Estimating Hospital Costs: A Case Study of Hospitals under Medicare's Prospective Payment System in the U.S.

Udomsak Seenprachawong*

บทคัดย่อ

บทความนี้ได้ศึกษาผลประกอบการด้านการเงินของโรงพยาบาลในประเทศสหรัฐอเมริกาที่อยู่ภายใต้ระบบการเบิกจ่ายแบบกำหนดอัตราการเบิกไว้ล่วงหน้าในช่วงปี ค.ศ. 1988-1990 บทความนี้ได้ประยุกต์ทฤษฎีเศรษฐศาสตร์ที่ว่าด้วยต้นทุนการผลิตของผู้ผลิตสินค้าหลายประเภทพร้อม ๆ กัน ทฤษฎีดังกล่าวได้ให้กรอบการวิเคราะห์การศึกษาเชิงประจักษ์ เพื่อทำความเข้าใจว่าเพราะเหตุใดโรงพยาบาลบางแห่งสามารถที่จะดำรงอยู่รอดได้ในขณะที่โรงพยาบาลแห่งอื่น ๆ ประสบปัญหาด้านการเงิน

Abstract

This paper examines hospitals' financial performance under Medicare's Prospective Payment System (PPS) in the U.S. during 1988-1990. It applies the economic theory of cost to a firm that produces multiple outputs. The theory provides a rigorous framework for the empirical analysis for understanding why some hospitals win and others lose under Medicare's PPS.

* School of Development Economics, National Institute of Development Administration Bangkok, Thailand 10240. The research underlying this paper was a dissertation presented for the Doctor of Philosophy Degree at The University of Memphis, August 1994.

1. Introduction

Responding to high and rising hospital costs, the U.S. government replaced the Medicare program's retrospective payment system with the prospective payment system (PPS) in fiscal years 1983 and 1984. PPS reimburses the same set of basic Diagnosis Related Group (DRG) operating costs for all hospitals. A hospital keeps the difference between the payment rate and its costs of providing the service. However, the hospital is at risk if its cost exceeds allowed PPS reimbursements. Hence, PPS rewards those hospitals that operate more efficiently and penalizes those whose costs are excessive. Hospitals' PPS margins (the difference between PPS payments and Medicare's portion of hospital inpatient operating costs) have declined sharply since the early years of PPS. Many critical questions remain regarding hospitals' financial performance under Medicare's PPS. For instance, are some hospitals profitable mainly because they are advantaged by the PPS design features?, or are they more productive and efficient? Conversely, are other hospitals losing money under PPS because they are unproductive and inefficient?, or are they disadvantaged by the PPS design features?

This study hypothesizes that, given a set of PPS design features and hospital characteristics, hospitals with better production and management efficiencies are likely to outperform their more poorly managed counterparts. Hospitals which can maintain or increase volumes are likely to be winning hospitals. This means winners can achieve substantial low unit cost from economies of scale. According to the economic theory, volume of production depends in part on the comparison be tween the long-run marginal cost of a unit of output and the average revenue per unit, or price, that the firm expects to receive, If marginal cost is less than price, the theory predicts that firms will undertake actions to expand more volume of outputs. Thus, given a lower marginal cost, hospitals are able to maintain or increase volume and can make greater use of equipment, facilities, and staff. Results from the analysis of hospital financial performance under Medicare's PPS helps policy makers understand how or why some hospitals do better than others. This information is important to confirm any possible design biases in PPS and to identify any performance-related factors beyond hospital's control that the payment system does not recognize. The plan for the remainder of this paper is as follows. Section 2 provides the theoretical framework underlying the cost function analysis. Following that is the empirical model underlying the multivariate analysis. Section 4 provides empirical results. The paper concludes in section 5 with a highlight of major findings and discussion of policy implication of the empirical results.

2. Theoretical Framework

The basic model postulates that a hospital's profitability depends on its revenue and cost. It is represented by equation (1),

(1) Profit = f (revenue, cost)

Thus, for any given level of revenue, a hospital with a lower cost will have a higher profit. While the impact of revenue on profit needs to be determined, it is beyond the scope of this research. A hospital's cost reflects the underlying cost structure or cost function. In highly simplified terms, the cost relationship can be represented by a cost function of the form:

(2) Cost = h (outputs, input prices, control factors)

Hence, the analysis will be completed by estimating the equation motivated by the underlying cost function. Equation (2) will indicate a hospital's production efficiency, its relationship with cost, and the relationship between cost and profitability. An appropriate functional form for a hospital cost study is the cost function for a multi-product firm since a hospital faces combinations of cost-paying, charge-paying, and prospective-paying patients and insurers. This paper utilizes a modified cost function which follows the work of Grannemann, Brown, and Pauly (1986) in specifying that a hospital's cost depends on the volume and a mix of multiple outputs, input prices, and a set of factors that reflects the hospital's characteristics. Grannemann, Brown, and Pauly used a very general functional form as shown in equation (3) for their cost function, which was adapted from the generalized translog multi-production cost function developed by Caves, Christensen, and Trethway (1980).

(3) $$C = \prod \mu_i W_i e^{F(Y_j, D_j CM, R, Z)} e^{\alpha X}$$

where C = total hospital costs

W_i = input prices, including maintenance hourly wage, food service hourly wage, lab tech hourly wage, and nursing hourly wage

Y_j = discharge by type of services including acute inpatient discharges, intensive care inpatient discharges, and subacute and other inpatient discharges

D_j = inpatient days by type of services including acute inpatient days, intensive care inpatient days, and subacute and others inpatient days

CM = vector of case mix measures such as pediatric admissions, surgery admissions, and psychiatry admissions

R = vector of revenue sources, including inpatient revenue from Medicaid, inpatient revenue from other sources, and outpatient revenue from Medicaid

Z = vector of other hospital outputs, including ambulatory ancillary procedures, physical therapy visits, home health care visits, and family planning visits, and

X = exogenous factors, including geographic region, type of ownership, teaching involvement, and per capita income.

The function $F(\cdot)$, which appears in the first exponential expression in equation (3), is a linear combination of squared and cross-product terms of the various outputs. The squared terms are included in the cost function to allow for diminishing return. The cross-product terms are included to allow for the possibility of interaction effects between any two outputs. This study uses a similar specification, but with one modification in the function $F(\cdot)$. Equation (3) does not permit the direct estimation of the marginal cost of a Medicare day or discharge, since days and discharges are measured by type of service, rather than by payment source, A modified multi-product theoretical cost function is represented by equation (4), following the approach of Hadley and Swartz (1989), who measured inpatient outputs by payment source (Medicare, Medicaid, and "Other"). This change makes it possible to estimate the marginal cost of a Medicare day or the marginal cost of a Medicare discharge. Thus the function $F(\cdot)$ in equation (3) is replaced by the function $G(\cdot)$ in equation (4). In equation (4), measures of case mix and service mix will be included in the set of variables represented by X.

(4) $$C = \mu W e^{G(Y_j, D_j, Z_k)} e^{\alpha X}, \text{ j = 1,2,3; k= 1,2}$$

where C = Total facility cost
W = Adjusted average hourly wage of hospital employees
Y_1 = Total Medicare discharges
Y_2 = Total Medicaid discharges
Y_3 = Total “Other” discharges
D_1 = Total Medicare inpatient days
D_2 = Total Medicaid inpatient days
D_3 = Total “Other” inpatient days
Z_1 = Total number of full-time residents
Z_2 = Total swing bed discharges
X = Control factors, including measure of case mix, service mix, and variables representing hospital characteristics (such as type of ownership and teaching involvement), and those representing the local area characteristics where hospitals are located (such as numbers of nursing home beds, per capita income, and numbers of physicians per capita).

The particular specification of the function G(•), which appears in the first exponential expression in equation (4), is represented by Equation (5).

(5) $$G(Y_j, D_j, Z_k) = \beta_{11}Y_1 + \beta_{12}Y_2 + \beta_{13}Y_3 + \beta_{21}Y_1^2 + \beta_{22}Y_2^2 + \beta_{23}Y_3^2 + \beta_{31}D_1 + \beta_{32}D_2 + \beta_{33}D_3 + \beta_{41}D_1^2 + \beta_{42}D_2^2 + \beta_{43}D_3^2 + \beta_{51}Z_1 + \beta_{52}Z_2 + \beta_{61}Z_1^2 + \beta_{62}Z_2^2 + \beta_{71}Y_1 Z_1 + \beta_{72}Y_1 Z_2 + \beta_{73}Y_1 Y_3$$

The cost variable (C) is total facility costs, which includes all costs incurred by the hospital for inpatient, outpatient, long-term care, other type of patient cares, research and education, and non-patient care activities conducted by the hospital. The input price variable (W) is the adjusted average hourly wage of hospital employees. Grannemann et al. suggested that prices of equipment and capital should not be included because they were presumed to be set in national markets and not to vary among hospitals in a cross-section sample.

An important feature of cost function in equation (4) is the separation of the cost of a discharge from the cost of a day, which was used by Grannemann et al., which view each hospital stay as consisting of (a) a quantity of hospital services associated with the discharge (1ab tests, ancillary services, surgical services) plus (b) daily services (including routine nursing) associated with the amount of day spent in the hospital. Hence, we have two inpatient care outputs measured by payer source-Medicare, Medicaid, and "Other". "Other" is defined as total less Medicare and Medicaid. It includes privately insured as well as uninsured, other government programs, and other charity care or uncompensated care. These inpatient care outputs are number of Medicare discharges (Y_1), number of Medicaid discharges (Y_2), number of "Other" discharges (Y_3), Medicare inpatient days of care (D_1), Medicaid inpatient days of care (D_2), and "Other" inpatient days of care (D_3). Z_k is other hospital outputs produced in some hospitals such as teaching and research output (Z_1) and hospital swing-bed care output (Z_2).Also included in the cost function are three interaction terms: 1) Medicare discharge x teaching output, 2) Medicare discharge x swing bed output, and 3) Medicare discharge x "Other" discharge. These interaction terms allow one to test a hypothesis on economies of scope. The interaction between teaching and research output and Medicare discharges will indicate whether the extent of teaching and research affects the cost of Medicare patients. Thus, if teaching and research activities decrease the cost of Medicare patients, β_{71} in the equation (5) is expected to be negative. For example, hospitals may reduce their operating costs by letting residents perform daily routine tests as a part of educational program.

Due largely to the impacts of Medicare PPS, a growing number of hospitals expand the swing-bed approach to post-acute care (Shaughnessy and Schlenker 1986). The approach appears to fill a gap between the relatively intense medical needs of post-acute care patients who now may be discharged early from the hospital. One relevant policy question regarding hospital swing beds care is that does the swing-bed care approach increase or decrease total costs to Medicare? The interaction between hospital swing-bed care and Medicare discharges will indicate whether the swing-bed approach affects the cost of treating Medicare patients. Thus, if swing-bed care outputs decrease the cost of treating Medicare patients, β_{72} in the equation (5) is expected to be negative. And if this hypothesis is correct, it will be consistent with Dobson et al. (1992). They have found that winning hospitals are likely to offer a variety of services such as post-acute services to increase revenues. The development of post-acute services may increase performance by attracting patients, thereby lowering per case costs. In addition, the units provide opportunities to allocate overhead costs and use staff and equipment more efficiently, thereby lowering per case costs. Moreover, post-acute services provide opportunities to improve the process of inpatient care and provide discharge options for some patients. Evidence indicates that swing beds SNF turned to be profitable under Medicare's PPS (Manning 1990). The various control factors (X) include measure of case mix, service mix, and variables representing hospital characteristics and those representing the local area characteristics. These control variables are assumed to affect the level of costs, but not the shape of the cost function with respect to outputs. The marginal cost of a Medicare discharge and a Medicare inpatient day can be derived from equation (4) as follow

$$(6.1) \quad MCY_1 = \frac{dC(W,\ Y,\ D,\ Z,\ X)}{dY_1}$$

$$= C(W,\ Y,\ D,\ Z,\ X) \cdot \left(\frac{dG(Y,\ D,\ Z)}{dY_1}\right)$$

$$= \mu W \cdot e^{G(Y,\ D,\ Z)} e^{\alpha X}(\beta_{11} + 2\beta_{21}Y_1 + \beta_{71}Z_1 + \beta_{72}Z_2 + \beta_{73}Y_3).$$

$$(6.2) \quad MCD_1 = \frac{dC(W,\ Y,\ D,\ Z,\ X)}{dD_1}$$

$$= C(W,\ Y,\ D,\ Z,\ X) \cdot \left(\frac{dG(Y,\ D,\ Z)}{dD_1}\right)$$

$$= \mu W \cdot e^{G(Y,\ D,\ Z)} e^{\alpha X}(\beta_{31} + 2\beta_{41}D_1).$$

The coefficient β_{71} should indicate whether the extent of teaching and research affects the cost of treating Medicare patients. The coefficient β_{72} should indicate whether the swing-bed approach affects the cost of treating Medicare patients. In general, equation (6.1) and (6.2) imply that any factor which shifts the entire cost function, C, also affects marginal cost, and that the marginal cost of any output depends on the volumes of all outputs in the cost function. In the single output case, economies of scale (EOS) can be shown to be equal to average cost divided by marginal cost (MC). Baumol, Panzar, and Willig (1982) derive the multi-product analogue of this concept, product-specific EOS, as

(7) $$EOS_i = AIC_i / MC_i.$$

The average costs for a multi-product cost function, the average incremental cost (AIC), can be calculated from equation (4). The incremental cost associated with a particular output (Q) is the difference between the cost function evaluated first at mean level of all outputs and then evaluated again with the value of that particular output set to zero. This difference indicates how much total cost increases when a new output is added to the product mix. Dividing the increase in costs by the number of units of the added output produces the estimate of average incremental cost. This can be shown mathematically as equation (8).

(8) $$AIC_i = [\, C\,(Q_1,\ Q_2,\ldots,Q_i,\ldots,Q_k) - C(Q_1,Q_2,\ldots,0,\ldots,Q_k)\,] \,/\, Q_i$$

The key measure of cost analyzed in this study is the long-run marginal cost. It is defined as the cost of treating one additional case, taking into account the levels of all other outputs, input prices, and other factors affecting costs. It is hypothesized that a winner is likely to have a lower marginal cost of a Medicare case than that of a loser. The lower marginal cost may reflect better production and management efficiencies, thereby using less hospital resources. Winners may control costs, for example, by reducing the use of "intermediate products" per case, such as controlling ancillary services per case, reducing average length of stay, equipment, and medical supply use. Economies of scale can be a result of the specialization of factors of production, It seems reasonable to expect that division and specialization of nursing services in hospitals would result in economies of scale. Economies of scale are also associated with the efficiencies of management. Dobson et al. (1992) have found that winners and losers were distinguished by largely historical differences in the productive relationship between physicians and administrators. These differences contributed to operating efficiencies and inefficiencies and affected cost per case. For example, winners were more likely to maintain or generate additional volume by more aggressive strategies to recruit and retain physicians.

3. Empirical Model

Equation (4) in the previous section can be estimated empirically by taking logarithms of both sides of the equation, resulting in equation (9).

(9) $\text{In}C = A + \mu \text{In}W + G(Y_j, D_j, Z_k) + \alpha X + \varepsilon$

A = constant term; ε = error term; j = 1, 2, 3; k = 1, 2;

αX = a_1MEDIUM+a_2LARGE+a_3TEACHING+a_4PROFTIT+ a_5NOPROFIT+a_6KIDNEY+a_7HEART+a_8SOLE+a_9EYE+ a_{10}PRIME+a_{11}CASEMIX+a_{12}PHYSICIAN+a_{13}RECIPIENT+ a_{14}NURSEHOME+a_{15}INCOME+a_{16}NE+a_{17}NC+a_{18}WE+a_{19}URBAN.

Table 1 details the definitions of the variables used in the regression analysis. We use total facility cost as a dependent variable[1]. Total facility cost includes all costs incurred by the hospital for inpatient, outpatient, long-term care, other types of patient care, research and education, and non-patient care activities conducted by the hospital. The underlying economic theory implies that input prices should be included as independent variables in the cost function. Unfortunately, direct measures of the prices hospitals pay or face for their inputs are not available. An alternative measure is HCFA hospital wage index provided in the 1990 Hospital Cost Report. The adjusted average hourly wage of hospital employees is used to represent labor input price. No data are available from published sources to construct a measure of the price of other purchased inputs. Most prior cost function studies have omitted this variable without causing any apparent bias in the estimates of other parameters (Grannemann et al., 1986).

[1] Hospital price index was used to deflate total facility cost. These indices are 143.9, 160.5, and 178.0 for 1988, 1989, and 1990, respectively.

Table 1 Definitions of Regression variables

Variable	**Definition**
Dependent Variable	
C	Total facility cost
Input Price Variables	
W	Adjusted average hourly wage of hospital employees
Output Variables	
Y_1	Total Medicare discharges
Y_2	Total Medicaid discharges
Y_3	Total "Other" discharges
D_1	Total Medicare inpatient days
D_2	Total Medicaid inpatient days
D_3	Total "Other" inpatient days
Z_1	Total number of full-time residents
Z_2	Total swing bed discharges
Control Variables	
SMALL	1 if a hospital's total beds are less than 100; 0; otherwise (small is the omitted category)
MEDIUM	1 if a hospital's total beds are 100-499; 0; otherwise
LARGE	1 if a hospital's total beds are 500 or more; 0; otherwise
TEACHING	1 if the hospital is affiliated with medical school; 0 otherwise
PROFIT	1 if the hospital is a private for-profit hospital; 0; otherwise
NOPROFIT	1 if the hospital is a non-profit hospital; o otherwise
GOVERNMENT	1 if the hospital is a governmental hospital; 0 otherwise (governmental is the omitted category)
KIDNEY	1 if the hospital is a Medicare certified kidney transplant center; 0 otherwise
HEART	1 if the hospital is a Medicare certified heart transplant center; 0 otherwise
SOLE	1 if the hospital is a sole community hospital; 0 otherwise
EYE	1 if the hospital is eye and ear specialty hospital; 0 otherwise
PRIME	1 if the hospital is a rural primary care hospital; 0 otherwise
CASEMIX	Medicare intensive care unit days as a percentage of total inpatient days

Table 1 (Continued)

PHYSICIAN	Number of physician per capita in the hospital's county
RECIPIENT	Number of beneficiaries per capita in the hospitals̃ county
NURSEHOME	Number of nursing home beds in the hospitals̃ county
INCOME	Per capita income in the hospital's county
NE	1 if the hospital is in the Northeast; 0 otherwise
NC	1 if the hospital is in the North-central; 0 otherwise
WE	1 if the hospital is in the West ; 0 otherwise
SO	1 if the hospital is in the South ; 0 otherwise (South is the omitted region)
URBAN	1 if the hospital is in urban; 0 otherwise

The major goal of this study is to estimate the marginal cost of inpatient care. The cost equation, therefore, contains separate measures of inpatient services -number of discharges and number of days of care. In principle, the output measures may be endogenous. That is, the hospital can manipulate the relationship between price charged and quantity demanded. Thus this affects the independence of output levels and costs. However, Grannemann et al. argue that "insurance coverage weakens the relationship between gross price charged and quantity demanded... hospital output decisions may be dominated by factors other than the cost of production... [the possible endogeneity of output] may be less of a problem for hospitals than for other types of firms."[2]

The output variables in the cost equation are total Medicare discharges, total Medicaid discharges, total "Other" discharges, total Medicare inpatient days, total Medicaid inpatient days, total "Other" inpatient days, net full-time interns and residents, and total swing bed discharges. The number of full-time residents is a proxy for hospital's teaching and research outputs. The inference here is that a high number of full-time residents represent a high teaching and research output. The number of swing bed discharges is a proxy for hospital's post-acute care outputs.

Also included in the cost equation are control variables. This study divides control variables into two groups: variables representing hospital characteristics

[2] Grannemann et a1., 1986 p. 109.

and those representing the local area characteristics where hospitals are located. A number of hospital characteristic variables accounted for their influences on hospitals' expenditure and utilization. There is much discussion on the effects various hospital characteristics have on hospital costs which reflect practice patterns, in so far as costs depend on service utilization (Becker and Sloan 1983: Keating 1984; Slon and Becker 1984; Granneman, Brown, and Pauly 1986; Vutakuabi 1987; Thorpe 1988; and Hadley and Swartz 1989). Costs have been found to be higher in larger hospitals, and those affiliated with medical schools. The positive relationship between hospital size and costs per case reflects diseconomies of scale (Robinson and Luft 1985; Thorpe 1988). Teaching hospitals have been found to have higher costs per case (Frick, Martin, and Swartz 1985; Thorpe 1988) which reflect their more intensive use of ancillary services and greater severity of illness of their patients. We measure this effect by a teaching involvement dummy variable. Hospital ownership also affects costs, although the effect differs across studies. Hadley and Swartz (1989) found higher costs in proprietary and public hospitals compared to private nonprofit institution; Grannemann, Brown, and Pauly (1986) found higher costs in proprietary hospitals; and Robinson and Luft (1985) found higher costs in public hospitals but lower costs in proprietary hospitals compared to those that were private nonprofit.

Service mix and case mix variables are included to account for variations in the kind of patients treated. Variations in service mix are proxied by dummy variables as follow: Medicare certified kidney transplant center, Medicare certified heart transplant center, sole community hospital, eye and ear specialty hospital, and rural primary care. Variations in case mix over hospitals are proxied by including Medicare intensive care unit days as a percentage of total inpatient days. The inference here is that the higher this percentage is the more severe and costly will be the cases treated by that hospital. Hospitals which selectively admit or equip themselves to treat those less severe cases will have lower percentages.

Local area characteristics are included in the equation to control for area influences on practice patterns. The number of physicians per capita reflects physician supply and patient access. An increase in physician supply should increase expenditures and volumes. More physicians also means that patients have greater access to physician services which may lead to more services being provided, thereby increasing expenditures and utilization. The number of beneficiaries per capita reflects patient demand and access. The more beneficiaries per capita ,the higher is the demand for Medicare services, which should lead to more services and higher expenditures, On the other hand, more beneficiaries means that patient access to medical care may be poorer so fewer services are likely to be provided. Thus the net result is uncertain. A larger supply of nursing home beds may lead to lower inpatient utilization and expenditures and higher outpatient volumes and expenditures because patients can be discharged sooner to a nursing home. Higher per capita income may increase non-Medicare demand and so may reduce Medicare volumes and expenditures. Further, the per capita income variable can account for differences in hospital quality and amenities that reflect the area's level of affluence. Finally, dummy variables representing the region (Northeast, North-central, South, and West) and area (urban and rural) in which a hospital is located are included to account for geographic differences in unobserved input prices, demand variations, and physician practice patterns. Evidence indicates that costs have been found to be higher in hospitals located in urban areas (Cromwell et a1., 1987; Gadket and Swartz 1989; Hadley and Zuckerman 1990).

The data source for this research is the PPS Minimum Data Set which contains Medicare Hospital Cost Reports compiled by Health Care Financing Administration (HCFA). An additional data source came from the Area Resource File compiled by National Institution of Health (NIH). The Area Resource File contains the characteristics of the local counties where the hospitals are located. This research analyzes Medicare cost report data for PPS hospitals for the cost reporting period October 1, 1988 through October 1, 1991 (PPS6-PPS8). Although PPS started in 1983-1984 (PPS1), 1988 was chosen as a base year for this research because Congress in 1986 and 1988 enacted a series of policy changes that were intended to mitigate perceived inequalities in payments under the initial design of PPS and accomplish certain other objectives. In 1986, the Indirect Medical Education (IME) adjustment was reduced and the Disproportionate Share Hospital (DSH) adjustment added. In addition, congress in 1988 mandated separate updates to the rural and urban standardized payment amounts.

4. Empirical Results

This section presents the econometric estimates of the cost function and discusses issues related to estimation methods, variable specification, and statistical significance of the parameter estimates.

I. Estimation Method

In this study, Medicare financial performance under PPS is measured by the PPS margins. This margin compares PPS payments to Medicare inpatient operating costs. It provides a measure of the relationship between the costs of Medicare covered services and how much was paid for them. Winning hospitals were defined as those hospitals that were in the top 25 percent of the distributions of PPS margins for the three consecutive years of 1988 to 1990; losing hospitals were defined as those in the bottom 25 percent of the distributions of PPS margins for the same years. This design assumed that winning hospitals were significantly different from the losing hospitals. Therefore the analysis was done separately for winning and losing hospitals. All results have been reported separately for each group of hospitals.

The ordinary least-square regression was used to estimate the coefficients in equation (9). I used Chow test for testing the equality of regression coefficients of three equations (1988, 1989, and 1990 equation). For the winning-hospital sample, I obtained $F(8,1288) = 0.469$ (for cost estimation from discharges) and $F(4,1298) = 0.2977$ (for cost estimation from inpatient days). For the losing-hospital sample, I obtained $F(8,1440) = 1.2131$ (for cost estimation from discharges) and $F(4,1449) = 1.0638$ (for cost estimation from inpatient days). Since all these F statistics are not significant at 0.05, the null hypothesis of equality of regression coefficients was not rejected. Therefore, I used the 3-year combined data to estimate the cost function. In the preliminary investigation, I found that number of discharges and numbers of inpatient days were highly correlated. By including these two outputs in the same model would have a multicollinearity problem. Therefore, I estimated the cost functions with the revised version of the equation (9) by two model specifications: 1) cost estimation from number of discharges and 2) cost estimation from inpatient days. I do not include "Other" type of patients outputs in the revised version of cost function because they are highly correlated with Medicare and Medicaid outputs.

Table 2 reports the means and standard deviations of the cost function variables for the winning-hospital sample and the losing-hospital sample. Three variables I had planned to use in the cost function do not appear in my final estimates because they were highly correlated with other included variables. These include total number of physician per capita in the hospital's county (PHYSICIAN), total number of Medicare beneficiaries per capita in the hospital's county (RECIPIENT), and total number of nursing home beds in the hospital's county (NURSEHOME).

II. Econometric Results

The detailed parameter estimates are presented in Table 3 and Table 4 for the winning-hospital samples, and in Table 5 and Table 6 for the losing-hospital sample. The numerical values of cost estimates and the implications of these findings will be discussed in the next section.

The overall models were significant for both the winning-hospital and the losing-hospital sample.[3] The F-statistics were significant at the 0.01 confidence level. The explained variations were about 90 percent for the winning-hospital sample, and about 80 percent for the losing-hospital sample. The input price variable (W) was consistently significant in all regression results. With the exception of swing bed discharges, all of the linear output terms enter with positive and significant signs.

[3] Since all predicted values of log of total facility cost are positive, they support, in part, the tendency for the cost function to represent a concave underlying production function for hospitals.

Table 2 Mean and Standard Deviation of Regression Variables

Variables	Winner (N = 1,325) Mean	Winner (N = 1,325) Std. Dev.	Loser (N = 1,476) Mean	Loser (N = 1,476) Std. Dev.
Log of Average Hourly Wage (W)	2.79	0.32	2.79	0.18
Medicare Discharges (Y1)	3,591.72	2,600.32	3,589.63	2,036.60
Medicaid Discharges (Y2)	2,391.78	3,163.54	1,032.58	1,126.59
Medicare Inpatient Days (D1)	32,534.29	28,253.61	32,981.30	20,103.72
Medicaid Inpatient Days (D2)	12,758.91	19,489.45	5,045.28	5,623.96
Full-Time Interns and Residents (Z1)	59.79	113.19	14.71	115.57
Swing bed Discharges (Z2)	2.73	16.69	4.29	142.62
Medium Dummy (MEDIUM)	0.68	0.46	0.86	0.33
Large Dummy (LARGE)	0.18	0.38	0.09	0.29
Teching Dummy (TEACHING)	0.48	0.49	0.23	0.42
Nonprofit Dummy (NOPRO)	0.76	0.42	0.76	0.42
Forprofit Dummy (FORPRO)	0.10	0.30	0.13	0.34
Kidney Transplant Center Dummy (KIDNEY)	0.13	0.34	0.03	0.19
Heart Transplant Center Dummy (HEART)	0.03	0.18	0.01	0.11
Sole community Dummy (SOLE)	0.03	0.18	0.01	0.13
Eye and Ear Specialty Dummy (EYE)	0.005	0.07	0.003	0.05
% Medicare ICU Days (CASEMIX)	0.02	0.02	0.03	0.02
Per Capita Income (INCOME)	13,184.71	7,424.37	12,575.39	7,442.78
North-east Dummy (NE)	0.25	0.43	0.28	0.45
North-central Dummy (NC)	0.28	0.45	0.24	0.42
West Dummy (WE)	0.20	0.40	0.06	0.24
Urban Dummy (URBAN)	0.61	0.48	0.51	0.49

Sources : Medicare Cost Reports, 1988-1990; Area Resource File, 1990.

For the winning-hospital sample, output variables and the squared terms were all significant at 0.05 confidence level. The quantity squared terms tend to have negative coefficients with the exception of the squared term of swing bed discharge output which has positive coefficient. As far as interaction terms are concerned, Medicare costs were more closely linked to other outputs in winning than in losing hospitals. In winning hospitals, Medicare discharge x number of interns and residents was statistically significant at 0.05 confidence level. This is an expected result. The coefficient of this interaction term is negative; there are economies of scope between Medicare outputs and teaching and research output in winning hospitals. One possible reason is that winning hospitals use their interns and residents to perform Medicare inpatient routine tests, thereby lowering total costs. The interaction term between Medicare discharge x swing bed discharge was not found statistically significant at 0.05 confidence level.

Table 3 Regression Results for the Winning-hospital Sample, Cost Estimation from Number of Discharges

Dependent Variable: Log of Total Facility Cost

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob. > F
Model	26	1598.5522	61.48278	443.115	0.0001
Error	1298	180.09936	0.13875		
C Total	1324	1778.6515			

Root MSE	0.37249	R-square	0.8987
Dep Mean	17.64257	Adj. R-sq	0.8967
C.V.	2.11133		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob.>ITI
Intercept	1	14.606709	0.10184909	146.361	0.0001
Log of Average Hourly Wage	1	0.197318	0.03784025	5.214	0.0001
Medicare Discharges	1	0.000387	0.00001494	25.869	0.0001
Medicaid Discharges	1	0.000111	0.00000953	11.679	0.0001
FT Residents	1	0.004178	0.00039212	10.654	0.0001
SW Bed Discharges	1	-0.010772	0.00201493	-5.346	0.0001
Medicare Discharges x FT Residents	1	-0.000000162	0.00000003	-4.849	0.0001
Medicaid Discharges x SW Bed Discharges	1	0.000004033	0.00000198	2.033	0.0582
Medicare Discharges squared	1	-1.61E-08	0.00000000	-12.252	0.0001
Medicaid Discharges squared	1	-3.62E-09	0.00000000	-6.800	0.0001
FT Residents squared	1	-0.000002543	0.00000039	-6.525	0.0001
SW Bed Discharges squared	1	0.000044292	0.00001042	4.251	0.0001
Medium Bed Size	1	0.711912	0.04193044	16.978	0.0001
Large Bed Size	1	0.564876	0.06409876	8.813	0.0001
Teaching Hospital	1	0.188992	0.02889966	6.540	0.0001
Non-profit hospital	1	-0.057593	0.03605649	-1.597	0.0564
For-profit hospital	1	-0.176016	0.04698101	-3.747	0.0001
Kidney Transplant Center	1	0.031647	0.04173445	0.758	0.3124
Heart Transplant Center	1	0.037461	0.06609365	0.567	0.7486
Sole community Hospital	1	0.007646	0.05924775	0.129	0.7841
Eye and Ear Specialty Hospital	1	-0.018510	0.14689621	-0.126	0.7226
% Medicare ICU Days	1	-0.919280	0.52194425	-1.761	0.0497
Per Capita Income	1	0.000010100	0.00000211	4.793	0.0001
North-east	1	-0.116712	0.03325747	-0.202	0.9707
North-central	1	0.098593	0.03031747	3.252	0.0002
West	1	0.265792	0.03440274	7.726	0.0001
Urban	1	-0.077347	0.02910455	-2.658	0.0061

Table 4 Regression Results for the Winning-hospital Sample, Cost Estimation from Inpatient Days

Dependent Variable: Log of Total Facility Cost

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob. > F
Model	20	1538.04860	76.90243	416.789	0.0001
Error	1304	240.60293	0.18451		
C Total	1324	1778.65153			

Root MSE	0.42955	R-square	0.8647
Dep Mean	17.64257	Adj R-sq	0.8627
C.V.	2.43472		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob.>ITI
Intercept	1	15.022085	0.11624916	129.223	0.0001
Log of Average Hourly Wage	1	0.215602	0.04350583	4.956	0.0001
Medicare Days	1	0.000038150	0.00000156	24.503	0.0001
Medicaid Days	1	0.000020598	0.00000186	11.074	0.0001
Medicare Days squared	1	-1.78E-10	0.00000000	-16.129	0.0001
Medicaid Days squared	1	-9.08E-11	0.00000000	-6.055	0.0001
Medium Bed Size	1	0.932121	0.04454087	20.927	0.0001
Large Bed Size	1	0.917429	0.07105930	12.911	0.0001
Teaching Hospital	1	0.320809	0.03138873	10.221	0.0001
Non-profit hospital	1	-0.139108	0.03981901	-3.494	0.0001
For-profit hospital	1	-0.289191	0.05273855	-5.483	0.0001
Kidney Transplant Center	1	0.296056	0.04409850	6.714	0.0001
Heart Transplant Center	1	0.054687	0.07036978	0.735	0.6148
Sole community Hospital	1	-0.021611	0.06770883	-0.319	0.4975
Eye and Ear Specialty Hospital	1	0.204989	0.16964956	1.208	0.2612
% Medicare ICU Days	1	-0.848857	0.60223904	-1.410	0.1232
Per Capita Income	1	0.000003474	0.00000245	1.418	0.1940
North-east	1	-0.224044	0.03853501	-5.814	0.0001
North-central	1	0.084584	0.03417590	2.475	0.0042
West	1	0.323646	0.04015944	8.059	0.0001
Urban	1	-0.037503	0.03328162	-1.127	0.2457

Table 5 Regression Results for the Losing-hospital Sample, Cost Estimation from Number of Discharges

Dependent Variable: Log of Total Facility Cost

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob. > F
Model	26	465.19879	17.89226	204.795	0.0001
Error	1449	126.59419	0.08737		
C Total	1475	591.79298			

Root MSE	0.29558	R-square	0.7861
Dep Mean	17.71389	Adj R-sq	0.7822
C.V.	1.66863		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob.>ITI
Intercept	1	14.848814	0.14371608	103.320	0.0001
Log of Average Hourly Wage	1	0.478544	0.04946718	9.674	0.0001
Medicare Discharges	1	0.000330	0.00001164	28.313	0.0001
Medicaid Discharges	1	0.000075207	0.00001839	4.089	0.0005
FT Residents	1	0.000173	0.00029936	0.577	0.2666
SW Bed Discharges	1	-0.000582	0.00058987	-0.0986	0.2707
Medicare Discharges x FT Residents	1	7.6997E-08	0.00000005	1.442	0.1298
Medicaid Discharges x SW Bed Discharges	1	0.000000574	0.00000070	0.823	0.5934
Medicare Discharges squared	1	-1.56E-08	0.00000000	-15.247	0.0001
Medicaid Discharges squared	1	2.13E-09	0.00000000	0.591	0.2260
FT Residents squared	1	-0.000000255	0.00000009	-2.801	0.0009
SW Bed Discharges squared	1	0.000000130	0.00000010	1.259	0.1488
Medium Bed Size	1	0.489713	0.04863419	10.069	0.0001
Large Bed Size	1	0.639466	0.06067926	10.538	0.0001
Teaching Hospital	1	0.146082	0.02115685	6.905	0.0001
Non-profit hospital	1	-0.048259	0.02834445	-1.703	0.0586
For-profit hospital	1	-0.166137	0.03515830	-4.725	0.0001
Kidney Transplant Center	1	0.197902	0.04580828	4.320	0.0001
Heart Transplant Center	1	0.167936	0.07905924	2.124	0.0141
Sole community Hospital	1	-0.042760	0.05774574	-0.740	0.2055
Eye and Ear Specialty Hospital	1	0.489257	0.13513425	3.621	0.0001
% Medicare ICU Days	1	-2.563772	0.38132222	-6.723	0.0001
Per Capita Income	1	0.000013230	0.00000142	9.349	0.0001
North-east	1	-0.097008	0.02140776	-4.531	0.0001
North-central	1	-0.009339	0.02153367	-0.434	0.0010
West	1	0.332025	0.03655235	9.084	0.0001
Urban	1	-0.045294	0.02034265	-2.227	0.1086

Table 6 Regression Results for the Losing-hospital Sample, Cost Estimation from Inpatient Days

Dependent Variable: Log of Total Facility Cost

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob. > F
Model	20	449.33498	22.46675	229.465	0.0001
Error	1455	142.45799	0.09791		
C Total	1475	561.79298			

Root MSE	0.31290	R-square	0.7593
Dep Mean	17.71389	Adj R-sq	0.7560
C.V.	1.76644		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob.>ITI
Intercept	1	14.933933	0.15136807	98.660	0.0001
Log of Average Hourly Wage	1	0.493454	0.05236229	9.424	0.0001
Medicare Days	1	0.000030475	0.00000120	25.317	0.0001
Medicaid Days	1	0.000010481	0.00000351	2.983	0.0130
Medicare Days squared	1	-1.27E-10	0.00000000	-12.242	0.0001
Medicaid Days squared	1	1.12E-10	0.00000000	1.043	0.0753
Medium Bed Size	1	0.566597	0.05097796	11.115	0.0001
Large Bed Size	1	0.677948	0.06436991	10.532	0.0001
Teaching Hospital	1	0.117610	0.02191026	5.368	0.0001
Non-profit hospital	1	-0.047636	0.02987610	-1.594	0.0782
For-profit hospital	1	-0.186761	0.03678444	-5.077	0.0001
Kidney Transplant Center	1	0.262498	0.04791528	5.478	0.0001
Heart Transplant Center	1	0.240578	0.08094248	2.972	0.0008
Sole community Hospital	1	-0.078871	0.06104701	-1.292	0.0599
Eye and Ear Specialty Hospital	1	0.439315	0.14312767	3.069	0.0009
% Medicare ICU Days	1	-2.297674	0.40289743	-5.703	0.0001
Per Capita Income	1	0.000011634	0.00000149	7.790	0.0001
North-east	1	-0.238978	0.02251994	-10.612	0.0001
North-central	1	0.012016	0.02276622	0.528	0.2678
West	1	0.395813	0.03887617	10.181	0.0001
Urban	1	-0.080131	0.02154986	-3.718	0.0006

The regression results of the losing-hospital sample produced qualitatively different results for some key variables. The results showed that Medicare and Medicaid discharges, and Medicare and Medicaid inpatient days were significant at 0.05 confidence level. Two other outputs, numbers of interns and residents, and swing bed discharge, were not significant. Overall, the interaction terms and the squared terms were not significant with the exceptions of the squared term of Medicare discharge, Medicare inpatient day, and number of interns and residents.

The regression results for the control variables generally were significant as expected. Hospital size variables were significant in all regressions. Robinson and Luft (1985) also showed that total hospital costs in large hospitals tend to be higher than those of small hospitals. The teaching status variables were uniformly significant in all regressions. In conformance with Frick, Martin, and Swartz (1985) and Thorpe (1988), teaching hospitals have been found to have higher total hospital costs, which may reflect their more intensive use of ancillary services and greater severity of illness of their patients. Indeed, Medicare's PPS also realized this fact and gave extra payments to medical cases treated in teaching hospitals. Governmental hospitals tend to have higher total hospital costs than non-governmental hospitals (for-profit, and non-profit hospitals). This is consistent with Robinson and Luft (1985); the results showed that costs tend to be higher in public hospitals but lower costs in proprietary hospitals compared to those that were private non-profits. Unexpected result was the negative relationship between total hospital cost and case mix variable; hospital costs found to be lower in hospitals which treated more severe cases. One possible reason to account for this negative relationship is the low data representation of the case mix variable in my study sample; there were only two and three percentage in total winning-hospital and losing-hospital sample, respectively. In addition, service mix variables are problematic because their low data representation. Thus regression analysis may not fully capture variations in hospital costs due to these case mix and service mix variables. Per capita income variable was conclusively statistically significant in all regressions. As expected, hospitals located in higher per capita income counties tend to have higher hospital costs than those located in low per capita income counties. This cost difference may reflect variations in hospital quality and amenities which are related to the county's level of affluence. The regression results for the region location of the winning-hospital sample were qualitatively similar to those of the losing-hospital sample. I found hospitals in the West tend to have higher hospital costs than those in the South. These results conform with the common perception that input prices are lower in the South than in the West. In addition, more physician-intensive medicine is practiced in the West. Finally, the regression results for the location factor were not conclusively significant. Generally, I found urban hospitals had lower hospital costs than those in rural hospitals. These findings were inconsistent with Cromwell et al. (1990); they found that hospital costs were higher in hospitals located in urban areas. The discrepancy may be a result of different data sources used in the studies.

III. Implications Drawn From The Cost Function Estimates

In this section I use parameter estimates from the cost equations, which were reported and discussed in the previous section, to address the research questions raised in section 1. Information is reported separately for winning and losing hospitals, because it has been found that they have significantly different cost structures. The primary focus is on the long run marginal cost of a Medicare case because marginal cost is a key factor in hospitals' decisions about expanding or contracting volumes.

1) Long-Run Marginal Costs and Average Incremental Costs of Medicare Outputs

I use the cost functions' parameter estimates to calculate long-run marginal cost (MC) and average incremental cost (AIC) for a Medicare discharge and a Medicare inpatient day. The estimated cost functions were used to calculate the long run marginal costs and average incremental costs, with all variables set at their sample means. Long run marginal cost is the cost of producing an additional unit of output, taking into account the level of all other outputs, input prices, and control factors affecting costs. The average incremental cost is the extra cost associated with producing each output, given mean volumes of all of the other outputs.

According to economic theory, the comparison between long-run marginal cost and revenue per case should be a primary determinant of whether a hospital decides to expand or contract the volume of care. The theory predicts that a hospital will take action to expand more volume of outputs, if marginal cost is less than average revenue per unit. The assumption of perfectly competitive market is valid because Medicare PPS reimburses the same set of basic DRG operating prices for all hospitals. Table 7 presents cost estimates of Medicare outputs. The estimated marginal cost of a Medicare discharge in a winning hospital was $12,750, approximately 13 percent more than that of a Medicare discharge in a losing hospital. The estimated marginal cost of a Medicare day in a winning hospital was $1,220, approximately 9 percent more than that of a Medicare day in a losing hospital. Although marginal cost of a Medicare discharge and marginal cost of a Medicare day were lower in a losing hospital, it is important to remember that average incremental cost may differ from marginal cost. (Average incremental cost includes fixed costs, but marginal cost dost not).

Table 7 Long-Run Marginal and Average Incremental Cost of a Medicare Output

	Winner	**Loser**
ALOS	8.5	9.04
Discharge		
MC	$12,750	$11,312
AIC	$8,650	$8,690
EOS	0.68	0.77
Inpatient Day		
MC	$1,220	$1,120
AIC	$844	$858
EOS	0.69	0.76
Stay		
MC	$23,120	$21,436
AIC	$15,824	$16,446

The estimated average incremental cost of a Medicare discharge in a losing hospital was $8,690, $40 more costly than that of a Medicare case in a winning hospital. In addition, the estimated average incremental cost of a Medicare inpatient day in a losing hospital was $858, $14 more costly than that of a winning hospital.

To examine the impact of the change in Medicare volume on the cost of a Medicare case, I calculated the percentage change in the long-run marginal cost of a Medicare case associated with a 10 percent change in the volume of Medicare case, defined as the second derivative of total cost function with respect to the Medicare discharge. I estimated that the marginal cost of a Medicare case falls by 20 percent for winning hospitals and by 9 percent for losing hospitals.

Figure 1 depicts the relationship between marginal cost and average incremental cost of a Medicare for winners and losers. The finding of a positive relationship between the change in marginal cost and volume implies that marginal cost of a Medicare case is higher in a hospital with a higher volume. As show in Figure 1, the change in marginal cost with respect to volume at point A is higher than that at point B. It follows that winners have more Medicare volume than losers have. (V_A is greater than V_B). The fact that winners tend to have lower average incremental costs per case than those of losers can be explained by the difference in Medicare volume. Winners tend to have more Medicare cases over which to spread fixed costs and thus experience relatively favorable PPS margins. The comparison in Table 7 also shows that average incremental cost of a Medicare day in a winning hospital was $14 lower than in a losing hospital. The average cost per day reflects the intensity of daily services provided. Winners may be more effective than losers in controlling costs by reducing the use of intermediate services per case such as controlling ancillary services per case, equipment and supply use. The finding of a positive relationship between the change in Medicare marginal cost and Medicare volume has a further implication. From the perspective of the economic theory of the firm, this finding is consistent with the proposition that a firm always operates on the upward sloping portion of its marginal function. As show in Table 7, marginal cost exceeds average incremental cost for each output in both winning and losing hospitals. There appears no economies of scale in Medicare inpatient care for both winning and losing hospitals since the estimate of the average incremental cost curve is increasing over the range of volume. This finding is consistent with the assumption of perfectly competitive market structure.

To explore further difference in costs between winning and losing hospitals, I calculated the marginal cost and the average incremental cost of a Medicare stay following the approach of Granneman et al. (1986) which define

$$MC_{Stay} = MC_{Discharge} + ALOS * MC_{Day}$$
$$AIC_{Stay} = AIC_{Discharge} + ALOS * AIC_{Day}$$

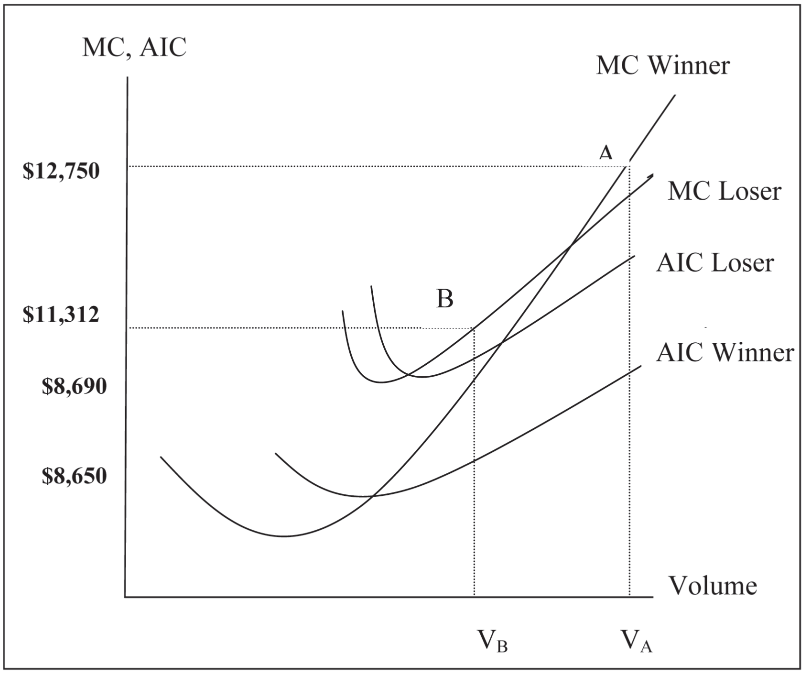

Figure 1 Relationship between MC and AIC

Examination of the information in Table 7 suggests that winners have a lower average incremental cost of a Medicare stay than losers have. This difference can be explained by three factors: average incremental cost per discharge, average length of stay, and average incremental cost per day. Winners tend to have a shorter Medicare length of stay, a lower average incremental cost of a Medicare discharge, and a lower average incremental cost per day. I estimated that average incremental cost of a Medicare stay was $15,824 in a winning hospital. Length of stay has an impact in cost per stay since routine daily tests and procedures will be increased with each increase in the length of stay. Dobson (1992) found that winners were characterized by lower length of stay than their losing counterparts. The lower length of stay in winning hospitals was driven by more efficient service delivery and greater physician participation in efforts to reduce length of stay. Winning hospitals may have achieved reductions in length of stay through a variety of mechanism. Diagnostic checkups may have been done on outpatient basis, physicians may have substituted intensive monitoring and high-tech services for longer stays, or patients may have been discharged to post-hospital care units.

2) Medicare Cost Variations across Hospital Size

PPS pays a single flat rate per type of discharge, with each case classified into a diagnosis-related group. The system is predicted on the idea that the law of large numbers would protect hospitals. It is expected that hospitals with large volumes of cases would approach the average. That is, for any given DRG, complex and resource intensive cases with costs exceeding DRG payments would be offset by cases consuming fewer resources in any given hospital. Small hospitals with low volumes are vulnerable to this law because unusually resource intensive cases may not be offset by less resource intensive cases. Moreover, small hospitals are vulnerable to economies of scale in that as volume declines, fixed costs are spread over fewer cases thereby increasing costs per case. In addition, schedule delay may be a cause of longer hospital stay in small facilities. For example, if a test is only given on Tuesdays and Thursdays because of low volume and the need for batch processing, then patients cannot be admitted on Sunday and released on Monday, simply because of schedule delay.

Table 8 shows the estimated of the marginal and average incremental cost of a Medicare discharge and a Medicare day of hospitals stratified by hospital bed size. The difference in estimated average costs per Medicare discharge between winning and losing hospitals vary across hospital bed size. The difference is largest in hospitals with less than 100 beds. The difference is smallest in hospitals with total beds are between 200 and 299. The substantial differences in estimated average costs for the Medicare discharge between small and larger hospitals seems too large

Table 8 Average Lengths of Stay, Marginal Cost and Average Incremental Cost of a Medicare Stay by Hospital Bed Size

	Winner	Loser	Difference in average cost per discharge
0-99			$ -2,407
ALOS	6.21	8.71	
Discharge			
MC	$5,296	$8,762	
AIC	$4,734	$7,141	
EOS	0.89	0.90	
Inpatient day			
MC	$662	$778	
AIC	$615	$712	
EOS	0.92	0.92	
Stay-AIC	$8,553	$13,342	
100-199			$ -1,209
ALOS	7.21	8.38	
Discharge			
MC	$8,455	$9,500	
AIC	$6,617	$7,826	
EOS	0.78	0.82	
Inpatient day			
MC	$880	$912	
AIC	$735	$780	
EOS	0.83	0.85	
Stay-AIC	$11,916	$14,362	
200-299			$ -507
ALOS	8.66	9.14	
Discharge			
MC	$11,900	$11,358	
AIC	$8,545	$9,052	
EOS	0.72	0.80	
Inpatient day			
MC	$1,216	$1,100	
AIC	$917	$880	
EOS	0.75	0.80	
Stay-AIC	$16,486	$17,095	

Table 8 (Continued)

	Winner	Loser	Difference in average cost per discharge
300-399			$1,654
ALOS	8.35	9.07	
Discharge			
MC	$16,104	$12,400	
AIC	$11,502	$9,848	
EOS	0.71	0.79	
Inpatient day			
MC	$1,402	$1,231	
AIC	$1,040	$960	
EOS	0.74	0.78	
Stay-AIC	$20,186	$18,555	
400-499			$3,136
ALOS	9.51	9.43	
Discharge			
MC	$18,750	$12,649	
AIC	$13,454	$10,318	
EOS	0.72	0.81	
Inpatient day			
MC	$1,615	$1,311	
AIC	$1,199	$1,018	
EOS	0.74	0.77	
Stay-AIC	$24,856	$19,918	
500+			$9,687
ALOS	10.24	9.81	
Discharge			
MC	$22,285	$10,540	
AIC	$19,868	$10,181	
EOS	0.89	0.96	
Inpatient day			
MC	$1,642	$1,268	
AIC	$1,491	$1,068	
EOS	0.90	0.84	
Stay-AIC	$35,135	$20,658	

to be a result of difference in efficiency. Among hospitals with total beds less than 100, the difference of average cost per Medicare discharge between that of a winner and that of a loser was $2,407 which is much larger than that of hospitals with total beds between 100 and 299. One implication is that small hospitals are likely to be disadvantaged under Medicare PPS. However, hospital size does not explain hospitals' financial performance in hospitals with bed sizes larger than 300. For example, among hospitals with bed sizes between 300 and 399, average cost per discharge is $11,502 in a winning hospital, about 16 percent more than that of a losing hospital.

One question then arises: why did winners have favorable PPS margins? There are two possible reasons. First, winners may be more likely than losers to maximize revenues under Medicare. Dobson et al. (1992) found that winning hospitals, particularly large ones, were more aggressive in identifying discretionary aspects of Medicare payment policy and seeking higher payments. In the winning hospital, financial expertise was superior to that found in the losing hospital. This allowed winning hospitals to complete Medicare Cost Reports in an advantageous manner and enable the hospitals to challenge Medicare on discretionary costs. Second, winners may be more likely to have good capital acquisition decisions. Dobson et al. found instances of questionable capital investments by losing hospitals that undermined their performance. By contrast, winning hospitals had managers who carefully considered and conservatively invested in capital.

3) Medicare Costs in Small Hospitals

Among small hospitals, for example, those with total beds less than 100, losers tend to have higher marginal and average incremental costs of a Medicare outputs. Does this mean that a small losing hospital tends to have more Medicare volumes? The answer is probably not. The Medicare volume does not play an important role to explain this difference. To support this argument, I calculated the percentage change in the long-run marginal cost of a Medicare case associated with a 10 percent change in the volume of Medicare cases. I estimate that the marginal cost of a Medicare case falls by 19 percent for winning hospitals and by 17 percent for losing hospitals. This difference is relatively small. This finding implies that small hospitals (no matter what they are winning or losing) tend to have relatively the same number of Medicare cases. There are two possible reasons to explain the cost difference in small hospitals. First, information in Table 8 shows that small losing hospitals tend to have longer length of stay than small winning hospitals have. This resulted in higher average cost per Medicare stay. The estimate average cost per Medicare stay of a small losing hospital was $13,342, about 56 percent higher than that of a winner. One mechanism that small winning hospitals may use to shorten length of stay is to discharge patients to such post-hospital care units as skilled nursing unit, swing bed unit, and home care service. Small losing hospitals may not have ability to do so because they may be less likely to have such post-hospital care units available. Second, evidence in Table 9 shows that small winning hospitals were more likely than small losing hospitals to develop new services such as post-hospital care units as a way to increase revenue. When paid at least partly on the basis of costs, non-PPS units, such as skilled nursing and rehabilitation units, present opportunities for winning hospitals to allocate overhead, thereby lowering their costs. Small hospitals appear to have a financial incentive to increase the number of Medicare case, since they were estimated to have lower marginal costs relative to those of larger hospitals. However, factors beyond their control may preclude them from expanding Medicare volume. For example, small hospitals may be at a disadvantage in competing with large hospitals for profitable Medicare cases.

Table 9 Numbers of Small Hospitals That Offer Post-Hospital Care Units

Type of service	Winner	Loser
Skilled nursing unit	35	18
Swing-bed unit	43	45
Distinct-part rehabilitation unit	32	18
Offers home care or hospice services	49	30

Source : ProPAC analysis. Medicare and the American Health Care system. Report to Congress. June 1992. Page 85.

4) Availability of Services

The final issue addressed in this section is availability of services relates to hospitals' financial performance. In order to attract physicians and patients and improve their production efficiency, hospitals have attempted to develop and effectively use post-acute services, including SNFs units, swing beds, and rehabilitation services. These post-acute services may create various opportunities for hospitals. These services offer hospitals considerable flexibility in term of using their physical plants and equipment and staff as well as allocating overhead costs. Moreover, these units generate revenues, attract patients, and enabled to supervise their services flexibility. By allowing hospitals to allocate overhead and staffing resourced, reported Medicare inpatient care costs may decrease, and in turn this will result in improved PPS margins. It is hypothesized that hospitals with more availability of services than those availability of services are likely to have lower Medicare costs. Table 10 presents cost estimates of Medicare inpatient outputs by the level of availability of services. To produce Table 10, I use a ratio of capital cost to total facility cost as the proxy for the level of availability services. Low level of availability of services was defined as hospitals of which the ratios were in the bottom 25 percent of the distribution; high level of availability of services was defined as hospitals of which the ratios were in the top 25 percent of the distribution.

Table 10 Long Run Marginal and Average Incremental Costs of A Medicare Output By The Level of Availability of Services

	Discharge			
	Winner		Loser	
	MC	AIC	MC	AIC
Low availability of services	$12,066	$8,305	$12,468	$9,393
High availability of services	$10,397	$7,188	$10,949	$8,313
	Day			
	Winner		Loser	
	MC	AIC	MC	AIC
Low availability of services	$1,155	$816	$1,190	$892
High availability of services	$1,010	$722	$1,156	$866

The inference is that the higher the capital cost is, the more the level of availability of services is. Total capital cost I used was the related costs available for pass-through which include capital related cost incurred in inpatient care unit, general routine care unit, intensive care unit, post-acute care unit, long-term care unit, emergency room services, and outpatient services. The information in Table 10 upports the hypothesis that hospital with more availability of services than those with less availability of services are likely to have lower Medicare costs. In other words, Medicare costs tend to be lower in hospital with high level of availability of services. The estimated marginal cost of a Medicare discharge and a Medicare day were found to be lower in hospitals that offer a wide range of services. The cost estimate of Medicare output were about 12 percent and 17 percent higher in hospitals which offered less availability of services for losers and winners, respectively. These findings also support that winning hospitals may have achieved reductions in length of stay through early discharging their patients to post-hospital care units.

5. Conclusions

The period covered by this study was one which saw the implementation of prospective payment system in the Medicare program as a major reform in order to contain hospital cost. How well an individual hospital has performed under the Medicare's PPS has depended on the hospital's production and management efficiencies. Among their responses are attempts to control cost by, for example, reducing the use of intermediate products per discharge such as controlling ancillary service per case; reducing average length of stay; maintaining or increasing volume of inpatients. The attempts that winning hospitals made to be cost efficient indicate that hospitals do indeed have some control over their financial performance. These findings support the basic notion of PPS. Give a set of external environment and PPS design features, hospitals with better production and management efficiencies can result in better financial performance than those are poorly managed. Moreover, the payment system was designed to reward good management. This assumption of the payment system seems to be valid.

I. Findings

The highlights of my findings as presented below are organized according to the study's research questions.

1) Are winners more likely than losers to maintain or increase volume?

The results from the cost analysis reveal that the estimated average incremental cost of a Medicare inpatient discharge in a losing hospital was $8,690, approximately $40 more costly than that of a Medicare case in a winning hospital. In addition, the estimated average incremental cost of a Medicare inpatient day in a losing hospital was $858, $14 more costly than that of a winning hospital. Differences in volumes between winning and losing hospitals have been reported by Bobson et al. (1992). They found that for the most part, losers experienced larger overall volume decreases than their matched winners between 1985 and 1988. In order to maintain or increase volume, wining hospitals uses several strategies. These include aggressive physician recruiting, the development of satellite "feeder" clinics, the procurement of managed care contracts, and new programs and services development. The development of satellite clinics provides opportunities to spread fixed costs. Empirical evidences were supported by the information in Table 9. The results showed that hospitals with more availability of services than those with less availability of services are likely to be winners. In consistence with Manning (1991), the results showed that skilled nursing facilities turned to be profitable under Medicare's PPS. With skilled nursing facilities, patients are not turned loose until they are well, and empty beds turn into profit centers. Small hospitals, however, used different approaches to maintain or increase volume. In order to attract patients, small winning hospitals developed non-acute service units such as swing bed unit and skilled nursing facility. In addition, the development of non-PPS units such as skilled nursing units presents opportunities for hospitals to allocate overhead, thereby lowering their PSS costs.

2) Are winners more likely than losers to have a low Medicare's inpatient length of stay?

In designing this study, I hypothesized that winners would be characterized by greater production efficiency than losers. Production efficiency refers to the average amount of resource use associated with each inpatient discharge. Under the PPS, hospitals that provide services more efficiently would be expected to outperform those hospitals that do not. Standard ways to measure the use of many resources are not readily available. Therefore I use average length of stay as a measure of production efficiency. Length of stay also serves as a good proxy for how efficiently different inputs are used together to provide patient care. These inputs include such resources as intensive care beds, general acute care beds, and lab and X-ray tests. The results showed that an average length of a Medicare stay in a winning hospital was 8.5 days whereas that of a losing hospital was 9.04 days. This difference clearly confirms that winning hospitals were more efficiently than losers in providing inpatient care. Another explanation for this difference in the average length of stay is that winners may be more aggressive in responding to the PPS by shifting their inpatient to outpatient care where the PPS does not regulate. Muller (1993) also found that financial incentives created by the PSS were very effective in reducing average lengths of stay. Shorter lengths of stay may also reduce the number of routine tests performed in the hospital, such as daily lab tests and X-rays, thereby lowering average cost per Medicare stay. The results show that average cost of a Medicare stay was $17,725 in a winning hospital, about 4 percent lower than that of a losing hospital.

3) Do small hospitals tend to be disadvantaged under Medicare's PPS?

Among small hospitals with total beds less than 100, the difference of average cost per Medicare discharge between that of a winner and that of a loser was $2,407 which is much larger than that of hospitals with total beds between 100 and 299. One implication of these findings is that a uniform set of payment rates for small and large hospitals is likely to cause greater financial pressure in small hospitals than in larger hospitals. This pressure creates the desirable incentive for small hospitals to increase production efficiency (lower costs). However, if the hospital is unable to realize these objectives, it may be likely to be forced to shut down in the absence of subsidies from other sources of revenue. If the access to health care considerations suggest that it is important to keep some small hospitals from closing, then revenues from other source, such as public grants, may be needed.

II. Study Implications

Many implications for both hospital administrators and PPS regulators can be drawn from the findings.

1) In theory, the PPS design assumes that hospital managers have some degree of control over hospital costs and hospital efficiency. To the extent that managers minimize controllable costs and maximize operating efficiency, they stand to win under PPS. Conversely, those that do not stand to lose.

2) While the PPS correctly assumes that many of the factors that contribute to unnecessarily high costs are controllable, it is highly unrealistic to assume that all hospitals will eventually operate at the highest standards of efficiency established by the most efficient hospitals given the complex nature of hospital internal and external operating environments. In addition, it is unrealistic to assume that a prospective payment system can ever wholly account for the uniqueness of individual markets. For example, hospitals always will be characterized by a wide range of strong and weak management abilities and more or less productive physicians. A small hospital that is doing well today may not do well tomorrow. To account for unique and often uncontrollable in efficiencies that may exist across markets and for the fact that prospective payments are based on only relatively gross measures, PPS payments should provide sufficient margins to allow for inherent differences in hospital efficiencies and imperfections in payment design.

3) It is important to recognize that strong Medicare financial performance under PPS has become more difficult and is likely to grow more difficult in the future. Analyses of hospital data by ProPAC indicate that winners are winning less and losers are losing more on their Medicare patients (ProPAC 1992). Assuming this situation intensifies, it will be increasingly difficult for even the strongest management to break even on Medicare patients.

4) The results of this research raise the question: what (if any) role should the Federal government play in promoting the improvement of managerial

effectiveness within hospitals. Through the cost function analysis of winning and losing hospitals under Medicare's PPS, this study found that specific hospitals' internal factors, such as production and management efficiencies, were related to strong financial performance. These findings suggest a number of broad guidelines that could be used by hospitals to improve their performance. It is important to recognize, however, that sharing such information alone cannot be expected to reduce this source of variation in hospital performance under PPS. There may be a useful role for government in publicizing the important of management actions, especially positive relations between physicians and administrators that were central to the success of winning hospitals.

III. Policy Implications

1) PPS Payment Rates

The most accessible source of data on hospital costs for government policy-makers is the Hospital Cost Report. The report contains information on costs and utilization, enabling the Medicare program to determine reasonable costs. These reports use a set of accounting rules to allocate both direct and indirect cost to Medicare cases. Medicare costs per case, as computed through these reports, were used as the basis for determining PPS payment amounts and continue to be used to estimate the amount of Medicare profits being earned under PPS. The cost estimate derived from the Cost Report in such manner is a measure of average total Medicare cost. From an economic perspective, this is not the correct measure of costs to use to assess how hospitals might respond to PPS payment rates. The more appropriate measure is marginal cost. This is because hospitals have the incentive to expand output when payments exceed marginal cost and contract output when the reverse is true. If the goal policy is to influence the quantity or mix of hospital outputs, then the focus should be on how payments relate to marginal not average cost.

The analysis of discharge and days costs in this study suggests that PPS rates should be set separately for discharges and days. Including both discharges and days can help account for differences among hospitals in the character of inpatient stays. The current DGR-based reimbursement system for Medicare has been criticized for encouraging hospitals to discharge patients too soon and to admit (or readmit) patients more often. The incentives for such activities presumably come from the fact that stay-based reimbursement pays more than marginal cost for discharges but pays nothing at the margin for additional days of care. Paying a fixed rate for each discharge based on diagnosis, plus a fixed amount per day of stay could bring reimbursement closer to the hospital's marginal cost of a stay, thereby reducing the profit potential of inappropriate admissions and early discharges.

2) Small hospitals

PPS pays a single flat rate per type of discharge, with each case classified into a DRG. It is expected that hospitals with large volumes of cases would approach the average. That is, for any given DRG, complex and resource intensive case with costs exceeding DRG payments would be offset by cases consuming fewer resources in any given hospital. Small hospitals are likely to be vulnerable to this assumption because unusually resource intensive cases may not be offset by less resource intensive cases. The results showed that the substantial differences in estimated average costs for the Medicare discharge between small and larger hospitals seems too large to be a result of differences in efficiency. If a prospective payment system does not account for such cost differences, small losing hospitals might reduce provision of inpatient services.

IV. Directions for Future Research

This study demonstrates that the application of the theory of multi-product cost function can be a useful tool for analyzing hospitals' financial performance under Medicare's PPS. Research of this type could benefit from better data availability in two critical areas, hospitals' outputs and input prices. Better measures of other type of patient care outputs such as privately insured and uninsured patients, other government program patients, and charity care patients would be helpful. It would allow one to explore the issue of cost-shifting under Medicare's PPS. Better input prices information would be useful not only for research activities, but also for the calculation of hospital wage indices and the annual update factor. The area need to be improved is to obtain more accurate information for specific occupations and major purchased supplied (food, energy, laundry, and maintenance, for example). Another area for further research is on hospitals' financial conditions under the new health care reform. The health care reform debate now focuses on the need for and types of reform necessary to cut down Medicare program spending. The uncertain outcome of this debate could have a dramatic effect on the hospital of the future. Already, hospitals under Medicare's PPS have responded in many ways to the financial pressures they face, diversifying the service they offer, pursuing different avenues to control costs, and adopting new strategies that govern their relationships with other providers and physicians. The anticipation of health care reform will further have an impact on hospitals and their role in health care delivery.

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