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The Accuracy of Proportional Cost Models: Evidence from Hospital Service Departments

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Abstract. Using data from hospitals in the state of Washington, we examine the time-series behavior of overhead costs. We find that more accurate predictions of changes in costs are usually generated by assuming a cost will not change at all (except for inflation) than by assuming that the cost will change in proportion to changes in activity. We also find that nearly all of the effect of a change in activity on costs appears to occur in the same year as the change in activity. Finally, using a multi-period regression model we find that the proportion of variable costs in the hospital overhead accounts is apparently very modest. These results suggest that costing systems, such as activity-based costing, that assume costs are proportional to activity, will grossly overstate relevant (i.e., incremental) overhead costs for decision-making and performance evaluation purposes.

Cost accounting systems, including activity-based costing systems, generally assume that the costs in an overhead pool are strictly proportional to the cost pool's measure of activity (or allocation basis). Using cross-sectional estimates of overhead cost functions for a sample of hospitals, Noreen and Soderstrom (1994) provide evidence that "long-run" overhead costs are *not* proportional to activity.[1] Consistent with increasing returns to scale, average costs overstate marginal costs, sometimes by large margins. However, overstatement of marginal costs may be more serious than the estimates in Noreen and Soderstrom would suggest. "Long-run" cost functions, estimated using cross-sectional data, may overstate marginal costs that organizations would actually experience as they change the scale of their operations, given that technology and knowledge improve over time. A "learning organization" does not necessarily repeat the mistakes of larger (and usually older) organizations as it expands. The expansion path of a "learning organization" may be below the cost function implied by cross-sectional estimates and hence its marginal costs may be lower.

Lately, there have been suggestions that activity-based costing data should be used in budgeting and performance evaluation, with the "variable" portions of overhead costs flexed in proportion to changes in activity.[2] An important unaddressed empirical issue is how much of overhead costs are really variable with respect to activity within a single budget period.

In this paper, we examine the time-series behavior of overhead costs rather than their cross-sectional behavior. To the best of our knowledge, there has been no large-scale study of the time-series behavior of overhead cost accounts. Since much of the management accountant's job is concerned with planning, forecasting, controlling, and evaluating overhead costs, detailed information concerning the actual time-series behavior of overhead costs should be of interest.

Results of the paper indicate that cost systems which assume costs are strictly proportional to activity (such as conventional or ABC systems) grossly overstate the impact of changes in activity on cost. When we estimate the proportion of departmental costs that are variable (i.e., proportional to activity), on average only about 30% of the overhead cost appears to be variable. We also find modest evidence that costs change more readily in response to increases in activity than to decreases in activity.

The paper is organized as follows. In the next section we describe the data and the regulatory environment under which hospitals were operating during the period covered by the study. In the second and third sections we assess the accuracy of predictions of changes in costs when it is assumed that cost (as in activity-based costing) is proportional to activity. In the fourth section we use regressions to estimate the proportion of costs that are variable. In the fifth section we discuss possible limitations of the study. The final section contains our conclusions.

1. The Data and Regulatory Environment

Data for this study were provided by the Washington State Department of Health (WSDOH), which collects data for hospitals located throughout the state. The database includes detailed cost, revenue, and activity information for an average of 108 hospitals in the years 1977 through 1992. As discussed in Noreen and Soderstrom (1994), WSDOH collects data for 36 predefined overhead accounts. Sixteen of these accounts are used in this study and are described in the Appendix to this paper. The other twenty accounts were not used in this study due to a relatively small number of observations (fewer than 200 observations for either budgeted or actual data). As revealed in Table 1, the sixteen accounts in this study on average constitute about 40% of the total operating costs of hospitals.

Each account has a measure of activity, called a Standard Unit of Measure, that has been selected by WSDOH. Most of the measures seem, *a priori*, to be reasonable summary measures of activity. For example, the activity measure for the Dietary account is the number of patient meals served.[3] Descriptions of each overhead account and its associated measure of activity are contained in the Appendix to this paper.

The WSDOH collects both actual and budgeted data. Each year, hospitals are required to submit their budgets for the following year. Within two years after submitting budgeted data, hospitals must file actual results. In this study, we report only the results of tests using actual data. Identical tests were run on budgeted data with no change in any inference.

The data submitted by hospitals are screened by the WSDOH for errors, but the database likely contains coding and keypunch errors.[4] Because of the likelihood of such errors, we use tests that are, by and large, insensitive to even large numbers of errors. In the regression tests, which can be affected by large coding errors in even a few observations, we use screens to delete extreme observations.

Prior to 1989, hospitals in Washington were subject to budget-based rate regulation. Blanchard, Chow, and Noreen (1986) and Eldenburg and Soderstrom (1996) provide evidence that hospitals biased budget data submitted to WSDOH in order to relax the effects of regu-

Table 1. Average of the department cost as a percent of hospital-wide operating expense.

Account		Average Percent
Dietary	8320	5.7
Cafeteria	8330	2.6
Laundry & Linen	8350	1.8
Plant	8430	6.1
Housekeeping	8460	3.2
Accounting	8510	3.6
Communications	8520	1.5
Patient Accounts	8530	2.9
Data Processing	8540	2.1
Admitting	8560	1.4
Hospital Administration	8610	4.9
Public Relations	8630	1.0
Personnel	8650	0.9
Auxiliary Groups	8660	0.2
Chaplaincy Services	8670	0.4
Medical Records	8690	2.1
Total		40.4

lation. Therefore, the cost behavior of budget data from this period may have been distorted somewhat by the regulatory environment, although it is not obvious what effect, if any, there would be on the present study. In addition, while the regulation did not explicitly rely upon actual cost data, WSDOH staff report that toward the end of the regulatory period they used actual data to check on budgets submitted by hospitals. It is therefore possible that the regulations may have affected actual cost and activity data, although it is unclear what the effect would have been. While we report results of tests for the entire 1977–1992 period, our conclusions did not change when we ran tests using only data from the post-regulation period.

In addition to revenue regulation and deregulation, hospitals in Washington experienced another major environmental change during the time period covered by this study. In 1983 the Medicare system changed from fee-for-service to prospective, flat-fee per diagnosis reimbursement.[5] However, it is not clear how this change would have affected the behavior of overhead costs that are traced directly to departments as in this study other than perhaps to make hospital administrators more conscious of costs. The change did not necessarily affect hospitals' cost accounting systems, which still had to provide data in a prescribed format for the WSDOH data collection system.

2. The One-Period Model

Activity-based costing is based on the notion that activities consume overhead resources which in turn result in costs. When activity- based costing is used in decisions, it is implicitly assumed that costs, resources, and activities are linked in a very specific way.[6] If TC is the total cost in a cost pool, then:

$$\textit{ABC model} \qquad TC = p\alpha q \tag{1}$$

where

p = the price per unit of the overhead resource
α = the amount of the overhead resource consumed per unit of activity
q = activity.

The typical activity-based costing implementation assumes this very simple model in which consumption of resources is strictly proportional to activity and cost is strictly proportional to consumption of resources. As a consequence, cost is assumed to be strictly proportional to activity. The above model also describes less sophisticated cost accounting models that assume, for example, that all overhead costs are strictly proportional to a single measure of activity such as direct labor hours.

In the next section, a multi-period version of the ABC model will be introduced. In the one-period version of the ABC model used in this section, it is assumed that overhead costs are contemporaneously variable with respect to changes in activity. In other words, we assume that the total cost in a cost pool for period t, TC_t, is determined as follows:

$$\textit{Single-period ABC model} \qquad TC_t = p_t \alpha q_t \tag{2}$$

where

p_t = the price per unit of the overhead resource in period t
α = the amount of the overhead resource consumed per unit of activity
q_t = activity level in period t.

This model assumes that the parameter α is a constant, but that the price p_t can vary from one period to the next.

In cost accounting systems (including ABC), the parameters α and p_t ordinarily are not estimated separately. Instead, their product—the cost per unit of activity—is estimated by dividing total cost by total activity to determine an overhead rate:

$$\textit{Overhead rate}_t = TC_t / q_t = \alpha p_t. \tag{3}$$

For example, total purchasing costs might be divided by the total number of purchase orders in order to arrive at a cost per purchase order.[7] This overhead rate is clearly an average cost. When such a rate is used to cost products or other objects for decision-making purposes or are used to develop benchmarks for performance evaluation purposes, it is implicitly assumed that the overhead rate is a marginal cost. In other words, it is implicitly assumed that the cost in the overhead cost pool is strictly proportional to activity and that the constant of proportionality is the average cost TC_t / q_t.[8]

The objective in this paper is to assess the accuracy of this costing procedure. Ideally, we would like to observe how total costs change as a result of specific decisions that affect activity and compare those actual changes to the changes in costs that would be estimated by applying overhead rates. Unfortunately, we cannot observe results of discrete decisions. We can, however, observe how total costs change from year to year and correlate those changes with changes in annual activity.

Using model (2) the overhead costs of period t can be estimated from prior period data and from foreknowledge of p_t and q_t as follows:

$$\textit{Proportional cost model} \qquad \widehat{TC}_t = \left(\frac{p_t}{p_{t-1}}\right)\left(\frac{TC_{t-1}}{q_{t-1}}\right) q_t \tag{4}$$

where $\widehat{TC}_t$ is the estimated total cost for a particular overhead pool for period t.

The actual change in cost is $TC_t - TC_{t-1}$. However, some of this change in cost is due to changes in input prices and some is due to changes in activity. We are only interested in the changes that are due to activity, so we use as a benchmark the actual change in costs, adjusted for changes in prices:

$$\begin{array}{l}\textit{Actual change in cost,}\\ \textit{adjusted for inflation}\end{array} = TC_t - \left(\frac{p_t}{p_{t-1}}\right) TC_{t-1}\,.$$

The estimated change in cost from the proportional cost model (4), likewise adjusted for inflation, is given by:

$$\begin{array}{l}\textit{Estimated change in cost,}\\ \textit{adjusted for inflation}\end{array} = \widehat{TC}_t - \left(\frac{p_t}{p_{t-1}}\right) TC_{t-1}\,.$$

We standardize the estimation error by dividing by the absolute value of the actual change in cost, adjusted for inflation:

$$\textit{Standardized prediction error} \qquad Z_t = \frac{\widehat{TC}_t - TC_t}{ABS\left(TC_t - \frac{p_t}{p_{t-1}} TC_{t-1}\right)}. \tag{5}$$

This standardized prediction error, Z_t, is the percentage error in estimating the change in total price-adjusted cost from one period to the next using the proportional cost model. When the proportional cost model correctly predicts the change in cost, the prediction error Z_t is zero. A negative value of Z_t indicates that the proportional cost model underestimated total cost. A positive value of Z_t indicates that the proportional cost model overestimated total cost.

All of the data required to compute the standardized prediction error Z_t are directly observable—with the exception of the price ratio, or inflation rate, p_t/p_{t-1}. We approximate this inflation rate with the inflation rate in the medical care consumer price index.[9] This approximation almost certainly contains measurement error. We return later in this section to a consideration of the potential impact of this measurement error on our results.

We computed the standardized prediction error Z_t for every hospital and every year for which there were data. Statistics concerning the distribution of the absolute value of Z_t across all hospitals and all years for the sixteen overhead accounts in our study appear in Table 2.

Table 2. Standardized prediction errors for the single-period proportional cost model.

Account		N	Interquartile range and median of $abs(Z_t)$: 25%	median	75%	The percentage of observations such that: $abs(Zt) < 0.05$	$abs(Zt) < 0.10$	$abs(Zt) < 0.25$	$abs(Zt) < 0.50$	$abs(Zt) \geq 1.00$
Dietary	8320	1352	0.67	1.30	3.29	1%	4%	10%	19%	62%
Cafeteria	8330	626	0.83	1.20	2.52	1%	2%	6%	13%	64%
Laundry & Linen	8350	1308	0.55	1.03	2.68	2%	4%	10%	22%	54%
Plant	8430	1354	1.00	1.00	1.14	1%	2%	3%	6%	84%
Housekeeping	8460	1305	0.52	1.16	3.35	3%	6%	13%	24%	59%
Accounting	8510	1184	0.80	1.32	3.66	2%	3%	8%	15%	66%
Communications	8520	817	0.77	1.23	3.47	2%	3%	6%	13%	63%
Patient Accounts	8530	858	1.14	3.42	25.76	1%	2%	6%	12%	78%
Data Processing	8540	774	0.94	2.71	18.33	1%	3%	7%	13%	73%
Admitting	8560	869	0.72	1.15	2.33	1%	3%	8%	17%	59%
Hospital Administration	8610	1266	0.84	1.13	2.57	1%	2%	4%	9%	61%
Public Relations	8630	561	0.81	1.55	6.51	2%	3%	6%	12%	63%
Personnel	8650	822	0.75	1.02	1.74	1%	2%	6%	13%	53%
Auxiliary Groups	8660	588	0.75	1.25	2.98	2%	3%	8%	16%	63%
Chaplaincy Services	8670	447	0.78	1.10	1.97	1%	2%	6%	12%	60%
Medical Records	8690	1313	0.73	1.39	3.97	2%	2%	7%	16%	64%
Mean			0.79	1.43	5.39	1%	3%	7%	14%	64%

The standardized prediction error is defined as $Z_t = \dfrac{\widehat{TC}_t - TC_t}{ABS\left(TC_t - \frac{p_t}{p_{t-1}} TC_{t-1}\right)}$ where

TC_t = the actual total cost for the cost pool in year t

$\widehat{TC}_t = \left(\frac{p_t}{p_{t-1}}\right)\left(\frac{TC_{t-1}}{q_{t-1}}\right) q_t$, the predicted cost based on the proportional cost model

p_t = the medical care consumer price index for year t

q_t = activity level in year t

N = number of observations

The first item to note from Table 2 is that the proportional cost model (4) does not appear to be very accurate. For example, in the Dietary account (the first entry in the table) the median absolute standardized prediction error, abs(Z_t), is 1.30. This means that for the median observation, the proportional cost model overstated the change in cost from one period to the next by 130%. In addition, for the Dietary account, only 10% of the prediction errors were within 25% of the actual change in cost and 62% of the prediction errors were larger than 100% of the actual change in costs.

The last column of Table 2 presents the percent of observations for which the absolute standardized prediction error was greater than 100%. For every account, the absolute standardized prediction error was greater than 100% more than half of the time. It is interesting to note that if it were assumed that costs were strictly fixed (apart from changes in prices), the absolute standardized prediction error would always be exactly 100%. If a fixed cost model were used, the prediction of period t's cost would be period t-1's inflation-adjusted cost (i.e., $\widehat{TC}_t = (p_t/p_{t-1})\,TC_{t-1}$). By the definition of the standardized prediction error in equation (5), a model that assumes all costs are entirely fixed would always have an absolute prediction error of 1.0. Thus, looking again at the Dietary account, a fixed cost model would have provided a smaller prediction error than the proportional cost model 62% of the time. Indeed, for every account in Table 2, a fixed cost model would have been more accurate than the proportional cost model most of the time.

The poor showing of the proportional cost model could be due to errors in measuring the inflation rates for accounts.[10] From equation (4), it is clear that an "appropriate" choice of the inflation rate p_t/p_{t-1} can purge the estimate of total cost of all error. It is always possible to choose a price ratio p_t/p_{t-1} such that $\widehat{TC}_t = TC_t$. Therefore, the prediction errors using the proportional cost model could, in principle, be due to errors in measuring the inflation rate. Looking at this in another way, the implicit inflation rate for the period—under the assumption that the single-period ABC model (2) is correct and that the parameter α is a constant—can be computed by simply dividing the average cost in this period by the average cost in the previous period.

$$\textit{Implicit inflation rate}_t = \frac{TC_t\,/q_t}{TC_{t-1}\,/q_{t-1}} = \frac{p_t}{p_{t-1}}. \tag{6}$$

The extent to which errors in the measurement of the inflation rate could have caused the poor performance of the proportional cost model can be assessed to some degree by comparing the implicit inflation rate for each hospital-year observation to the inflation rate estimated using the medical care consumer price index. For example, let us suppose that the inflation rate in the medical care consumer price index for a particular year is 9%. An implicit inflation rate for a particular hospital-year in the Laundry and Linen account of 7% is plausible and mismeasurement of the inflation rate could account for the prediction error using the proportional cost model. On the other hand, if the implicit inflation rate from equation (6) for this hospital-year is 34%, it is much less plausible that misspecification of the inflation rate is the source of error in the proportional cost model's predictions. Such a large inflation rate in a single year in a particular account is unlikely when the overall inflation rate for medical care is only 9%.

To provide some evidence concerning this issue, we computed the implicit inflation rate for each hospital-year observation in each account. We tabulated the percentage of observations

Table 3. Distribution of implicit inflation rates under the assumption that the single-period ABC cost model is correct.

			% of implicit inflation rates within specified interval of the medical care consumer price index inflation rate		
Account		N	±0.05	±0.10	±0.20
Dietary	8320	1,352	29.1%	47.3%	68.2%
Cafeteria	8330	626	18.2%	35.0%	54.6%
Laundry & Linen	8350	1,308	26.6%	48.5%	68.7%
Plant	8430	1,354	26.9%	49.6%	73.9%
Housekeeping	8460	1,305	36.6%	55.1%	70.5%
Accounting	8510	1,184	21.4%	37.6%	57.6%
Communications	8520	817	21.5%	40.8%	64.0%
Patient Accounts	8530	858	8.9%	20.5%	43.7%
Data Processing	8540	774	10.2%	20.5%	39.4%
Admitting	8560	869	29.0%	48.6%	69.7%
Hospital Administration	8610	1,268	14.1%	27.0%	48.5%
Public Relations	8630	561	7.3%	14.6%	28.2%
Personnel	8650	822	16.5%	33.5%	52.2%
Auxiliary Groups	8660	588	19.4%	31.5%	53.2%
Chaplaincy Services	8670	447	20.8%	39.1%	60.6%
Medical Records	8690	1,313	22.5%	39.5%	60.8%
	Mean		20.6%	36.8%	57.1%

Implicit inflation rate$_t = \frac{TC_t/q_t}{TC_{t-1}/q_{t-1}} = \frac{p_t}{p_{t-1}}$
where

TC_t = the actual total cost for the cost pool for year t
q_t = activity level in year t
N = number of observations

for which the implicit inflation rate was within 5%, 10%, and 20% of the inflation rate in the medical care consumer price index. For example, if the implicit inflation rate for a hospital-year observation is 18% and the inflation rate in the medical care consumer price index for that year is 10%, then the observation would be counted as falling within the ±0.10 and ±0.20 intervals, but not the ±0.50 interval. The results of these computations are displayed in Table 3.

For example, in the Dietary account, 29.1% of the implicit inflation rates were within 5% of the inflation rates for the medical care consumer price index. It is believable that the prediction errors tabulated in Table 2 for these observations *could* have been due to misspecification of the inflation rate. This does not mean that the prediction errors *were* due to misspecification of the inflation rate, but it is plausible that they *could* have been due to that cause. On the other hand, for over half of the observations, the implicit inflation rate was more than 10% above or 10% below the inflation rate for the medical care consumer price index. (If, for example, the inflation rate for the medical care consumer price index was 9% in a particular year, an observation fell outside of the ±10% range if it was below −1% or above 19%.) Such inflation rates are much less plausible. We leave it to the reader to judge the extent to which misspecification of the inflation rates can account for the poor showing of the proportional cost model.[11,12]

Before developing the multi-period model, we conducted two statistical tests of the proportional cost model. The tests are based on the observation that if there are increasing returns to scale (due, for example, to the presence of fixed costs) in an overhead cost pool, the proportional cost model will tend to overestimate total costs when there is an increase in activity and to underestimate total costs when there is a decrease in activity. Therefore, if we divide observations into those where there is an increase in activity and those where there is a decrease in activity, we should observe that the percentage of observations where costs are overestimated with the proportional cost model is higher for the group with an increase in activity than for the group with a decrease in activity. This expected pattern is confirmed in Table 4. For example, in the Dietary account, when activity increases the proportional cost model overestimates the cost 78% of the time. In contrast, when activity decreases the proportional cost model overestimates cost only 28% of the time (and therefore underestimates cost 72% of the time). Using a binomial test, the difference in percentages of overestimated costs between the two groups is statistically significant beyond the .001 level for every account.[13]

In the second test, we computed the median standardized prediction error Z_t for the activity-increasing group and for the activity-decreasing group. If there are increasing returns to scale in an overhead account, we would expect the median standardized prediction error Z_t to be positive for the activity-increasing group and to be negative for the activity-decreasing group. This expected pattern is also confirmed in Table 4. For example, the median prediction error for the Dietary account was 1.61 for years in which activity increased and -1.17 for years in which activity decreased. In other words, the proportional cost model greatly overestimated the increase in costs when activity increased and greatly overestimated the decrease in costs when activity decreased. For every account, the median prediction error Z_t was positive for the activity-increasing group and negative for the activity-decreasing group.

While statistical significance of this result may be obvious, we conducted a formal significance test. The test statistic was the difference in median Z_t scores for the two groups. Again using the Dietary account as an example, the value of the test statistic for this account was 2.78 [$= 1.61 - (-1.17)$]. The significance of this statistic was assessed using approximate randomization.[14] The null hypothesis that the proportional cost model is unbiased (i.e., the prediction errors are independent of whether activity is increasing or decreasing) was rejected at the .001 level for every overhead cost pool.

3. A Multi-Period Model

The activity-based costing literature typically justifies use of the ABC model with the assertion "in the long-run all costs are variable" or, equivalently, "activity-based costing provides approximations to long-run marginal costs." Unfortunately, there is no evidence to support this assertion, and indeed, Noreen and Soderstrom (1994) provide evidence to the contrary. Using the traditional cross-sectional approach to estimating long-run cost functions, Noreen and Soderstrom demonstrate that marginal costs are significantly less

Table 4. Tests for increasing returns to scale in overhead pools.

		q increasing: ($q_t > q_{t-1}$)			q decreasing: ($q_t < q_{t-1}$)			q static		
Account		N	median Z_t	Percentage of observations where $Z_t > 0$	N	median Z_t	Percentage of observations where $Z_t > 0$	N	Significance level of the percentage of observations where $Z_t > 0$ (Binomial Test)	Significance level for a test of the difference in medians (Approximate randomization test)
Dietary	8320	711	1.61	78%	618	−1.17	28%	23	0.000	0.001
Cafeteria	8330	408	1.32	76%	209	−1.09	35%	9	0.000	0.001
Laundry & Linen	8350	662	1.28	70%	620	−0.54	40%	26	0.000	0.001
Plant	8430	428	1.19	70%	205	−1.55	18%	721	0.000	0.001
Housekeeping	8460	718	1.40	78%	438	−1.08	33%	49	0.000	0.001
Accounting	8510	732	1.30	69%	407	−1.49	21%	45	0.000	0.001
Communications	8520	540	1.25	68%	252	−1.33	23%	25	0.000	0.001
Patient Accounts	8530	673	3.31	85%	178	−5.09	8%	7	0.000	0.001
Data Processing	8540	613	2.63	80%	154	−3.32	9%	7	0.000	0.001
Admitting	8560	445	1.04	59%	414	−1.20	25%	10	0.000	0.001
Hospital Administration	8610	838	1.11	61%	389	−1.28	25%	39	0.000	0.001
Public Relations	8630	444	1.53	68%	115	−1.72	13%	2	0.000	0.001
Personnel	8650	581	0.21	52%	222	−1.19	25%	19	0.000	0.001
Auxiliary Groups	8660	380	1.39	73%	189	−1.20	23%	19	0.000	0.001
Caplaincy Services	8670	229	1.07	61%	215	−1.13	27%	3	0.000	0.001
Medical Records	8690	785	1.38	69%	507	−1.44	18%	21	0.000	0.001
Mean			1.44	70%		−1.61	23%			

Where $Z_t = \dfrac{\widehat{TC}_t - TC_t}{ABS\left(TC_t - \frac{p_t}{p_{t-1}} TC_{t-1}\right)}$

TC_t = the actual total cost for the cost pool in year t

$\widehat{TC}_t = \left(\frac{p_t}{p_{t-1}}\right)\left(\frac{TC_{t-1}}{q_{t-1}}\right) q_t$, the predicted cost based on the proportional cost model

p_t = the medical care consumer price index for year t

q_t = activity level in year t

N = number of observations

than average costs across virtually all of the overhead accounts examined. However, as we mentioned earlier, the "long-run" cost functions estimated with cross-sectional data may not accurately represent the expansion path any given organization would follow.

Our interpretation of the activity-based costing model is that activities consume resources (in fixed amounts) and consumption of resources creates pressures to incur costs that are proportional to the amount of the resources consumed. These pressures may be resisted for some time, but they will eventually lead to increased costs unless removed.[15] This is what we believe activity-based costing advocates mean when they say "in the long-run all costs are variable." Formally, the multi-period model can be written as follows:

$$\textit{Multi-period ABC model} \qquad C(q_\eta) = \sum_{\tau=\eta}^{\eta+T} p_\tau \partial_{\tau-\eta} \alpha q_\eta \tag{7}$$

$$\sum_{\tau=\eta}^{\eta+T} \partial_{\tau-\eta} = 1$$

where

q_η = activity level in period η

$C(q_\eta)$ = cumulative undiscounted cost consequences over all future periods of q_η

α = amount of resource consumed per unit of activity

∂_t = percentage of resource consumption whose cost is realized in the t^{th} period subsequent to the change in activity

p_τ = the price per unit of resource in period τ.

Note that if prices are constant (i.e., $p_\tau = p, = p$, for all τ) then:

$$C(q_\eta) = p\alpha q_\eta. \tag{8}$$

Note the essential similarity between this multi-period model and the basic ABC model (1). The assumption here is that the cost may not be realized in the current period, but it will eventually be realized.

Return to the basic model in equation (7), without the assumption that $p_\tau = p$. The cost realized in period t, $\eta \leq t \leq \eta + T$, as a consequence of activity q_η in period η, is $p_t \partial_{t-\eta} \alpha q_\eta$. The realized total cost for a particular cost pool in period t, TC_t, is the result of activity in the current and previous T periods as follows:

$$TC_t = \sum_{\tau=t}^{t-T} p_t \partial_{t-\tau} \alpha q_\tau. \tag{9}$$

Now take the ratio of this period's total cost to last period's total cost:

$$\frac{TC_t}{TC_{t-1}} = \frac{\sum_{\tau=t}^{t-T} p_t \partial_{t-\tau} \alpha q_\tau}{\sum_{\tau=t-1}^{t-1-T} p_{t-1} \partial_{t-1-\tau} \alpha q_\tau}. \tag{10}$$

This expression can be rewritten as follows:

$$\frac{TC_t}{TC_{t-1}} = \left(\frac{p_t}{p_{t-1}}\right)\left(\frac{\partial_0 q_t + \partial_1 q_{t-1} + \cdots + \partial_T q_{t-T}}{\partial_0 q_{t-1} + \partial_1 q_{t-2} + \cdots + \partial_T q_{t-1-T}}\right) \tag{11}$$

where $\partial_0 + \partial_1 + \cdots + \partial_T = 1$.

This model is surprisingly simple. According to this multi-period version of the ABC model, the ratio of successive changes in total costs for a cost pool is a function of the ratios of successive prices for the resource and of successive weighted measures of present and past activity.

Using this multi-period model, predicted total cost in period t would be computed as follows:

Multi-period proportional cost model

$$\widehat{TC}_t = \left(\frac{p_t}{p_{t-1}}\right)(TC_{t-1})\left(\frac{\partial_0 q_t + \partial_1 q_{t-1} + \cdots + \partial_T q_{t-T}}{\partial_0 q_{t-1} + \partial_1 q_{t-2} + \cdots + \partial_T q_{t-1-T}}\right). \tag{12}$$

Note that when $\partial_0 = 1$ (and hence all of the other ∂_is are zero), the multi-period model (12) is identical to the single-period proportional cost model (4).

In order to test the multi-period model (12), we again use the medical care consumer price index to estimate relative prices. All of the other variables are directly observable except for the $\partial_0, \partial_1, \ldots, \partial_T$ parameters. To estimate these, we used a grid search technique. We started with a two-period model and for each account, we tried all values of ∂_0 between 0 and 1 in steps of size 0.005. (The value of ∂_1 in a two-period model is simply $1 - \partial_0$.) For each value of ∂_0 (and hence of ∂_1), we computed the percentage of observations in the account where the two-period model (12) had a smaller prediction error than a simple fixed cost model which predicted that this year's total cost would be equal to last year's inflation-adjusted total cost. Mechanically, this is the percentage of observations for which $\text{abs}(Z_t) < 1$. Basically, we searched until we found the value of ∂_0 that would make the multi-period proportional cost model look as good as possible relative to the simple fixed cost model.[16] Results of this estimation process appear in Table 5.[17]

Although the two-period proportional cost model outperformed the one-period model for all cost pools, the improvement was generally very modest. For example, for the Dietary cost pool, the one-period proportional cost model was superior to the simple fixed cost model only 38.7% of the time. (That is to say, the fixed cost model was at least as accurate as the proportional cost model 61.3% of the time.) When the two-period model was used and ∂_0 was chosen to maximize the apparent superiority of the two-period proportional cost model over the fixed cost model, the percentage increased to only 42.4%. In other words, even after optimizing the two-period proportional cost model, the fixed cost model was still at least as accurate as the proportional cost model for nearly 60% of the observations. Of course, improvement when moving from the one-period to the two-period proportional cost model follows since the values of the parameters were selected precisely to maximize the amount of apparent improvement. An approximate randomization test was used to assess the statistical significance of these improvements.[18] These significance levels are listed in the last column in Table 5. While the improvements in the two-period over the one-period models were generally statistically significant, the magnitudes of the improvements were

Table 5. Test of a two-period proportional cost model.

Account		N	Percentage of observations where the proportional cost model provides more accurate preditions than the fixed cost model[a]: Single-period proportional cost model	Two-period proportional cost model	Improvement going from a one-period to a two-period model	Significance of the improvement. (Approximate randomization test.)
Dietary	8320	1174	38.7%	42.4%	3.7%	0.01
Cafeteria	8330	537	35.6%	41.7%	6.1%	0.01
Laundry & Linen	8350	1135	46.4%	49.0%	2.6%	0.01
Plant	8430	1176	16.7%	27.8%	11.1%	1.00
Housekeeping	8460	1118	41.5%	43.4%	1.9%	0.14
Accounting	8510	982	33.3%	39.7%	6.4%	0.01
Communications	8520	701	35.9%	42.3%	6.4%	0.01
Patient Accounts	8530	716	22.6%	23.0%	0.4%	0.01
Data Processing	8540	645	25.3%	26.7%	1.4%	0.01
Admitting	8560	761	40.9%	48.3%	7.4%	0.01
Hospital Administration	8610	1073	39.1%	41.6%	2.5%	0.01
Public Relations	8630	450	36.0%	36.2%	0.2%	0.01
Personnel	8650	703	46.5%	48.2%	1.7%	0.01
Auxiliary Groups	8660	511	37.8%	41.1%	3.3%	0.01
Chaplaincy Services	8670	391	41.4%	46.0%	4.6%	0.01
Medical Records	8690	1126	35.3%	38.8%	3.5%	0.01
Mean			35.8%	39.8%	4.0%	

[a]The variable cost model provides more accurate predictions than the fixed cost model when $\text{abs}(Z_t) < 1$ and Z_t is defined as in Table 4.

small. Even after selecting parameters to make the two-period ABC model look as attractive as possible relative to the simple fixed cost model, the fixed cost model was more accurate than the ABC model most of the time for all of the accounts.

Due to the very slight improvement of the two-period proportional cost model over the one-period model, we did not pursue testing the multi-period model (12) with three or more periods. (As discussed below, the regression version of the model deteriorated when we went from two to three periods.)

4. Regression Analysis

Since the results of the previous sections indicate that overhead cost pools are not strictly proportional to activity, the obvious next step is to estimate how much of the overhead costs are variable. Taking the logs of both sides of equation (12) and rearranging slightly, we obtain:

$$\ln\left(\frac{TC_t}{TC_{t-1}}\right) = \ln\left(\frac{p_t}{p_{t-1}}\right) + \ln\left(\frac{(\partial_0 q_t + \partial_1 q_{t-1} + \cdots + \partial_T q_{t-T})}{(\partial_0 q_{t-1} + \partial_1 q_{t-2} + \cdots + \partial_T q_{t-1-T})}\right). \tag{13}$$

And, assuming that the ratios of the successive activity levels are close to one, the following approximation to equation (13) can be used:[19]

$$\begin{aligned}\ln\left(\frac{TC_t}{TC_{t-1}}\right) &\approx \ln\left(\frac{p_t}{p_{t-1}}\right) + \partial_0 \ln\left(\frac{q_t}{q_{t-1}}\right)\\ &\quad + \partial_1 \ln\left(\frac{q_{t-1}}{q_{t-2}}\right) + \cdots + \partial_T \ln\left(\frac{q_{t-T}}{q_{t-(T+1)}}\right).\end{aligned} \tag{14}$$

The empirical form of model (14) we test is:

$$\begin{aligned}\ln\left(\frac{TC_t}{TC_{t-1}}\right) &= \theta \ln\left(\frac{p_t}{p_{t-1}}\right) + \beta_0 \ln\left(\frac{q_t}{q_{t-1}}\right)\\ &\quad + \beta_1 \ln\left(\frac{q_{t-1}}{q_{t-2}}\right) + \cdots + \beta_T \ln\left(\frac{q_{t-T}}{q_{t-(T+1)}}\right)\end{aligned} \tag{15}$$

where p_t is the value of the medical care consumer price index in year t. The parameter θ allows prices in a particular overhead cost pool to grow at a different rate than the rate of growth in the medical care consumer price index. Estimates of the βs in the regression provide an estimate of the percentage of costs that are variable (i.e., proportional to activity). Or, stated a bit differently, the sum of the βs is the ratio of marginal cost to average cost. If the sum of the βs is one, then marginal cost equals average cost and all of the cost is variable. If the sum of the βs is less than one, marginal cost is less than average cost and a costing system that assumes costs are variable will overstate marginal costs.

When we ran a single-period version of the regression model (15) using all of the data, the results were nonsensical and clearly dominated by outliers. Coding and keypunching errors are a recurrent problem in hospital databases. These errors were not an issue in the tests in the previous section since those tests are largely immune to the presence of outliers.[20] However, regressions can be very sensitive to the presence of extreme observations. Because of the abundance of data, we used a simple screening rule. We rejected any observation if the absolute value of one of the regression variables was greater than 0.4.[21] Since the regression variables are in log form, this meant we discarded any observation for which the value of a variable changed by more than about 50% within the span of one year.

Results of running a simple one-period form of the regression model appear in Table 6. The β_0 coefficients are all significantly less than 1 at the 0.0005 level or better. The average β_0 is only 0.20 and varies from a low of 0.11 to a high of 0.42.[22] In other words, variable costs are on average only about 20% of the cost in an overhead cost pool.[23] Stated a little differently, the marginal cost is only about 20% of the average cost.

Results of running a two-period form of the regression model appear in Table 7. While all but one of the β_1 coefficients are positive as expected and most are significantly different from zero, the average β_1 coefficient is only 0.07, which together with the average β_0 coefficient of 0.22, raises the sum of the β coefficients to just 0.29.[24] The sum of the β coefficients is significantly less than 1 at the 0.0005 level or better for each of the accounts. When we ran the regression using a three-period model, the coefficients behaved less well and the overall results did not materially improve.

The prior tests all assume that changes in cost are contemporaneous with or lag changes in activity. However, it is possible that costs are incurred in anticipation of future changes in activity. That is, changes in cost may lead rather than lag changes in activity. As a check on this possibility, we ran a three-period version of the regression model (15) in which there is a lead term as well as a lag term for the changes in activity. The lead-lag form of the model we ran was:

$$\ln\left(\frac{TC_t}{TC_{t-1}}\right) = \theta \ln\left(\frac{p_t}{p_{t-1}}\right) + \beta_+ \ln\left(\frac{q_{t+1}}{q_t}\right) + \beta_0 \ln\left(\frac{q_t}{q_{t-1}}\right) + \beta_- \ln\left(\frac{q_{t-1}}{q_{t-2}}\right).$$

The results of this test appear in Table 8. On average, the coefficient on the lead term is only 0.05 and only three of the sixteen coefficients are statistically different from zero at the 0.10 level of significance. Overall the average sum of the beta coefficients is 0.41. For two of the sums, the hypothesis that the sum of the betas is 1 cannot be rejected at the 0.10 level.

Finally, we ran a version of the one-period model in which an interactive dummy term was added for decreases in activity. This is a test of the folklore that costs behave differently when activity is decreasing than when activity is increasing. (Namely, costs increase much more easily in response to increases in activity than they decrease in response to decreases in activity.) The results are reported in Table 9. While very few of the interactive dummy coefficients were significantly different from zero, all but three were negative. The probability of obtaining 13 out of 16 coefficients with the "right sign" is about 0.01. This suggests that costs are indeed more difficult to adjust when decreasing activity, although the effect is generally statistically insignificant for any one account.

5. Limitations

A number of potential limitations should be noted. First, the costs reported by hospitals do not include opportunity costs. Service departments operating at or near capacity impose

Table 6. Regression results for the single-period model.

Account		N	$\ln(p_t/p_{t-1})$ θ	$se(\theta)$	β_0	$\ln(q_t/q_{t-1})$ $se(\beta_0)$	Probability $\beta_0 = 0$	Probability $\beta_0 = 1$	$adj R2$
Dietary	8320	1057	0.91	0.04	0.25	0.03	0.000	0.000	0.38
Cafeteria	8330	412	1.00	0.08	0.20	0.05	0.000	0.000	0.35
Laundry & Linen	8350	1061	0.92	0.04	0.41	0.03	0.000	0.000	0.35
Plant	8430	1206	1.15	0.04	0.12	0.04	0.001	0.000	0.40
Housekeeping	8460	1027	0.99	0.04	0.42	0.03	0.000	0.000	0.55
Accounting	8510	874	1.20	0.05	0.11	0.04	0.004	0.000	0.39
Communications	8520	642	1.13	0.06	0.21	0.05	0.000	0.000	0.40
Patient Accounts	8530	514	0.88	0.14	0.20	0.07	0.003	0.000	0.36
Data Processing	8540	430	1.20	0.18	0.11	0.09	0.117	0.000	0.38
Admitting	8560	732	1.30	0.05	0.20	0.05	0.000	0.000	0.46
Hospital Administration	8610	894	1.40	0.07	0.11	0.07	0.056	0.000	0.34
Public Relations	8630	237	1.17	0.28	0.20	0.15	0.089	0.000	0.32
Personnel	8650	604	1.55	0.09	0.20	0.09	0.012	0.000	0.40
Auxiliary Groups	8660	408	1.31	0.10	0.13	0.06	0.013	0.000	0.39
Chaplaincy Services	8670	341	1.39	0.09	0.24	0.08	0.001	0.000	0.43
Medical Records	8690	1035	1.39	0.05	0.11	0.03	0.000	0.000	0.51
Mean			1.18	0.09	0.20	0.06			0.40

The regression model is: $\ln\left(\frac{TC_t}{TC_{t-1}}\right) = \theta \ln\left(\frac{p_t}{p_{t-1}}\right) + \beta_0 \ln\left(\frac{q_t}{q_{t-1}}\right) + \varepsilon_t$

where

TC_t = the actual total cost for the cost pool for year t
p_t = the medical care consumer price index for year t
q_t = activity level in year t
N = number of observations

Table 7. Regression results for the two-period model.

Account		N	$\ln(p_t/p_{t-1})$ θ	$se(\theta)$	$\ln(q_t/q_{t-1})$ β_0	$se(\beta_0)$	$\ln(q_{t-1}/q_{t-2})$ β_1	$se(\beta_1)$	prob. $\beta_1 = 0$	Sum of βs Sum: $\beta_0 + \beta_1$	prob. $Sum = 1$	$adj R^2$
Dietary	8320	818	0.89	0.04	0.21	0.03	0.14	0.03	0.000	0.35	0.000	0.40
Cafeteria	8330	326	0.90	0.09	0.20	0.05	0.11	0.05	0.013	0.31	0.000	0.38
Laundry & Linen	8350	833	0.92	0.05	0.50	0.04	0.07	0.04	0.031	0.57	0.000	0.39
Plant	8430	993	1.14	0.05	0.17	0.04	0.02	0.04	0.341	0.18	0.000	0.42
Housekeeping	8460	774	0.95	0.04	0.44	0.03	0.15	0.03	0.000	0.59	0.000	0.57
Accounting	8510	652	1.16	0.06	0.11	0.05	0.13	0.05	0.004	0.24	0.000	0.40
Communications	8520	512	1.04	0.07	0.21	0.05	0.11	0.05	0.020	0.32	0.000	0.40
Patient Accounts	8530	300	0.21	0.23	0.30	0.10	0.31	0.10	0.001	0.61	0.001	0.41
Data Processing	8540	256	0.75	0.30	0.21	0.12	0.15	0.12	0.105	0.36	0.000	0.38
Admitting	8560	602	1.26	0.06	0.23	0.05	0.08	0.05	0.045	0.31	0.000	0.47
Hospital Administration	8610	671	1.44	0.09	0.13	0.09	−0.03	0.09	0.629	0.10	0.000	0.35
Public Relations	8630	148	0.98	0.41	0.14	0.18	0.20	0.15	0.094	0.34	0.001	0.34
Personnel	8650	467	1.54	0.11	0.16	0.10	0.26	0.10	0.006	0.42	0.000	0.45
Auxiliary Groups	8660	317	1.25	0.12	0.08	0.07	0.07	0.07	0.150	0.15	0.000	0.38
Chaplaincy Services	8670	276	1.33	0.10	0.27	0.09	−0.08	0.10	0.792	0.19	0.000	0.42
Medical Records	8690	777	1.33	0.05	0.12	0.03	0.09	0.03	0.003	0.21	0.000	0.52
Mean			1.07	0.12	0.22	0.07	0.11	0.07		0.33	0.000	0.42

The regression model is: $\ln\left(\frac{TC_t}{TC_{t-1}}\right) = \theta \ln\left(\frac{p_t}{p_{t-1}}\right) + \beta_0 \ln\left(\frac{q_t}{q_{t-1}}\right) + \beta_1 \ln\left(\frac{q_{t-1}}{q_{t-2}}\right) + \varepsilon_t$

where

TC_t = the actual total cost for the cost pool for year t
p_t = the hospital price index for year t
q_t = activity level in year t
N = number of observations

Table 8. Regression results for the model with leads and lags.

Account		N	$\ln(p_t/p_{t-1})$ θ	$se(\theta)$	$\ln(q_{t+1}/q_t)$ β_+	$se(\beta_+)$	$\ln(q_t/q_{t-1})$ β_0	$se(\beta_0)$	$\ln(q_{t-1}/q_{t-2})$ β_-	$se(\beta_-)$	Sum of βs — Sum: $\beta_+ + \beta_0 + \beta_-$	prob. $Sum = 1$	adj R^2
Dietary	8320	650	0.93	0.46	0.05	0.04	0.22†	0.03	0.15†	0.03	0.416	0.000	0.44
Cafeteria	8330	257	0.89	0.10	−0.05	0.06	0.22†	0.06	0.15†	0.06	0.320	0.000	0.39
Laundry & Linen	8350	668	0.94	0.05	0.05	0.04	0.49†	0.04	0.10†	0.04	0.638	0.000	0.41
Plant	8430	817	1.15	0.05	−0.01	0.05	0.19†	0.05	0.01	0.05	0.189	0.000	0.45
Housekeeping	8460	592	0.97	0.04	0.15†	0.03	0.43†	0.04	0.14†	0.03	0.722	0.000	0.64
Accounting	8510	498	1.16	0.07	0.08	0.05	0.10†	0.06	0.09	0.06	0.264	0.000	0.42
Communications	8520	414	1.04	0.08	0.14†	0.05	0.25†	0.06	0.05	0.06	0.444	0.000	0.43
Patient Accounts	8530	184	−0.11	0.33	0.07	0.11	0.37†	0.13	0.41†	0.12	0.846	0.212	0.44
Data Processing	8540	157	0.72	0.44	0.22	0.14	0.04	0.16	0.08	0.15	0.338	0.005	0.35
Admitting	8560	508	1.27	0.06	0.06	0.06	0.26†	0.06	0.68	0.06	0.384	0.000	0.47
Hospital Administration	8610	521	1.52	0.11	−0.01	0.10	0.14	0.10	−0.09	0.10	0.040	0.000	0.37
Public Relations	8630	89	0.50	0.64	0.03	0.19	0.22	0.24	0.37	0.24	0.623	0.139	0.33
Personnel	8650	376	1.45	0.13	0.06	0.11	0.28†	0.12	0.36†	0.13	0.699	0.067	0.46
Auxiliary Groups	8660	260	1.25	0.13	0.04	0.07	0.10	0.08	0.06	0.07	0.203	0.000	0.42
Chaplaincy Services	8670	230	1.31	0.11	−0.12	0.11	0.34†	0.10	−0.12	0.11	0.084	0.000	0.42
Medical Records	8690	592	1.35	0.05	0.07†	0.04	0.12†	0.04	0.11†	0.04	0.303	0.000	0.56
Mean			1.02	0.18	0.05	0.08	0.24	0.09	0.16	0.08	0.407	0.025	0.44

†Denotes a β coefficient significantly different from zero at the 0.10 level.

The regression model is: $\ln\left(\frac{TC_t}{TC_{t-1}}\right) = \theta \ln\left(\frac{p_t}{p_{t-1}}\right) + \beta_+ \ln\left(\frac{q_{t+1}}{q}\right) + \beta_0 \ln\left(\frac{q_t}{q_{t-1}}\right) + \beta_- \ln\left(\frac{q_{t-1}}{q_{t-2}}\right) + \varepsilon_t$

where

TC_t = the actual total cost for the cost pool for year t
p_t = the hospital price index for year t
q_t = activity level in year t
N = number of observations

Table 9. Regression results for the single-period model with a dummy variable for decreases in activity.

Account		N	$\ln(p_t/p_{t-1})$ θ	$se(\theta)$	$\ln(q_t/q_{t-1})$ β_0	$se(\beta_0)$	Prob $\beta_0 = 1$	$\ln(q_t/q_{t-1})$ if $q_t < q_{t-1}$ β_D	$se(\beta_D)$	Prob $\beta_D = 0$	adjR^2
Dietary	8320	1057	0.90	0.06	0.26	0.05	0.000	−0.01	0.08	0.437	0.38
Cafeteria	8330	412	0.70	0.12	0.40	0.08	0.000	−0.49	0.15	0.000	0.36
Laundry & Linen	8350	1061	0.92	0.06	0.41	0.06	0.000	0.00	0.10	0.511	0.35
Plant	8430	1206	1.14	0.05	0.13	0.05	0.000	−0.04	0.09	0.317	0.40
Housekeeping	8460	1027	0.95	0.05	0.46	0.04	0.000	−0.08	0.07	0.120	0.55
Accounting	8510	874	1.14	0.08	0.17	0.07	0.000	−0.12	0.11	0.142	0.39
Communications	8520	642	1.12	0.09	0.22	0.08	0.000	−0.03	0.13	0.401	0.40
Patient Accounts	8530	514	0.53	0.16	0.38	0.09	0.000	−1.10	0.28	0.000	0.38
Data Processing	8540	430	1.14	0.19	0.14	0.10	0.000	−0.42	0.60	0.239	0.38
Admitting	8560	732	1.35	0.07	0.13	0.08	0.000	0.13	0.13	0.850	0.46
Hospital Administration	8610	894	1.34	0.10	0.18	0.11	0.000	−0.16	0.20	0.208	0.34
Public Relations	8630	237	1.37	0.33	0.10	0.17	0.000	0.91	0.81	0.869	0.32
Personnel	8650	604	1.51	0.12	0.25	0.12	0.000	−0.14	0.25	0.279	0.40
Auxiliary Groups	8660	408	1.22	0.14	0.20	0.09	0.000	−0.19	0.19	0.155	0.39
Chaplaincy Services	8670	341	1.42	0.12	0.19	0.13	0.000	0.10	0.21	0.682	0.43
Medical Records	8690	1035	1.32	0.06	0.17	0.05	0.000	−0.13	0.08	0.051	0.51
Mean			1.13	0.11	0.24	0.08	0.000	−0.11	0.22	0.329	0.40

The regression model is: $\ln\left(\frac{TC_t}{TC_{t-1}}\right) = \theta \ln\left(\frac{p_t}{p_{t-1}}\right) + \beta_0 \ln\left(\frac{q_t}{q_{t-1}}\right) + \beta_D D^* \ln\left(\frac{q_t}{q_{t-1}}\right) + \varepsilon_t$

where

TC_t = the actual total cost for the cost pool for year t
p_t = the medical care consumer price index for year t
q_t = activity level in year t
$D = 1$ if $q_t < q_{t-1}$, 0 otherwise
N = number of observations

indirect costs on users in terms of waiting and service degradation and it is possible that total costs (including these opportunity costs) are strictly proportional to activity even though reported costs are not.

Second, there are coding and other errors in the data. The non-regression tests are robust to random errors. However, the regression tests are potentially very sensitive to such errors. While the regression tests were run on screened data, any data errors that were not screened out will tend to reduce the estimate of the proportion of costs that are variable due to the errors-in-variables problem.

Third, it can be argued that even though costs do not appear to be proportional to activity, that could just be a symptom that the cost pools and/or measures of activity are misspecified.[25] While that may certainly be true, it is not obvious that the typical activity-based costing implementation has better specified cost pools and activity measures than those required by the Washington State Department of Health.

There is one potential source of misspecification in the activity measure that is of particular concern and was discussed in Noreen and Soderstrom (1994, 272–273). It may be that overhead costs are proportional to the activity that could be supported at capacity rather than to the actual or budgeted activity. In other words, overhead costs may be more a function of planned capacity than the amount of the capacity that is used. In that case, the apparent amount of fixed cost in an account is really a measure of the average amount of unused spare capacity—i.e., "surge capacity." Some accounts should have more surge capacity than others due to the inherent variability of activity and the relative costliness of exceeding capacity in terms of degraded service and additional out-of-pocket costs. (For example, it is likely that a hospital would want to maintain more surge capacity in the Admitting function than in Chaplaincy Services.) To check on this possibility, we surveyed hospital controllers, asking them to identify the average percentage of unused capacity in each overhead account. They tended to agree that certain accounts had more surge capacity than others. The mean response for the controllers ranged from 14% surge capacity for the Cafeteria to 6% for Accounting, Auxiliary Groups, and Medical Records. However, the reported levels of surge capacity were uncorrelated with the apparent amount of fixed costs in overhead accounts.

Fourth, it is also possible that if hospitals had different cost systems, their costs would behave differently. While it is not clear how an activity-based costing system would differ at the departmental level from the cost system Washington state hospitals already use, it is possible that a conscious implementation of activity-based costing would lead to a materially different cost system and this in turn may lead to different cost behavior over time. However, it is difficult to believe that the outcome would be "better" if costs were more variable with respect to activity. The evidence strongly suggests that the hospitals have been able to handle increases in activity with far less than proportional increases in costs. Since activity is increasing most of the time in most of the overhead functions, a system such as activity-based costing that views proportional increases in costs as normal would seem to create a built-in bias toward generating excessive costs.

Fifth, the tests are biased against the proportional cost model if the weights ∂_t in the multi-period model (12) are not constant—which is surely the case. However, in simulations where we generated synthetic overhead costs using the multi-period model and entirely random weights ∂_i (within the limitation that they sum to one) for each hospital-year, we were unable to generate results that were as unfavorable for the proportional cost model as those in this paper. Nevertheless, it must be acknowledged that nonconstant ∂_i weights almost surely contribute to the apparent poor performance of the proportional cost model.

Finally, one issue that has been receiving attention lately is the nature of the measure of activity that is used in the denominator of the overhead rate. While some academics have advocated the use of activity at "practical capacity" as the appropriate measure of activity in the denominator, practice seems to be dominated by the use of either actual activity or budgeted activity. If "practical capacity" were used instead of budgeted or actual activity, the rates would ordinarily be lower and the overall predictive ability of the ABC model would improve. Unfortunately, there is no way to estimate "practical capacity" in this study, so the extent of improvement cannot be determined.

6. Conclusion

Results of this study provide strong evidence that there is very little variable cost in the overhead accounts of hospitals for the years we examined. If one must choose between a model in which it is assumed all costs are variable and proportional to activity, such as an ABC model, and one in which it is assumed all costs are fixed, the fixed cost model is usually more accurate. It appears that the proportion of variable costs in hospital overhead accounts is typically much less than 50%, averaging around 20%. Consequently, costs produced by costing systems such as activity-based costing that assume proportionality are likely to grossly overstate incremental costs for both decision making and performance evaluation purposes.

Appendix

The following descriptions of overhead accounts used in this study are abstracted from the Washington State Department of Health's Accounting and Reporting Manual for Hospitals—1994 Revision.

The direct expenses under each account include salaries and wages, employee benefits, professional fees, supplies, purchased services, depreciation/rental/lease, and other direct expenses. Transfer payments from other accounts, while considered as an offset to direct expenses by WSDOH, have been excluded in this study. We are interested in the costs of providing an overhead service whether or not those costs happen to be offset by transfer payments from other parts of the organization.

Account 8320 Dietary
This cost center contains the direct expenses incurred in preparing and delivering food to patients. Also included is dietary's share of common costs of the cafeteria.
Standard Unit of Measure: Number of patient meals served

Account 8330 Cafeteria
This cost center contains the directly identifiable expenses incurred in preparing and deliv-

ering food to employees and other nonpatients. Also included is the cafeteria's share of the common costs of dietary.
Standard Unit of Measure: Equivalent number of cafeteria meals served

Account 8350 Laundry and Linen
This cost center contains the direct expenses incurred in providing laundry and linen services for hospital use, including student and employee quarters. Costs of disposable linen should be recorded in this account.
Standard Unit of Measure: Number of dry and clean pounds processed

Account 8430 Plant
This cost center contains the direct expense incurred in the operation of the hospital plant and equipment.
Standard Unit of Measure: Number of gross square feet

Account 8460 Housekeeping
This cost center contains the direct expense incurred by the units responsible for maintaining general cleanliness and sanitation throughout the hospital and other areas serviced (such as student and employee quarters).
Standard Unit of Measure: Hours of service

Account 8510 Accounting
This cost center contains the direct expenses incurred in providing the general accounting requirements of the hospital.
Standard Unit of Measure: Average number of hospital employees

Account 8520 Communications
This cost center contains the direct expense incurred in carrying on communications (both in and out of the hospital), including the telephone switchboard and related telephone services, messenger activities, internal information systems, and mail services.
Standard Unit of Measure: Average number of hospital employees

Account 8530 Patient Accounts
This cost center contains the direct expense incurred in patient-related billing activities and in extending credit and collecting accounts.
Standard Unit of Measure: Gross patient revenue

Account 8540 Data Processing
This cost center contains the costs incurred in operating an electronic data processing center. Expenses incurred in the operation of terminals of the EDP center throughout the hospital shall be included in the data processing cost center. However, outside service bureau costs directly chargeable to a specific nursing or ancillary cost center should be included in the

specific cost center. Outside service bureau costs benefiting more than one cost center shall be included in the data processing cost center.
Standard Unit of Measure: Gross patient revenue

Account 8560 Admitting
This cost center contains the direct expense incurred in operating all general inpatient admitting offices.
Standard Unit of Measure: Number of admissions

Account 8610 Hospital Administration
This cost center contains the direct expense associated with the overall management and administration of the institution, including the office of administrative director, governing board, and planning activities. Also expenses which are not assignable to a particular cost center should be included here. However, care should be taken to ascertain that all costs included in this cost center do not belong to a different cost center.
Standard Unit of Measure: Number of FTE employees

Account 8630 Public Relations
This cost center contains the direct expenses incurred in the public relations/community relations function and expenses associated with fund-raising.
Standard Unit of Measure: Total revenue

Account 8650 Personnel
This cost center shall be used to record the direct expenses incurred in carrying out the personnel function of the hospital.
Standard Unit of Measure: Number of FTE employees

Account 8660 Auxiliary Groups
This cost center contains the direct expenses incurred in connection with hospital auxiliary or volunteer groups.
Standard Unit of Measure: Number of volunteer hours

Account 8670 Chaplaincy Services
This cost center contains the direct expenses incurred in providing chaplaincy services and in maintaining a chapel for patients and visitors. It does not include those services as defined in "Social Services."
Standard Unit of Measure: Number of hospital patient days

Account 8690 Medical Records
This cost center contains the direct expenses incurred in maintaining the medical records function.
Standard Unit of Measure: Number of inpatient admissions plus one-eighth of total emergency room and clinic visits

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Notes

1. The only accounting paper that we know of apart from Noreen and Soderstrom (1994) that has explicitly tested the assumption that overhead costs are strictly proportional to activity is Banker and Johnston (1993). The focus of their paper is estimation of cost drivers for the U.S. Airline industry. In the course of their analysis, they note that there appear to be increasing returns to scale for ground property and equipment, general overhead, and maintenance materials and overhead in their time-series study of aggregate industry costs and activity. However, they do not explore the extent and implications of the increasing returns to scale that they find.
2. See Mak and Roush (1994), Malcolm (1991), and Kaplan (1994).
3. Conversations with several hospital controllers and with personnel having extensive experience with accounting systems in hospitals in Washington State indicated that hospitals ordinarily use the WSDOH chart of accounts and activity definitions in their internal reporting systems. In addition, we mailed a questionnaire to the hospitals in Washington state. For the accounts we analyze, the activity measures specified by the WSDOH for use in regulatory reports were also used by an average of 82% of the hospitals in their internal management accounting systems.
4. WSDOH mainly uses automated checks of the data. They verify that cost elements add up to the totals given by the hospital. If there are large variations from year to year in the data, the data are examined in greater detail. Variables that appear more than once in the data set are checked for consistency. Personnel at WSDOH believe errors are most likely in the units of measure data since there are no totals or redundant data available for cross-checking. Hospitals also have an opportunity, prior to publication, to correct any errors in reports that are based on the data.
5. See Soderstrom (1993) for a discussion of the Medicare system.
6. See Noreen (1991) for derivation of the assumptions of activity-based costing and conventional cost systems.
7. Some have suggested that the denominator in the overhead rate should be the activity level at practical capacity rather than actual or budgeted activity. As discussed later, if this suggestion is followed, it should improve the predictive accuracy of the ABC model.
8. A distinction is drawn in the ABC literature between spending models and resource consumption models. Advocates point out that ABC is intended to be a resource consumption model rather than a spending model that attempts to predict changes in spending. However, consumption of a resource is important only if (a) spending ultimately is affected or (b) the resource is a constraint or (c) the resource can be shifted to a constraint. The data allow us to measure the costs of (a) and (c), but not (b). If, for example, there is a decline in activity in a cost pool and the resource is not a constraint, then resources can presumably be saved or redeployed. In either case, there should eventually be a reduction in spending in the cost pool. However, we cannot measure opportunity costs associated with consumption of constrained resources.
9. The medical care consumer price index was taken from the *Statistical Abstract of the United States, 1993, 113th edition*, US Department of Commerce, Bernan Press, Lanham, MD, p. 482.
10. Note that errors in estimating the inflation rate would still be a concern to the extent that decision-makers in hospitals are unable to predict future changes in prices with precision.
11. If the technology parameter α is not constant, the "implicit inflation rate" will impound changes in α as well as changes in input prices.
12. The procedure followed in constructing Table 3 allowed implicit inflation rates to differ by hospital for each year and account. We also ran a test in which the inflation rate was constrained to be the same across hospitals for each account and year. Specifically, we performed a grid search for implicit inflation rates within $\pm 10\%$ of the inflation rate in the medical care consumer price index for each account and year in our analysis. We searched for the implicit inflation rate within that band that maximized the number of observations for which the proportional cost model outperformed the fixed cost model for that particular account and year. If, for over

50% of the hospitals in a particular account-year, the estimation error for total cost was less for the proportional cost model than for the fixed cost model, we counted the account-year as a success for the proportional cost model. Otherwise, we counted it as a failure for the proportional cost model. Overall, the proportional cost model outperformed the fixed cost model in only 17% of the account-year combinations—even though the inflation rate was explicitly adjusted to make the proportional cost model look as good as possible relative to the fixed cost model. In the other 83% of the account-years, the fixed cost model still outperformed the proportional cost model.

13. The binomial test is based upon the overall percentage of observations in which costs were overestimated with the proportional cost model. In the case of the Dietary account, there were a total of 711 observations in which activity was up and 618 observations in which activity was down. Excluding the 23 observations in which there was no change in activity, the overall percentage of observations in which costs were overestimated was 55% $(= (711 \times 78\% + 618 \times 28\%)/(711 + 618))$. The binomial test consisted of computing the probability of obtaining a record of 78% successes in 711 trials in which the probability of a success on any one trial was 55%.
14. See Noreen (1989) for an explanation of approximate randomization tests. In this particular case, the data can be visualized as a matrix, one for each account. The rows of the matrix each represent a hospital-year observation. There are two columns. The first column contains a dummy variable that indicates whether activity increased or decreased. The second column contains the value of Z_t for the hospital-year. To assess significance of the test statistic, the first column was shuffled relative to the second column. This effectively scattered the Z_t observations at random across the two groups—increasing-activity and decreasing-activity. The test statistic was then recomputed for this random grouping. In this way, an empirically-determined distribution of the test statistic was constructed for each account under the null hypothesis that the prediction errors are independent of whether activity increased or decreased. In 999 randomization trials for each account, there was not a single trial in which the value of the test statistic was as large as it was for the original, unshuffled data.
15. Or, alternatively, costs may be incurred in anticipation of future increases in activity. We will consider the possibility that changes in costs lead, rather than lag, changes in activity in the next section.
16. Unfortunately, the percentage of observations for which the variable cost model is more accurate than the fixed cost model is not generally a well-behaved concave function of ∂_0 with a unique maximum. Therefore, a grid search was necessary in order to find the maximum of the function. The possibility exists that the grid search was not fine enough to find the true maximum, although we find that to be highly unlikely based on graphs of the function.
17. There are differences in the number of observations between Tables 2 and 5 due to lagged activity data was required to construct Table 5. Some of the observations in Table 2 dropped out due to missing lagged activity data.
18. The approximate randomization test was based upon a data matrix in which each row represented a hospital-year and each column represented a variable. (There was one data matrix for each overhead account.) The variables consisted of the deflated total costs for period t and t-1, the activity measures q_t and q_{t-1}, and the ratios q_{t-1}/q_t and q_{t-2}/q_{t-1}. The test statistic was the improvement in percentage of observations in which the variable cost model was more accurate than the fixed costs model. Using the original data matrix, the value of ∂_0 that maximizes the test statistic was determined by a grid search. This resulted in the value of the test statistic that appears in Table 5. For example, the value of the test statistic for Dietary is 3.7%. To assess the value of this test statistic, the ratios q_{t-1}/q_t and q_{t-2}/q_{t-1} were shuffled together relative to the rest of the data in the data matrix. The shuffled q_{t-1}/q_t ratios were multiplied by the unshuffled values q_t to determine the "pseudo" values of q_{t-1} to use in the numerator of the multi-period model (12). The shuffled q_{t-2}/q_{t-1} ratios were multiplied by the unshuffled values q_{t-1} to determine the "pseudo" values of q_{t-2} to use in the denominator of the multi-period model (12). The grid search was then carried out to find the value of ∂_0 that maximizes the test statistic for this generated data. In this way, the distribution of the test statistic was generated under the null hypothesis that the cost data are independent of the lagged activity terms.
19. Approximation (14) is obtained from equation (13) using a Taylor's series expansion.
20. The earlier tests are robust since they depend only upon the percentage of observations for which the absolute prediction error is greater than 1 and the sign of the prediction error. Therefore, the magnitude of an outlier would have little or no impact on the tests. Nevertheless, to check the robustness of our earlier tests, we reran them after applying the data screen described in this section. There was no material change in any results.
21. We deflated the total cost using the medical consumer price index before screening the data.

22. In addition to using a screening value of 0.4, we reran the tests for all accounts using screening values of 0.1, 0.2, 0.3, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.5, 2.0 as well as no screen at all. In no case was the estimated marginal cost greater than 45% of the average cost and the hypothesis that the β_0 is 1 was rejected at the 0.0005 level or better in every case.
23. Adding an intercept term to the model mainly affected the θ coefficient. The impact on other terms in the regression was very minor and did not change any inferences.
24. There are fewer observations in Table 7 than in Table 6 due to the additional variable, q_{t-2}, which must be screened.
25. One possibility, suggested by the results reported in Foster and Gupta (1990), is that more aggregate activity measures should be used. They found that direct labor-hours, an aggregate measure of activity, explained more of the variation in most overhead accounts at one company than more refined activity measures suggested in the activity-based costing literature. We reran all of the tests in this study using two measures of overall hospital activity—adjusted patient-days and total hospital revenue. None of the results were any more favorable to the variable cost model.

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