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A Cost Function for Nursing Homes: Toward a System of Diagnostic Reimbursement Groupings

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The increase in the total cost of nursing home care from approximately \$2.8 billion in 1967 to approximately \$24.2 billion in 1981 and the increase in government's share of total expenditures to approximately sixty percent have stimulated a number of nursing home cost studies [Lee, et al., 1983; Mieners, 1982; Birnbaum, et al., 1982; Ullmann, 1984; and French and Ginsburg, 1981]. While these studies have contributed to our understanding of the complexity of this industry, they have not fully utilized theoretical or econometric techniques. Thus, it is generally not possible to identify important attributes of nursing home production functions and cost structures. Important statistics, like the elasticity of substitution among inputs, are either impossible to calculate or never reported.

In this paper a nursing home cost function and the relevant input share equations implied by economic theory are simultaneously estimated. A translog variable cost function is assumed to provide maximum flexibility and appropriate restrictions are imposed as required by economic theory. The efficiency of the estimates, obtained by maximum likelihood techniques, is thus increased. Our study allows us to capture the complexities of the nursing home technology: multiple outputs, different input prices, different organizational forms, etc. among homes; yet, we are able to maintain the integrity of the underlying economic theory.

THE THEORETICAL MODEL

Given the underlying implicit production function

$$f(Q, X, K) = 0$$

in which Q is the vector of outputs, X is the vector of inputs, and K is the vector of fixed factors; and given that firms minimize costs [Varian, 1978], a variable cost function is derived:

$$C = C(Q, p, K)$$

This derived cost function contains all the information in the underlying production function. Data concerning input prices, p, and outputs for estimating the cost function are often available when actual input quantities for estimating the production function are unknown or difficult to determine. In addition, the derived cost function allows us to see the implications of procedures used in empirical cost functions. For example, to determine the substitution possibilities among inputs, we derive the Allen-Uzawa partial elasticity of substitution between two inputs, $G_{ij} = CC_{ij}/C_iC_j$, $i \neq j$, where subscripts represent partial derivatives.

Along these same lines, aggregation of different outputs into one measured output—a practice often followed in empirical studies of nursing homes—as in $Q^* = h(Q_i)$, $i = 1 \ldots n$

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[Hall, 1973], constrains the cost function so the ratio of the marginal costs of any two outputs is rendered independent of input prices and/or fixed inputs. To understand this, assume aggregation is possible and the multiple output cost function can be written as $C = C(h(Q_i, p, K)$. Then, $C_{Qi} = C_h h_{Qi}$ and $C_{Qi}/C_{Qj} = h_{Qi}/h_{Qj}$, $i \neq j$, in which the subscripts represent partial derivatives.

Of course, aggregation of outputs into one output measure precludes consideration of economies of scope. For example, in the two output case, economies of scope exist when $C(O, Q_2) + C(Q_1, O) > C(Q_1, Q_2)$, where Q_1 and Q_2 represent different outputs. That is, economies of scope exist when it is less costly to produce the services together than to produce them separately. Since nursing homes produce multiple services, this is an important attribute to be considered.

In addition, a multiple output cost function facilitates calculation of the marginal cost of producing each of the separate services offered by a nursing home, thereby yielding appropriate cost estimates for determining optimal charges under a system of diagnostic reimbursement groupings. Reimbursement groupings are being used in some hospitals, and are likely to be required of nursing homes as governmental agencies attempt to control increasing expenditures on health care.

A number of assumptions, many of which are implicit in earlier studies of nursing home costs, are also adopted in this study. Specifically, it is assumed that nursing homes minimize the cost of producing services, that the demand for their services and their input prices are exogenous. Given competition among private nursing homes, government nursing homes and nonprofit nursing homes, the assumption of cost minimization is very plausible. Cost minimization is consistent with many theories of non-profit organization behavior and is a less restrictive assumption than the assumption of profit maximization. All empirical cost functions implicitly assume cost minimization.

On the basis of the theoretical model presented above and the translog econometric model we specify below, it is hoped that understanding of the role of economies of scale, economies of scope, input prices and the type of ownership in determining nursing home costs will be clarified.

THE ECONOMETRIC MODEL

We estimate a multiservice translog variable cost function for nursing homes of the following type:

$$(1) \qquad \ln C = \alpha_0 + \sum_r \alpha_r \ln Q_r + \frac{1}{2}\sum_r\sum_s \alpha_{rs} \ln Q_r Q_s + \sum_i b_i \ln p_i + \frac{1}{2}\sum_i\sum_j b_{ij} \ln p_i \ln p_j + \phi_K \ln K + \frac{1}{2}\phi_{KK}(\ln k)^2 + \frac{1}{2}\sum_r\sum_i \Omega_{ri} \ln Q_r \ln p_i + \frac{1}{2}\sum_r \gamma_r \ln Q_r \ln K + \frac{1}{2}\sum_i \Theta_i \ln p_i \ln K + \cdots$$

where C is the variable cost of the nursing home; Q_r is a set of five patients categories: patient days of service for patients with one or zero disabilities, patient days of service for patients with two disabilities, patient days of service for patients with three disabilities, patient days of service for patients with four disabilities, and patient days of service for patients with five or more disabilities. Our output measures bear a close resemblance to the average daily living index of dependency used in gerentology studies [Katz, 1963]. Disabilities are defined in terms of inability to bathe, dress, toilet, walk, and eat unaided; p_i is a set of input prices for administrators, physician staff, registered nurses, licensed practical nurses, aides and orderlies; K is fixed capital, measured by dollars of reported fixed costs.

In addition, dummy variables represent government, non-profit, and for-profit nursing homes and regional impacts on the cost of nursing home care. Even after controlling for input prices cost varies by region, because of different reimbursement schemes and technologies available in various areas. Four dummy variables represent certification: homes certified as skilled nursing facilities, homes certified as intermediate care facilities, homes certified as both skilled and intermediate care facilities and homes not certified. Finally, dummy variables distinguish between nursing homes associated with hospitals and others. One category in each group is dropped from the estimating equations and forms the basis for comparisons.

As indicated earlier, the cost function and the cost shares associated with each input in the production process are simultaneously estimated. Partially differentiating costs with respect to an input price establishes the factor demand for an input, $\partial C/\partial p_i = x_i$. Thus, the logarithmic differentiation of (1), $\partial \ln C/\partial \ln p_i = (\partial C/\partial p_i)(p_i/C) = p_i x_i/C$, or the cost shares associated with (1) are

$$(2) \qquad S_i^v = \partial \ln C/\partial \ln p_i = b_i + \frac{1}{2}\sum_j b_{ij} \ln p_j + \frac{1}{2}\sum_r \Omega_{ri} \ln Q_r + \frac{1}{2}\Theta_i \ln K$$

Data have been mean scaled so that, at the mean of each variable, the logarithm will equal zero and the mean share of a factor will be equal to its own-price coefficient, b_i. This approach facilitates interpretation of the results in terms of the mean or average nursing home.

Following convention, we assume cost functions are homogeneous of degree one with respect to input prices ie, doubling all input prices doubles costs. Hence, our estimates are restricted as follows:

$$(3) \qquad \sum b_i = 1, \quad \sum_i b_{ij} = 0, \quad \sum_i \Omega_{ri} = 0, \quad \sum_i \Theta_i = 0$$

One cost share equation (that relating to food, drugs, and supplies) is deleted to avoid singularity. Finally, to avoid the econometric problems associated with least squares estimating procedures, maximum likelihood techniques are used to estimate the cost function and share equations.

THE DATA

Data used in this study are taken from the 1977 National Nursing Home Survey conducted by the National Center for Health Statistics. While the data set contains information from 1,451 nursing homes throughout the United States, we were only able to use 1,055 of the observations. Nursing homes are generally not large providing, on average, approximately 200 patients with service at any point in time. The service outputs of each home were imputed by assuming that the percent of patients with each level of debility in a sample of patients from each home was representative of the population of patients in that home. Thus, for example, if ten percent of the sample of patients reported one debility, we imputed ten percent of the annual patient days to this category. In general, this sample seems to be consistent with other samples drawn from the United States nursing home population and it should be representative of the population.

To determine the wages for each nursing home, a sample of wages from each home was relied on. The mean wage for each home was used as the price of a particular input. Thus, there were 1,055 observations for each input price. Similarly, the average cost per patient for food, medicine, and supplies was taken to be the price of supplies for each home. Since this method established home specific wage estimates, it was an improvement on earlier studies.

Daily prices for labor services vary from a mean of $91.70 for medical staff to a low of approximately $24 for orderlies and aides' services. Administrators had a daily wage of about $70, while nurses and licensed practical nurses had wages of $48 and $34 per day, respectively. The average total variable cost for the sample is approximately one million dollars, with a standard deviation of approximately one and one-half million dollars.

The industry is dominated by the approximately seven hundred private for-profit nursing homes. Nevertheless, with approximately two hundred fifty non-profit nursing homes and approximately one hundred ten government operated nursing homes, a substantial part of the industry is operated on a non-profit basis.

EMPIRICAL RESULTS

As can be seen from Table I, the empirical results are quite plausible. For example, the five labor input shares for administrators, medical staff, registered nurses, licensed practical nurses, and aides and orderlies are positive and significant. According to the results, labor's share of total variable costs is approximately 72 percent, with registered nurses, licensed practical nurses and orderlies accounting for about 45 percent. As we would anticipate, medical staff share of costs is small, being approximately 2 percent of the total.

Turning to the outputs, note that all the cost elasticities are positive and significant as anticipated. It is interesting that the cost elasticity is lowest for patient days of service to those with only one debility, but, perhaps surprisingly, the second lowest cost elasticity is associated with patient days of service to those with five or more debilities. These cost elasticities, of course, are closely related to the marginal cost of producing each level of service.

With respect to types of certification, we note that homes certified only as skilled nursing homes or intermediate care homes do not have costs that are meaningfully different from those of uncertified homes. This is not a surprising result because cost differences are attributable to differences in the services provided and are reflected in the coefficients of our five output variables. Therefore, to the extent that reimbursements to different types of homes reflect differences in the services they provided, reimbursement schemes may, in fact, approximate the marginal cost of providing service, although a more exact relationship between marginal cost and reimbursement might be desirable. It is somewhat puzzling that homes offering both intermediate and skilled nursing home care under the same roof appear to have higher costs than uncertified homes, even after controlling for differences in services offered. This result suggests that organizational structure may have an important impact on cost, and this aspect of the nursing home industry deserves more detailed investigation.

Along these same lines, it may be noted in Table I that both nonprofit and government nursing homes have higher costs than proprietary homes. While this result has been observed before, greater clarity emerges from this study about their likely source. Specifically, differences in input prices by individual facility have been controlled for, making it clear that higher wages in nonprofit and government homes do not completely account for the observed

TABLE 1
Estimated Cost Function Parameters

Variable	Parameter Estimate	t Ratio	Variable	Parameter Estimate	t Ratio
INTERCEPT	−0.174841	−3.2709	ADMN × PD3	0.054464	1.1076
ADMN	0.251643	98.8367	ADMN × PD4	0.130786	2.6853
MEDS	0.018970	8.9902	ADMN × PD5	−0.060490	−1.2194
RN	0.218283	83.4488	MEDS × PD1	0.011271	0.3558
LPN	0.133250	54.2596	MEDS × PD2	−0.012858	−0.3344
ORDS	0.099179	66.1909	MEDS × PD3	−0.002339	−0.0705
FOOD	0.278676	126.3343	MEDS × PD4	−0.025735	−0.8019
PD1	0.052897	2.3580	MEDS × PD5	−0.066215	−1.9095
PD2	0.097778	3.8265	RNS × PD1	−0.122068	−1.2625
PD3	0.098709	3.8220	RNS × PD2	−0.016286	−0.1526
PD4	0.139338	5.7634	RNS × PD3	−0.168431	−1.8462
PD5	0.075184	3.0201	RNS × PD4	−0.012236	−0.1484
(ADMN)^2	0.026229	0.5767	RNS × PD5	−0.062532	−0.6861
ADMN × MEDS	0.014086	0.2675	LPN × PD1	0.161349	1.4597
ADMN × RN	0.167758	1.1592	LPN × PD2	−0.098045	−0.8374
ADMN × LPN	−0.135250	−0.8170	LPN × PD3	−0.154472	−1.5112
ADMN × ORDS	−0.138205	−0.8375	LPN × PD4	0.106683	1.1251
ADMN × FOOD	0.065382	1.0702	LPN × PD5	−0.054200	−0.5058
(MEDS)^2	0.016665	0.6507	ORDS × PD1	−0.062219	−0.6535
MEDS × RN	−0.062340	−0.6625	ORDS × PD2	0.208570	1.9091
MEDS × PLN	0.106031	0.9625	ORDS × PD3	0.298250	3.0195
MEDS × ORDS	0.041990	0.4064	ORDS × PD4	−0.223556	−2.4576
MEDS × FOOD	−0.116431	−2.9402	ORDS × PD5	0.307815	3.1130
(RN)^2	0.046494	0.3021	KPTL × PD1	−0.042922	−3.0130
RN × LPN	0.145552	0.6472	KPTL × PD2	0.051525	3.2116
RN × ORDS	−0.222717	−0.8569	KPTL × PD3	0.010017	0.7746
RN × FOOD	−0.074746	−0.6358	KPTL × PD4	−0.031658	−2.1225
(LPN)^2	−0.100564	−0.6289	KPTL × PD5	0.013038	0.8874
LPN × ORDS	−0.365631	−1.5718	FOOD × PD1	−0.008207	−0.2632
LPN × FOOD	0.349863	2.7374	FOOD × PD2	−0.036578	−1.0570
(ORDS)^2	0.745233	3.8641	FOOD × PD3	−0.027472	−0.9522
ORDS × FOOD	−0.060670	−0.5128	FOOD × PD4	0.024058	0.9172
(FOOD)^2	−0.163399	−7.7672	FOOD × PD5	−0.064379	−2.0562
(PD1)^2	0.048510	2.4064	ADMN × KPTL	−0.050943	−1.6285
PD1 × PD2	0.011704	0.4350	MEDS × KPTL	0.097757	5.2057
PD1 × PD3	0.007977	0.3231	RN × KPTL	0.118235	2.0387
PD1 × PD4	0.019763	0.8526	LPN × KPTL	−0.005482	−0.0972
PD1 × PD5	−0.030296	−1.1668	ORDS × KPTL	−0.244128	−4.8301
(PD2)^2	−0.049719	−2.1440	(KPTL)^2	0.046922	9.8012
PD2 × PD3	0.044899	1.7712	FOOD × KPTL	0.084561	4.3474
PD2 × PD4	0.057466	2.4614	KPTL	0.480197	28.4567
PD2 × PD5	−0.080446	−3.1209	NCENT	−0.023470	−0.8177
(PD3)^2	0.017108	0.8878	SOUTH	0.029782	0.9746
PD3 × PD4	0.008971	0.4312	WEST	−0.103258	−2.9622
PD3 × PD5	−0.019018	−0.8041	HOSP	−0.051702	−1.7537
(PD4)^2	−0.009529	−0.4778	ICFSNF	0.091889	2.0416
PD4 × PD5	0.076138	3.4399	SNF	0.028361	0.5857
(PD5)^2	0.000202	0.0092	ICF	−0.056874	−1.2329
ADMN × PD1	0.019874	0.4088	NONPROF	0.229868	8.6224
ADMN × PD2	−0.044804	−0.7761	GOVT	0.485018	12.2489

cost differences. Some [Frech and Ginsburg; 1981] have argued that government and non-profit nursing homes are less efficient than proprietary homes. While our data are consistent with that hypothesis, we believe that a better specification of all the services provided by governmental and non-profit homes would account for the cost differences. This inference is also based on the fact that non-profit nursing homes attract numerous gifts, which suggests that there is a social dimension to the services they produce.

As mentioned earlier, marginal costs are indeed related to cost elasticities of output. In this study marginal costs are the cost elasticities weighted by the ratio of predicted cost to output. Table II presents the marginal cost of each service as calculated at their appropriate mean. The table is designed in such a way that the relative importance of ownership and certification can also be easily noted.

Marginal costs of \$3.37, \$8.41, \$7.53, \$9.55 and \$5.76 were estimated for patients with one or less debility through those with five or more debilities. Further breakdown of these estimates reveals that depending on certification levels and types of ownership the range of estimated marginal costs are \$2.75–\$5.18, \$6.88–\$12.94, \$6.15–\$11.59, \$7.77–\$14.63 and \$4.72–\$8.89, respectively. Again, it is interesting that, in general, services to patients with four debilities have the highest marginal costs. Irrespective of certification, privately owned facilities have the lowest marginal costs in the production of each service. Facilities that jointly provide skilled and intermediate care generally exhibit the highest marginal costs. Table II, further

TABLE 2

Marginal Costs in Nursing Homes

	Ownership	Not Certified	ICF	SNF	Joint	
PD1	Private	2.91	2.75	3.00	3.19	3.00
	Non Profit	3.66	3.46	3.77	4.01	3.77
	Government	4.72	4.46	4.86	5.18	4.87
		3.26	3.08	3.36	3.58	3.37
PD2	Private	7.27	6.86	7.48	7.97	7.50
	Non Profit	9.14	8.64	9.41	10.02	9.40
	Government	11.80	11.15	12.14	12.94	12.10
		8.17	7.70	8.40	8.95	8.41
PD3	Private	6.51	6.15	6.69	7.13	6.70
	Non Profit	8.19	7.74	8.43	8.98	8.45
	Government	10.57	9.99	10.87	11.59	10.90
		7.31	6.54	7.50	7.36	7.53
PD4	Private	8.22	7.77	8.45	9.00	8.50
	Non Profit	10.34	9.77	10.64	11.34	10.70
	Government	13.35	12.61	13.73	14.63	13.80
		9.23	8.70	9.49	10.11	9.55
PD5	Private	4.99	4.72	5.14	5.47	5.10
	Non Profit	6.28	5.94	6.46	6.89	6.50
	Government	8.11	7.66	8.34	8.89	8.40
		5.61	5.30	5.77	6.14	5.76

illustrates that patient placement is perhaps the key to cost minimization in the nursing home industry. However, some of the variations in marginal costs may be due to quality of care differences. Further studies are needed to discern the causes for the variations in marginal costs.

Returning to the influence of inputs on nursing home costs, we report the elasticity of substitution between inputs in Table III. In this case, a negative sign suggests that inputs are complements and a positive sign suggests that inputs are substitutes. Thus, as might be anticipated, registered nurses and licensed practical nurses are substitutes, but orderlies are complements to both registered nurses and licensed practical nurses. This suggests that substitution is only likely among professional groups, but not between professional and nonprofessional groups. While one might hypothesize about the other elasticities of substitution, they are not likely to be critical for policy purposes.

All own elasticities must be negative—factor demand equations slope downward. Considering Table III, however, it should be noted that the own elasticity of demand for orderlies is positive. This is inconsistent with theory and we interpret this result to mean that the demand for orderlies is highly inelastic.

The concept of scale for a short-run, multiple output firm is not well defined, but the impact on costs of increasing all five services by one percent, holding capital constant, can be estimated. If all services are increased by one percent, cost will increase approximately .47%. Given the caveat that nursing homes would not likely increase all outputs by exactly one percent, this result seems to suggest that nursing homes are not operating close enough to capacity.

In this same vein, it is relevant that the coefficient for capital in Table I is positive and significant, suggesting that nursing homes are not in long-run equilibrium. To understand this, recall that the long-run cost function can be written as $C_L = C(Q, p, K) + p_K K$, where p_K is the price of capital and all other symbols are as they were defined earlier. Thus, consistent with the envelope theorem of long-run equilibrium, $\partial C_L/\partial K = \partial C_L/\partial K + p_K = 0$. Therefore, $\partial C/\partial K = -p_K$, which implies that the elasticity estimate for capital in Table I should be negative. Again, this suggests that nursing homes have too much "capital" for their current level of operations.

Finally, we turn to the issue of economies of scope: It is cheaper to produce services jointly or separately? To identify the presence of economies of scope, we search for the condition $C_{QiQj} < 0$, $i \neq j$ (subscripts representing partial derivatives) for all Q, which implies that the marginal cost of producing one service decreases with an increase in provision of another service—a condition implying short-run economies of scope [Cowing and Holtmann, 1983; Holtmann, 1984].

TABLE 3

Estimated Input Substitution Elasticities

	ADMN	MEDS	RN	LPN	ORDS	FOOD
ADMN	−2.5597	–	–	–	–	–
MEDS	3.9506	−5.4044	–	–	–	–
RN	4.0541	−14.055	−2.6054	–	–	–
LPN	−3.0335	42.9461	6.0042	−12.169	–	–
ORDS	−4.5376	23.3177	−9.2871	−26.667	66.679	–
FOOD	1.9323	−21.024	−0.2287	10.422	−1.1951	−4.69

In terms of equation (1), we can calculate $C_{QiQj} = e^{\alpha o}(\alpha_{ij} + \alpha_i\alpha_j)$. Hence, for $C_{qiQj} < 0$, we must have $(\alpha_{ij} + \alpha_i\alpha_j) < 0$, where α_{ij} is the interaction elasticity between Q_i and Q_j reported in Table I and α_i and α_j are the own elasticities for Q_i and Q_j. Calculating $(\alpha_{ij} + \alpha_i\alpha_j)$ from our sample, we find that the marginal cost of the first three services, representing increasing debility, are negatively related to the fifth service level, the service to most debilitated patients. In short, economies of scope in the provision as services are identifiable.

SUMMARY

It has been shown that it is possible to estimate a multiproduct nursing home cost function that is completely consistent with modern economic theory and that provides reasonable estimates of marginal cost, economies of scope and economies of scale in this industry. These estimates can provide important information for optimal pricing policies and regulation of the industry. One study, of course, does not provide answers to all the questions policymakers might wish addressed, but this framework offers the flexibility to be extended to more detailed data sets—data sets that include more detailed descriptions of services provided, for example. In the meantime, these estimates provide some quide to policymakers.

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