variable	*Regression Coefficients (t-Statistic)* 1	2	3
Residents * reserve ratio	-3.932E-05 (-2.483)	-3.460E-05 (-2.293)	-4.551E-05 (-2.938)
Residents * outpatient visits	1.109E-09 (1.253)	6.692E-10 (0.791)	7.584E-10 (0.876)
Discharges * reserve ratio	1.0496E-07 (0.302)	3.6804E-07 (1.117)	-5.092E-08 (-0.159)
Discharges * outpatient visits	-9.072E-12 (0.417)	-7.027E-12 (0.342)	2.2829E-11 (1.106)
Outpatient visits * reserve ratio	-7.875E-09 (-0.656)	-5.055E-09 (-0.451)	-6.118E-09 (-0.541)
Case mix	1.844 (4.260)	1.259 (2.923)	1.389 (3.239)
Discharges * case mix	-1.736E-05 (-0.538)	-7.382E-06 (-0.242)	-1.829E-05 (-0.593)
Inpatient days * case mix	4.9302E-07 (0.115)	-4.704E-07 (-0.116)	6.4253E-07 (0.156)
Residents * case mix	-1.106E-03 (-1.101)	-3.689E-04 (-0.391)	-9.629E-04 (-1.038)
Outpatient visits * case mix	-9.466E-07 (-0.975)	-1.044E-06 (-1.142)	-1.921E-06 (-2.098)
Nonprofit hospital	0.005 (0.200)	0.037 (1.357)	0.045 (1.585)
For-profit hospital	0.104 (1.835)	0.133 (2.451)	0.142 (2.665)
Multihospital system member	-0.014 (-0.883)	-0.021 (-1.413)	-0.008 (-0.578)
Obstetrics hospital	0.154 (0.857)	0.201 (1.013)	0.175 (0.912)
COTH member	0.071 (3.208)	0.056 (2.642)	0.057 (2.712)
Percent discharges Medicare	0.452 (3.595)	0.410 (3.119)	0.397 (3.092)
Percent discharges Medicaid	0.090 (0.950)	0.020 (0.209)	-0.034 (-0.370)
Hospital Location			
1984 Medicare index of prevailing charge	1.687E-06 (1.057)	3.833E-06 (2.372)	4.649E-06 (2.984)
Reserve ratio * index of prevailing charge	-1.784E-02 (-2.061)	-5.504E-03 (-0.597)	-7.536E-03 (-0.816)
Nurse's wage index	1.793E-05 (3.754)	1.702E-05 (3.680)	1.871E-05 (4.213)
North Central census region	0.103 (4.893)	0.102 (5.089)	0.123 (6.155)

Continued

Table A2: Continued

Dependent Variable = Log of Total Hospital Expenses

Independent Variable	*Regression Coefficients (t-Statistic)* 1	2	3
South census region	0.066	0.067	0.089
	(2.697)	(2.830)	(3.839)
West census region	0.240	0.202	0.208
	(8.423)	(6.904)	(7.367)
Suburban county of large	-0.066	-0.063	-0.062
SMSA	(-2.738)	(-2.747)	(-2.792)
Small city	-0.112	-0.096	-0.073
	(-5.571)	(-4.840)	(-3.808)
Non-SMSA county	-0.226	-0.179	-0.142
	(-5.710)	(-4.607)	(-3.801)
Medical Staff Variables			
Percent female	–	0.457	0.496
	–	(2.705)	(2.937)
Percent foreign medical	–	-0.135	-0.193
school graduate	–	(-2.051)	(-2.886)
Average experience	–	0.080	0.080
	–	(4.828)	(4.918)
Average experience squared	–	-0.002	-0.002
	–	(-4.798)	(-4.886)
Percent internists	–	0.238	0.152
	–	(2.954)	(1.907)
Percent surgeons	–	-0.079	-0.017
	–	(-0.833)	(-0.172)
Percent pediatricians	–	0.171	0.141
	–	(1.315)	(1.107)
Percent obstetrician/	–	-0.168	-0.151
gynecologists	–	(-1.071)	(-0.984)
Percent radiologists	–	0.881	0.738
	–	(3.122)	(2.691)
Percent psychiatrists	–	0.392	0.249
	–	(2.809)	(1.814)
Percent anesthesiologists	–	0.317	0.319
	–	(1.261)	(1.288)
Percent pathologists	–	-0.230	-0.378
	–	(-0.590)	(-0.973)
Percent other specialty	–	0.335	0.362
	–	(2.370)	(2.504)
Percent board-certified	–	0.412	-0.356
	–	(1.764)	(-1.902)
Primary affiliation	–	-0.500	0.272
	–	(-2.680)	(1.151)

Continued

Table A2: Continued

Dependent Variable = Log of Total Hospital Expenses

Independent Variable	Regression Coefficients (t-Statistic) *1*	*2*	*3*
Percent of Medical Staff Time in			
Administration	–	–	0.902
	–	–	(1.980)
Teaching	–	–	-0.058
	–	–	(-0.165)
Research	–	–	1.950
	–	–	(4.967)
Non-hospital group practice	–	–	-0.041
	–	–	(-0.714)
Non-hospital partnership	–	–	0.195
practice	–	–	(1.537)
Non-hospital medical school	–	–	-0.265
	–	–	(-2.833)
Other non-hospital	–	–	-0.358
employment	–	–	(-1.073)
Not employed by hospital	–	–	0.028
	–	–	(0.110)
Outputs-Medical Staff Interactions			
Residents * non-hospital	–	–	0.002
hours	–	–	(2.330)
Inpatient days * non-hospital	–	–	-1.232E-05
hours	–	–	(-4.908)
Discharges * non-hospital	–	–	6.715E-05
hours	–	–	(3.104)
Reserve ratio * non-hospital	–	–	-0.003
hours	–	–	(-0.411)
Outpatient visits * non-	–	–	5.459E-08
hospital hours	–	–	(0.093)
Intercept	13.514	13.243	13.078
	(27.365)	(26.440)	(27.034)
R-square	0.9432	0.9525	0.9585
Adjusted R-square	0.9382	0.9467	0.9523
N =	564	564	564

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