Allocating Physicians' Overhead Costs to Services: An Econometric/Accounting -Activity Based- Approach

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Abstract

Using the optimizing properties of econometric analysis, this study analyzes how physician overhead costs can be allocated to multiple activities to maximize precision in reimbursing the costs of services. Drawing on work by Leibenstein and Friedman, the analysis also shows that allocating overhead costs to multiple activities unbiased by revenue requires controlling for revenue when making the estimates. Further econometric analysis shows that it is possible to save about 10 percent of overhead costs by paying only for those that are necessary.
Key Words: Activity-based-costing, physicians, overhead, regression, allocation.

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Introduction

Both insurance companies and governments (at all levels) must pay for physicians' services. One recommended way of doing this is to pay resource costs, economists’ 'average cost pricing'. For example, Medicare hospital payments by diagnosis are designed to do this on average. It is straightforward, if not trivial, to pay resource costs by service for physician work and direct practice expenses. Values exist for each as seen respectively in the Resource Based Relative (physician work) Values established by Hsaio et.al and the direct practice cost values developed by the Health Care Financing Administration's Office of Strategic Planning and Abt. Associates are found in the Federal Register.[1] However, paying resource costs for overhead is not as easy, since linkages between these costs and services are indirect and ambiguous.[2]

The accounting technique activity based costing (ABC) can be used to allocate physician overhead costs (OC) to activities, and given that activity quantities are known by service, to services.[3] Our observed OC are on a per physician basis within surveyed practices as reported in the 1988 Physicians’ Practice Costs and Income Survey (PPCIS).[4] Unit OC for activities (starting with a single activity) are estimated using econometric cost functions so that knowing activity levels –for services, practices, etc.- one can determine the OC associated with those levels. Using multiple activities (along with relevant control variables) improves the allocative precision vis a vis a single activity because of the optimizing properties of regression analysis. Bringing efficiency criteria to bear reveals potential cost savings. ABC has been adopted by several federal government agencies to promote efficiency.[5] We propose extending that idea here.

Background, Overview and Preview of Results

Activity-Based-Costing. ABC is an accounting technique for allocating OC to services (or goods) which as Baker (1998) states, "differs from the traditional approach because of its fundamental concentration on activities."[6] The ABC methodology measures OC and their consumption by activities used to perform services -recognizing the causal relationship: OC to activities to services- so that OC can be allocated to services. Thus a typical ABC approach utilizes a series of cost pools and a proportionately greater number of activities than do most traditional costing approaches to OC. The ABC approach also differs from the traditional approach to assignment of OC because of its fundamental concentration on the inputs to services.

After activities are identified and defined, ABC is done in two steps: 1. OC per unit activity are estimated for one or more activities used in producing services (which are defined by Current Procedural Terminology (CPT) codes, American Medical Association);[7] and 2. The allocation of OC to each service is then calculated, first by multiplying the unit costs from step 1 by the respective quantities of activities used to produce each service (e.g. for physician office visits take X minutes of physician time, Y units of staff time, etc.), and then summing the results.

Stuart and Baker give an example of how OC can be allocated to one activity, a physician’s time in hours (PH).[8] In this instance a physician practice's OC are divided by PH to get OC per physician hour (step 1). Taking PH by service from practice records, OC for each service are then calculated: OC per hour times PH for that service (step 2). Dunn and Latimer use the same method to assign OC to services with national data. Backing this up with analytical work, Latimer and Becker (L&B) argue that OC (what they call indirect costs) "***should*** … be allocated on the basis of [PH] … ." [Emphasis added.][9]

The L&B article criticizes a Physician Payment Review Commission (PPRC) report, which argues that OC should be allocated on the basis of (physician) work plus direct costs.[10] Their critique draws two conclusions; we agree with them about the second but not the first.

Taking these conclusions in turn, L&B first argue that direct cost measures should not also be used to allocate OC. They summarize PPRC's reasoning for using direct costs (in terms of nonphysician work) as follows, "If [overhead] costs are to be allocated on the basis of work [pay rate times hours], and if physician and nonphysician work are somewhat substitutable, then [overhead] costs may be allocated on the basis of physician and nonphysician work combined, which is fairly closely related to the sum of physician work and direct costs." In their critique L&B note that "physicians are more constrained by their own time than by the sum of their own time and nonphysician time or work," reasoning that "[a]llowing physicians to recover more [overhead] costs for services that require more nonphysician assistance would give them an incentive to favor those services." They conclude that using direct costs items such as staff hours (SH) as allocators of OC is not appropriate; PH alone should be used.

While we agree that the sum of PH and SH (or their costs) is inappropriate, we do not agree that SH (and/or other direct cost measures) should not be used. This is because the L&B incentive argument is symmetrical. If both SH and PH are necessary to produce services and both affect OC, both should be included as allocators, even though staff hours (or their cost) may have a relatively lower per unit affect on OC than physician hours (or their cost). In our view the task is to determine the distinguishable effects of all relevant allocators on OC; eliminating SH as an allocator is inappropriate since using PH alone would give practices the incentive to favor services requiring little or no SH. L&B state that their criterion is an "incentive-neutral fee schedule." It is ours as well.

Accordingly, after estimating simple one-activity models where OC are a function of PH, we estimate a series of models where OC are a function of multiple activities used to produce services. Each successive refinement of the models brings to bear an additional relevant criterion. The result of this process is to give unit OC for the various activities, which -if used for payment purposes- will lead to incentive-neutrality and improve precision in matching payments to the costs of services.

The ABC Method. In ABC, the costs of producing services are allocated first by determining the actual costs of the variable inputs (activities) used in the process. The balance, overhead costs, are then allocated through a cause-and-effect relationship with activities. The choice of activities to be used for purposes of allocation is a key step in the application of ABC methodology. Our data set includes a number of activities, which might generate OC but a number -potentially associated with OC- were ruled out. Most of these were excluded because reasonable cause and effect relationships were not present. Others did not have standard values by service (e.g. office space per physician).

We chose the four activities we did to gain precision across specialties and practice types, while not violating the parsimony dictum. They include patient activity time per physician, the above noted hours per physician (PH), but split into in-office hours (INH) and out-of-office hours (OUTH). The former would be expected to generate greater OC per hour than the latter because INH require greater facility use. We also posit two other germane activities: per physician staff hours (SH) and per physician equipment and supply dollars (E&SD).[11] SH should, for example, help distinguish the OC of internists from psychiatrists; higher numbers of staff per physician are required for the former than the latter and as a consequence generate a greater need for facilities and other overhead. E&SD should help differentiate the OC of opthamologists from neurosurgeons; the former require greater levels of equipment and supplies per physician –and thus more space and support services, pushing OC higher- than the latter. In both instances, OC vary directly with requisite inputs (activities), respectively, SH and E&SD.

Data. Our data base, the 1988 PPCIS, is composed of responses from 3,505 practices; 2,737 are usable.[12] It includes 1988 OC, numerous potential driving activities, and other relevant variables. More recent (American Medical Association) surveys are only half its size and do not define OC as precisely. Since our purpose is both to develop a methodology and get precise baseline estimates of unit activity costs, we chose the older, but more promising, data set.

Our regressions use 2,137 of the 2,737 practices as observations. We omitted data outliers which could influence the results, but whose values are unrealistic or did not reflect the ordinary range of practice circumstances. These included six types: 1. Extremely lucrative practices, per physician revenue (REV) more than $650,000 (it ranged up to $1.8 million); 2. Low REV practices, less than $50,000; 3. Practices for which OC exceeded $50,000; 4. Practices with extraordinarily low office rent or purchase costs per physician, under $1,000 (The latter may reflect the perceptions of some practices, but probably not opportunity costs); 5. Practices where PH were less than 10 hours per week; and 6. Practices where PH exceeded 70.

Methodology. OC are posited to be a linear function of the four activities with no intercept. Under this specification, each activity's regression coefficient is its estimated unit OC: OC per hour for INH, OUTH, and SH, and OC per dollar for E&SD. Each resultant unit cost can then be multiplied by its respective average per physician activity amount to get average dollars per physician for each activity and implicitly the distribution of OC by activity. Multiplying respective unit costs by standard service values for INH, OUTH, SH and E&SD gives each service's OC by activity; adding then gives the OC for each service.

A linear activity cost function is used because it gives unique average unit overhead costs by activity. Including an intercept yields activity coefficients, which are estimates of marginal unit costs, and the intercept is a residual of OC not assigned to an activity (if it is positive, as in our estimates). But such a residual is our original problem of unassigned OC all over again. Other more complex functions ordinarily used when estimating cost functions (e.g. a translog) produce nonunique unit activity costs varying with activity amounts. But without unique unit activity costs, we will not get unique OC by service. As a check on the efficacy of this linear specification, below we compare its explanatory power (precision) with a specification having a highly flexible functional form.

We could have broken OC into various constituent parts (e.g. rent and utilities, services to practices,[13] automobile, education), but did not, as it led to serious computational difficulties without adding materially to the analysis. However, such an extension would not be beyond the pale of future work.

Accounting for revenue effects. ABC methodology as it is typically applied uses only activities themselves as regressors in the OC equation thus resulting in activity coefficients reflecting current spending patterns. But the results can be further improved by extending this methodology. Leibenstein's theory of the firm tells us that practices' spending patterns reflect their financial well being as well as their activities. This will occur, for instance, if higher REV caused practices to spend more on overhead, staff, and equipment and supplies for its physicians. In this case, the coefficients will be biased by the omitted REV effect, with the coefficients of activities most correlated with REV overestimated and the others underestimated.[14] To find activity coefficients independent of REV, we control for it in two ways: 1. Specifying REV in our regression so that the four activities pay total current OC and 2. Specifying it so that the four activities pay the lower total OC to be had by assuming

REV has a central tendency equal to its typical rather than its higher mean value. The latter generates savings.

Finally, we respecify our regressions to eliminate the positive error term skewness reflecting inefficiency costs.

Results. Each of our four activities is an important determinant of OC. Their coefficients are all positive and highly significant in all regressions. In our ultimate result (controlling for REV, assuming typical REV and eliminating inefficiencies), INH account for 50 percent of OC; OUTH for 28 percent; SH for 17 percent; and E&SD 5 percent. Results were tested for robustness by splitting our sample. Separate regressions on the two subsets resulted in coefficients not significantly different from their counterparts; full data set coefficients are in between the two. Using the results from each subset to predict the other's average OC and their distribution by activity gives very similar results.

Our study has three innovations: 1. It develops a method to precisely assign unit OC to multiple activities, and since activity quantities are known by service, to services; 2. It shows how to allocate unit OC to activities independent of REV; and 3. It shows how payments can be set to cover only necessary OC. With regard to the latter, total OC are eight percent lower when assuming the central tendency of REV is its typical rather than mean value and two percent lower still when the model is respecified to eliminate the inefficiencies inherent in positively skewed errors. Potential savings in OC thus total 10 percent.

Allocating Overhead Costs to Activities

A Single Activity. The simplist way to do ABC is to find OC per unit for a single activity. For example, Stuart and Baker calculate OC per physician hour = OC/PH for a single practice.[15] But the procedure is analogous across practices: OC per hour = mOC/mPH, where m preceding a variable indicates its weighted mean. For our 2,737 useable PPCIS observations, mOC = $43,986.47 and mPH = 2,533.7 so that OC per hour = $17.36, or $.29 per minute.[16] OC can then be allocated to services based on physician minutes.

Regression analysis is a potentially more fruitful way to assign OC to activities. Equation (1) shows OC for the i^{th} physician as a simple linear function of PH:

$$OC_i = k \cdot PH_i, \tag{1}$$

where k is OC per physician hour. Running equation (1) weighted least squares (WLS) on our analytic data set of 2,137 observations results in:

$$\underset{}{OC_i} = \underset{(.23)}{17.10} \cdot PH_i, \tag{2}$$

standard error (s.e.) in parenthesis; R^2 = .728, which means PH alone explain nearly 73 percent of the ΣOC_i^2.[17] Regression errors are positively (and significantly) skewed, skew = 1.29. Their absolute values are also significantly correlated with PH (.12), the latter indicating heteroscedasticity.

Equation (2) implies OC can be allocated as $17.10 per physician hour ($.29 a minute). While this will not cover total OC for the full data set, our fitted k, k_f, can be adjusted. Using k_f we estimate fitted OC, $OC_{fi} = k_f \cdot P_i$, for all i=1, …, 2737 so that $mOC_f = k_f \cdot mPH$. To cover total OC (i.e. across all physicians) the needed adjustment is $ß=[\Sigma OC_i/\Sigma OC_{fi} = mOC/mOC_f)]$.[18] Multiplying k_f by ß gives payment per physician hour. Alternatively we could run:

$$OC_i = k' \cdot (1/ß) = PH_i, \qquad (3)$$

which results in:

$$OC_i = \underset{(.23)}{17.36} = (1/ß) \cdot PH_i. \qquad (4)$$

[19]

Multiple Activities. While the above is helpful, OC are driven by numerous activities, not just PH. Here we use four theoretically based activities for which data are available: INH, OUTH, SH, and E&SD. While finer gradations of these are possible and the list could be expanded, these seemed a suitable compromise between more drivers with greater precision and parsimony. Such decisions are important for applying ABC to data.

We rationalize the four activities as follows: 1. OC will vary with PH because greater physician hours result in greater facility use. But OUTH should generate lower OC per hour than INH. The greater the portion of PH represented by OUTH, the more facilities and their costs can be shared, or smaller facilities made to suffice, or facilities can be left vacant (thus reducing per physician janitorial costs, utility costs, etc.). 2. OC will vary directly with both SH and E&SD since each will drive work space and office expense requirements.

To allocate OC by activity, we assume constant OC per hour for each time based activity, respectively for INH, OUTH, and SH: a, b, and c, and constant OC per dollar for E&SD, d, so that:

$$OC_i = a \cdot INH_i + b \cdot OUTH_i + c \cdot SH_i + d \cdot E\&SD_i. \quad (5)$$

Running equation (5) WLS, again using our analytic data set of 2,137 observations, gives:

$$\underset{(.59)}{OC_i = 9.37 \cdot INH_i} + \underset{(.60)}{10.33 \cdot OUTH_i} + \underset{(.16)}{2.38 \cdot SH_i} + \underset{(.028)}{.278 \cdot E\&SD_i}, \quad (6)$$

s.e.'s in parens, R^2=.779; errors again skewed significantly positive, skew=1.22, and a White test rejects homoscedasticity, $chi^2(10)$=63.8.[20] Rescaling each coefficient by the ratio = mOC/mOC_f = $43,987/$43,440 so that all OCs are covered (following the method seen above) for equations (3) and (4), we get:

$$\underset{(.59)}{OC_i = 9.49 \cdot INH_i} + \underset{(.60)}{10.46 \cdot OUTH_i} + \underset{(.16)}{2.41 \cdot SH_i} + \underset{(.028)}{.282 \cdot E\&SDOLS_i}. \quad (7)$$

Going from one activity to four increases precision, the explained sum of squares rising from 73 to 78 percent of the total. Comparing equation (4) to equation (7) –i.e. including additional activities- the unit cost of PH drops from $17 to about $10 per hour for both INH and OUTH. The difference between latter two ($9.49/hr-$10.46/hr) is insignificant and negative (z=-1.1), so we cannot accept the hypothesis that the first exceeds the second. The SH coefficient is highly significant, implying that using just PH would underpay physicians with high staff to physician ratios (e.g. pediatricians) and overpay those with the reverse (e.g. psychiatrists). A similar type of specialty distortion would exist for low vs. high E&SD

practices.

Equation (7)'s coefficients multiplied by the respective activity weighted averages for all practices from Figure 1, gives the estimated average OC and its distribution by activity in Figure 2.

- Figures 1 and 2 are found at the end of the paper -

Figure 2 implies that while INH and OUTH account for something over half of OC, SH and E&SD are also major drivers of OC.

But further refinements are needed. To start with, a problem arises when regressing OC only on activities; the results will automatically reflect the current activity mix, which in turn will reflect per physician revenue (REV). To see why this is, and why it is important, we next consider REV effects on the allocation of OC.

Controlling for Revenue

To see the effects of REV on OC we start with Leibenstein's theory of the firm (1979), wherein he says, "the pressure that the management imposes inside the firm will depend not only on cost but also the level of environmental tightness ... [F]or a tighter environment [output unit cost is below] what it would be for [a] looser environment."[21] All else equal, the higher the price, the lower the pressure and the higher the unit cost. He concludes: "1. the [unit] cost of a commodity is not independent of the price of the commodity; 2. except in the extreme circumstances firms do not minimize costs; 3. [unit] cost of production has a tendency to rise toward the price level; and 4. there is no production function independent of the environment of the firm and the history of the firm."

We apply Leibenstein's theory by positing that fiscal pressure is an inverse function of REV (price times volume): the greater the REV, the lower the pressure and the greater the total costs (output unit cost times volume). That is, if you have it, you spend it. This theory is analogous to Milton Friedman's permanent income hypothesis, wherein permanent household consumption varies with permanent income so that the long-run consumption to income ratio is constant.[22] Supporting this proposition for medical firms, a study of hospitals by Peden (1992) showed that permanent costs vary directly with permanent revenue; total costs adjust adaptively to revenues so that over time the cost-revenue ratio is constant.[23] The Peden study's causality tests also indicate that revenue causes costs, not vice versa.

Following the above logic, we posit that OC varies directly with REV, but not necessarily proportionally, since OC are only a part of total costs and the spending mix can change for different levels of REV (just as it does for individuals of different income levels). REV will also affect spending for other inputs (activities) and their mix. For example, we posit that higher REV practices will employ more staff per physician than others. But if this is the case and REV also has a direct effect on OC, regressing OC on activities with no control for REV would result in SH picking up REV effects, that is, its coefficient will reflect relative prosperity, not just the unit overhead cost of staff hours. An analogous situation may also exist for the E&SD coefficient as more lucrative practices pay more for more (and more upscale) equipment and supplies. Another activity may not be affected by REV, but be correlated with it and coincidentally pick up its effects. For instance, the OUTH coefficient reflects surgeons' hospital time and -since surgeons tend to have higher REV than most other types of physicians- the effect of REV on OC. In sum, in regressions omitting REV, the coefficients of activities differentially correlated with REV will be biased since they reflect these relative correlations, not just resource requirements. Seen another way, by including REV the relative weights of activity coefficients will not reflect it.[24] The ABC methodology assumes that activities consume overhead resources to produce an output.[25] Controlling for REV neutralizes the effects of external pressure and allows us to gauge each activity's effect on OC independent of it.

We control for REV in our regressions using two alternative criteria: 1. All current OC are allocated to our four activities (so that in total REV effects are zero) and 2. Activity coefficients are scaled down so that activities cover only requisite OC.

One way to control for REV without affecting total OC, is to add the variable (REV-mREV) to equation (5). However, existing evidence indicates the relationship between cost and revenue is a power function, i.e. REV is a multiplicative term on the right-hand-side.[26] Indeed when comparing regressions, those with a multiplicative REV term have smaller sums of squared errors than those with an additive term.[27] Initially, we express the multiplicative form as:

$$OC_i = [a \cdot INH_i + b \cdot OUTH_i + c \cdot SH_i + d \cdot E\&SD_i] \cdot (REV_i/sREV)^e, \qquad (8)$$

where sREV is level of REV such that all OC are covered when $REV_i/sREV=1$. Under this specification, per unit activity costs (the activity coefficients) will be reckoned independent of REV effects.

Not knowing sREV, we estimate it as follows. First run equation

(8) setting sREV=mREV as a first approximation. The parameter e will be the same (with the same s.e.) using mREV as using sREV. But more importantly, the relative activity coefficients will differ from equation (8)'s coefficients only by their scale. This can be seen if we express equation (8) as:

$$OC_i = [a \cdot INH_i + b \cdot OUTH_i + c \cdot SH_i + d \cdot E\&SD_i] \cdot [(REV_i/mREV) \cdot (mREV/sREV)]^e$$

$$= [a \cdot INH_i + b \cdot OUTH_i + c \cdot SH_i + d \cdot E\&SD_i] \cdot (REV_i/mREV)^e \cdot (mREV/sREV)^e. \quad (9)$$

In equation (9) the last term, $(mREV/sREV)^e$, is a constant whose inverse is the needed scaling factor. Thus after running equation (8) we can use mREV to calculate the rescaling factor and then sREV as follows:

1. Calculate the mean of the fitted OC_{fi},

$$mOC_f = [a \cdot mINH + b \cdot mOUTH + c \cdot mSH + d \cdot mE\&SD]. \quad (10)$$

2. Solve for the scaling factor $1/(mREV/sREV)^e$:

$$1/(mREV/sREV)^e = (mOC/mOC_f), \quad (11)$$

(since mOC is known).

3. Solve for sREV as we already know mREV. Putting sREV in equation (8), the latter can then be rerun.[28]

Following these steps, first we substitute mREV for sREV in equation (8) and run it weighted nonlinear least squares (WNLS):

$$OC_i = [\underset{(.66)}{17.00} \cdot INH_i + \underset{(.52)}{11.03} \cdot OUTH_i + \underset{(.14)}{1.14} \cdot SH_i + \underset{(.023)}{.076} \cdot E\&SD_i] \cdot (REV_i/mREV)^{\underset{(.031)}{.649}}, \quad (12)$$

asymptotic s.e. in parenthesis. R^2=.817, error skewness is significant (skew=0.89), and a White test strongly rejects homoscedasticity: $chi^2(14)=220.8$.[29] These summary statistics apply to equations (13)-(15) as well. By controlling for REV, the percentage of ΣOC^2 explained rises from 77.9 [equation (7)] to 81.7. More importantly, controlling for REV gives unbiased relative unit costs for the activity drivers.[30]

Since mOC = $43,986.47 -and using the activity coefficients of equation (12) and the means of Table 1 in equation (10) to get mOC_f = $44,300.09- the rescaling factor of equation (11), $1/(mREV/sREV)^e$, is equal to .9929. Thus since e=.649 and mREV = $291,459, sREV=$288,287.

Rerunning equation (8) WNLS given the latter, results in:

$$OC_i=[\underset{(.65)}{16.88}\cdot INH_i+\underset{(.51)}{10.95}\cdot OUTH_i+\underset{(.14)}{1.13}\cdot SH_i+\underset{(.022)}{.075}\cdot E\&SD_i]\cdot[(REV_i/sREV)]^{\underset{(.031)}{.649}}. \quad (13)$$

A possible drawback of using REV as a regressor is that OC may affect REV as well as vice versa. If greater spending for rent, practice managers, etc. increases REV, causality runs both ways and REV is endogenous. If true, an exogenous instrument should be used in its place. Unfortunately the WNLS endogeniety test used did not converge for equation (8). In our ultimate regression, equation (19) below, it does; we discuss the latter results below.

In equations (12) and (13) REV is highly significant and its presence consequential. The estimated exponent of REV, 0.649, is an elasticity implying that a 10 percent REV increase causes a 6.5 percent rise in OC. While each activity coefficient is again highly significant, there is a marked change from equation (7) in their relative effects; the INH coefficient rises from $9 to $17 per hour in equation (13). Those of SH and E&SD drop sharply (in turn, from $2.41 to $1.13 per hour and .282 to .075). The OUTH coefficient stays about the same. While equation (7) showed no significant difference between INH and OUTH effects, in equation (13) the effect of INH is significantly greater than the effect of OUTH, supporting our original hypothesis (The z-statistic of the difference is 7.0). This implies that the absence of REV caused equation (7)'s INH effect to be understated and its SH and E&SD effects overstated because the latter were picking up positive REV effects. Correlations of REV with INH, OUTH, SH and E&SD (in turn: -.10, .24, .47, and .42) support this scenario.

There is another notable item. REV is highly skewed to the right: starting from 0, its frequency rises to a peak of $257 thousand, declines quickly, and then tails off slowly (maximum REV=$1.8 million, see Figure). Restricting REV to the range $50-$650 thousand simply cuts off the tails. Using equation (13), OC is allocated to activities assuming REV=sREV=$288 thousand, which is about $30 thousand above the typical (peak) range of REV levels. This implies that the scale of the activity coefficients -in this regression where activities cover total OC- is strongly influenced by relatively few lucrative practices in the right tail of the REV distribution, rather than reflecting typical REV levels. Assuming that typical REV practices are covering their costs satisfactorily, we infer that the OC generated by REV in excess of what is typical are not necessary; OC reimbursement savings can be realized by assuming REV has a central tendency equal to its typical rather than its mean value.

We define typical REV, tREV, in four steps: 1. Transform REV to be REV^{α});[31] 2. Search over the possible values of α so that REV^{α} is not skewed [for the data set of 2,737 observations, α=.2]; 3. Find the mean of the transformed variable, $m(REV^{.2})$ [the peak of the distribution of $REV^{.2}$]; and 4. Invert $m(REV^{.2})$ by 1/.2 to get tREV [$=m(REV^{.2})^{1/.2}$=\$256,869, which, as we've seen, is near the peak of the distribution of REV].[32,33] Modifying equation (8) to account for the change in central tendency from mREV to tREV results in:

$$OC_i=[a\cdot INH_i+b\cdot OUTH_i+c\cdot SH_i+d\cdot E\&SD_i]\cdot(REV_i/sREV)^e\cdot(mREV/tREV)]^e$$

$$=[a\cdot INH_i+b\cdot OUTH_i+c\cdot SHR_i+d\cdot E\&SD_i]\cdot[(REV_i/sREV)\cdot(mREV/tREV)]^e. \quad (14)$$

Running equation (14) scales down equation (13)'s the activity coefficients by the factor $1/(mREV/tREV)^e$ since the REV term, $(REV_i/sREV)^e\cdot(mREV/tREV)^e$, is scaled up by $(mREV/tREV)^e$.

WNLS on equation (14) gives:

$$OC_i=[\underset{(.57)}{15.55}\cdot INH_i+\underset{(.48)}{10.09}\cdot OUTH_i+\underset{(.13)}{1.04}\cdot SH_i+$$

$$\underset{(.021)}{.069}\cdot E\&SD_i]\cdot[(REV_i/sREV)\cdot(mREV/tREV)]^{\underset{(.031)}{.649}}, \quad (15)$$

Using Figure 1 activity averages, equation (13) implies greater average OC than equation (15) but the same distribution by activity (see Figure 3).

- Figure 3 is at the end of the paper -

Average OC predicted by equation (13) is \$43,965, by equation (15) \$40,497, an 8 percent drop. In Figure 3 over half of average OC is accounted for by INH; one-quarter by OUTH; one-seventh by SH and one-thirtieth by E&SD. This contrasts sharply with Table 2 (no control for REV): one-third INH, one-quarter OUTH, one-third SH and one-eighth

E&SD.

But positively skewed and heteroscedastic errors imply that even further refinement is required.

Solving Error Skewness and Additional Cost Cutting

When estimating cost functions using firm level data positively skewed errors -like those of equations (12)-(15)- often reflect inefficiencies, i.e. costs above those necessary. A payment system covering requisite costs would eliminate these.[34]

Fortunately a requisite cost function can be estimated by lowering the weights given to inefficient practices, i.e. those generating the positively skewed errors. Up until this point an additive error term has been assumed. But our latest theoretical expression, equation (14), can be amended to have the multiplicative error term, $\exp(v_i)$ seen in equation (16).

$$OC_i=[a\cdot INH_i+b\cdot OUTH_i+c\cdot SH_i+d\cdot E\&SD_i]\cdot[(REV_i/sREV)\cdot(mREV/tREV)]^e\cdot\exp(v_i), \quad (16)$$

where we assume $v_i.N(0,\sigma_v^2)$. Taking the natural log gives:

$$\log(OC_i)=\log[a\cdot INH_i+b\cdot OUTH_i+c\cdot SH_i+d\cdot E\&SD_i]+e\cdot[\log(REV_i)-\log(sREV)+ \log(mREV)-\log(tREV)]+v_i. \quad (17)$$

The test will be whether the estimated errors are well-behaved when equation (17) is run. Accordingly WNLS results in:

$$\log(OC_i)=\log[\underset{(.53)}{13.75}\cdot INH_i+\underset{(.44)}{9.82}\cdot OUTH_i+\underset{(.14)}{1.24}\cdot SH_i+ \underset{(.028)}{.123}\cdot E\&SD]+\underset{(.027)}{.466}\cdot[\log(REV_i)-\log(sREV)+\log(mREV)-\log(tREV)], \quad (18)$$

asymptotic s.e.s in parenthesis. Error skewness and nonnormality tests are insignificant, respectively: skew = 0.01 (z=0.18) and $chi^2(2)$ = 0.09.[35] But homoscedasticity is again rejected, as a White test is highly significant, $chi^2(14)$= 104.9.

To correct for heteroscedasticity, we used a two-step reweighting procedure from Fomby, Hill and Johnson.[36] This resulted in the following reestimate of equation (17):

$$\log(OC_i)=\log[\underset{(.51)}{13.89}\cdot INH_i+\underset{(.40)}{9.91}\cdot OUTH_i+\underset{(.13)}{1.19}\cdot SH_i+\underset{(.026)}{0.109}\cdot E\&SD]+$$

$$\underset{(.025)}{.462}\cdot[\log(REV_i)-\log(sREV)+\log(mREV)-\log(tREV)]. \quad (19)$$

Skewness and nonnormality tests are again insignificant: skew = 0.01 (z=0.17) and $chi^2(2)$ = 0.04. A White test indicates heteroscedasticity is present, but the test statistic is less than for equation (18), $chi^2(14)$= 75.0; finally, the s.e.'s declined. Coefficient changes from equation (18) to (19) are negligible.[37,38]

Equations (18) and (19) assume $\log(REV_i)$ is exogenous. A simultaneity test from Spencer and Berk is used to test this.[39] To wit, an instrument for the questionable variable, $\log(REV_i)$, is estimated by regressing it on exogenous variables and adding it to the original regression; if it is significant, exogeneity is rejected. We regressed $\log(REV_i)$ on 95 exogenous variables, including: practice size, parts of the country dummies, specialty, physician age, a solo dummy, board certification, and numerous polynomial terms. Its fit, $\log(REV_{fi})$, was then added to equation (17) as $[\log(REV_{fi})-\log(sREV)+\log(mREV)-\log(tREV)]$. In the ensuing run, the latter’s coefficient is not significant in either its equation (18) form, asymptotic t=-0.50, or its equation (19) form, t=-.74, form; exogeneity is not rejected and the above results stand.[40]

Equation (19) -our reported result- implies that both INH and OUTH have significant positive effects on OC. But the OC per hour generated by INH are significantly greater than OUTH, and greater than when not controlling for REV, equation (7). SH and E&SD also have significant positive effects on OC, but the respective per hour and per dollar OC generated by these activities, are each are less than half of their equation (7) estimates. The coefficient of REV implies that the elasticity of REV on OC is about 0.46; if REV increases 10 percent, OC will rise about 4.6 percent. This seems sensible since a number of OC categories -e.g. rent, utilities, janitorial services- are analogous to consumer necessities whose income elasticities are less than 1. Using equation (19) and Figure 1 activity averages, Figure 4 shows the estimated average OC and its distribution by activity driver: INH account for 50 percent of OC, OUTH 28 percent, SH 17 percent and E&SD 5 percent.

- Figure 4 is at the end of the paper -

The estimated average OC drops from $40,497 (Figure 3) to $39,529 here, implying that the efficiency savings from assuming multiplicative, as opposed to additive, errors are 2.4 percent. Adding this to 7.9 percent in savings from estimating average OC at typical, as opposed to cost covering, REV levels, results in total savings of 10.3 percent. From Gonzalez and Zhang OC are 18.3 percent of REV, so reimbursement rates might be reduced 1.9 percent.[41] For Medicare in 1996 this would have been $650 million: 1.9 percent of $34.7 billion in 1996 physician fee-for-service payments.[42]

Checking for Robustness

To see if equation (18) and (19) results are robust we split our data into two groups: one with odd practice identification numbers (ids) (o) and a second with even ids (e). Running equation (17) WNLS for each group with no heteroscedasticity correction (see below) gives:

$$\log(OC_{oi})=\log[\underset{(.74)}{13.20}\cdot INH_{oi}+\underset{(.67)}{10.27}\cdot OUTH_{oi}+\underset{(.20)}{1.17}\cdot SH_{oi}+\underset{(.040)}{.156}\cdot E\&SD_{oi}]+$$

$$+\underset{(.038)}{.419}\cdot[\log(REV_{oi})-\log(sREV_{o})+\log(mREV_{o})-\log(tREV_{o})], \qquad (20)$$

for 1,066 observations, and

$$\log(OC_{ei})=\log[\underset{(.76)}{14.40}\cdot INH_{ei}+\underset{(.58)}{9.28}\cdot OUTH_{ei}+\underset{(.20)}{1.27}\cdot SH_{ei}+\underset{(.038)}{.084}\cdot E\&SD_{ei}]+$$

$$+\underset{(.038)}{.523}\cdot[\log(REV_{ei})-\log(sREV_{e})+\log(mREV_{e})-\log(tREV_{e})], \qquad (21)$$

for 1,071 observations. Both sets of errors are fairly well behaved: neither is skewed significantly ($skew_o$=-.03 and $skew_e$=.04) and normality is not rejected ($chi^2(2)$ statistics are 0.41 and 0.33). Neither simultaneity test rejects the exogeneity of $\log(REV_i)$.[43] But homoscedasticity is rejected for both runs; White tests are highly significant, respectively $chi^2(14)$=71.9 and $chi^2(14)$=47.2. No heterosecdasticity corrections were made as White statistics in each reweighted regression increased rather than decreased.[44]

All equation (18) and (19) coefficients are well within the range of their split sample counterparts from equations (20) and (21). Moreover, as a whole, the latters' coefficients are reasonably close to one another. The coefficients of INH, OUTH, and SH are very near their counterparts; the respective differences (8-10 percent of their levels) are not significantly different from 0. The two coefficients of E&SD are noticeably different -the second is about half the first- but again their difference is insignificant. Finally, the approximately 20 percent difference between the two coefficients of the REV variable is not significant, but this is marginal.[45]

To see what equations (20) and (21) imply, their respective activity coefficients are used to predict average OC and its distribution by activity (see Figure 5, activity averages from Figure 1).

- Figure 5 is found at the end of the paper -

Estimated average OC in Figure 5 are both close to the overall, $39,529 (from Figure 4). Their distributions by activity also follow the overall closely: INH account for about half of average OC in both; OUTH for a little over one-quarter; and SH for about one-sixth. Only E&SD are a little unstable, respectively at 7 and 4 percent.

Final checks used evens regression coefficients with even id activity averages to predict average OC and their distribution, then odds coefficients with odd averages, odds coefficients with even averages and evens coefficients with odd averages. All supported the similarities of Figure 5; but these flow naturally from the closeness of the even and odd averages seen in Figure 6.

- Figure 6 is found at the end of the paper -

Using equation (20) and (21) results across the three sets of activity averages: INH predicts 47-52 percent of average OC, OUTH 26-

29 percent, SH 16-18 percent, and E&SD 4-8 percent. Predicted average OC are also similar: odds coefficients-odd averages: $39,900, evens coefficients-even averages: $39,400, evens coefficients-odd averages: $39,700, and odds coefficients-even averages: $39,600. The full data set results, whether looking at total average OC or its distribution by activities, Figure 4, fall in the middle of the split sample results.

Summing Up What Was Found

Using the ABC paradigm, our analysis of 1988 PPCIS data shows that OC can be largely accounted for by practice activities. Regression (no intercept) shows PH alone explain nearly 73 percent of ΣOC_i^2. But multiple activities explain OC more precisely. Four activities -splitting PH into INH and OUTH, and including SH and E&SD- explain 78 percent with all coefficients highly significant. These activities (as opposed to PH alone) will, for example, pick up OC differences between pediatricians, with large staffs and copious equipment and supplies, and psychiatrists, who require less.

Regressing OC on activities alone however, gives biased coefficients when REV is omitted because OC is a function of REV and the latter is differentially correlated with the various activities. When REV are omitted coefficients reflect both activity effects and their relative correlations with REV. E.g., high REV practices spend more on overhead, but also on staff, equipment and supplies, which leads to coefficients weighted too heavily toward SH and E&SD. Unbiased activity coefficients require controlling for REV.

Controlling for REV, the INH coefficient rises sharply, but that of OUTH changes little. With no control for REV, they were about equal. The hypothesis that INH have a greater per hour effect on OC than OUTH is confirmed. SH and E&SD coefficients are cut in half, which implies that high REV practices spend freely for both overhead and support activities. The latter reflect an affluent 'business style', just as the extraordinary spending of high income households reflects an affluent 'life style'.

To control for REV we first used the variable REV/sREV in the regression given by equation (8). sREV is the fixed REV level such that, when summing over the estimated activity coefficients (their unit costs) times respective activity averages, exactly covers average OC; which also means current total OC will be covered. This occurs at sREV=$288 thousand, just below mean REV, mREV=$291 thousand. But mREV and sREV are both well above typical REV, tREV=$257 thousand, being strongly influenced by relatively few high REV practices. Adjusting sREV to reflect the central tendency tREV rather than mREV -as seen in equation (14)- removes the effects of lucrative practices. In the resulting regression summing over the revised activity coefficients times their respective averages results in average OC eight percent less than when using sREV. Thus by incorporating this REV adjustment, payments can be set eight percent lower than those which would reimburse current total OC across all physicians.

In all regressions up to this juncture [through equation (15)], errors are positively skewed, reflecting inefficiency costs. To remove the effects of these extraneous costs on the regression coefficients, the error structure of our model was modified from being additive to being multiplicative (additive when the model is logged). This indeed eliminated the positive skewness. Moreover, estimated OC were reduced by two percent, which is in addition to the eight percent reduction already seen. This implies that payments based on the latter model's activity coefficients -because they cover only requisite costs- result in total overhead reimbursements 10 percent below current total overhead costs.

Multiplying the activity coefficients (unit costs) of our ultimate regression [equation (19)] by their respective activity averages, results in overhead costs being distributed: INH: 50 percent, OUTH: 28 percent, SH: 17 percent, and E&SD: 5 percent.

Tests to determine if REV should be considered exogenous or endogenous, where the latter would mean replacing it with an instrument, do not reject exogeniety.

Finally we split our data set in half to see if our findings are robust. Analyzing each subset separately gives similar regressions. Respective activity coefficients of INH, OUTH and SH are within 10 percent of one another and their differences are not significant. The two coefficients of E&SD are different, but again their difference is not significant. The two coefficients of the REV variable are close; but their difference, although not significant, is marginal. Coefficients from our full sample regression [equation (19)] are, in all cases bracketed by their split sample counterparts.

Our full sample regression predicts average OC of $39,500 using overall activity averages; the split sample results respectively predict $39,700 and $39,500 using the same activity averages. In all three results INH, OUTH, and SH account for similar portions of OC (respectively half, a little over a quarter, and one-sixth). For E&SD

the portion varies between four and seven percent; its full sample portion is six percent. For each activity, its full sample OC percentage is bracketed by its split sample counterparts.

Inferences and Perspective.

Our study has three potentially useful inferences:

1. Pay based on multiple activities. ABC based on four activities distributes OC more precisely than just one. While this does not preclude the future inclusion of added and/or alternative activities (meeting theoretical and quantifiability criteria), things improved markedly in going from one to four.

2. Control for REV. When using multiple activity regressions to allocate unit costs to activities, controlling for REV neutralizes its effect on the relative unit costs of activities.

3. Realize savings. Base activity unit cost estimates on typical, rather than the higher mean REV. Regression results indicate that this saves about eight percent in unnecessary overhead expenses. Furthermore, an additional two percent in OC savings can be realized by not paying for other practice inefficiencies. Thus there are potential savings of around 10 percent when reimbursing OC, about 1.5 percent of all payments for physician services.

Based on our split sample check, our results appear robust enough to be used for payment purposes. However, we used only one year's data, and that is from 14 years past (1988) at this writing (2002). Even though we might expect some parts of OC (rent, utilities, janitorial services, etc.) to be fairly stable functions of the four activities, other parts (insurance, practice manager costs) probably change over time. This implies that the analysis might profitably be redone with more recent data: first, for verification purposes, and second, because intertemporal changes should become apparent when the analysis is repeated. Finally, the analysis might profitably be updated periodically as new data become available. This way, if any one year's results are at odds with intertemporal patterns, they can be discounted when setting payment rates.

Endnotes

1 Hsiao W.C., P. Braun, et al., A National Study of Resource-Based Relative Value Scales for Physician Services: Phase II. Cambridge, MA: Harvard University Publishing, 1988. Direct practice expense values (RVUs) are in Federal Register for June 18, 1997, vol. 62, Addendum C: pp. 33,196 - 33,300.

2 The final part of practice costs, malpractice insurance, was not included in this analysis because these costs could be assigned to activities in the same way as overhead. For one thing, they vary by specialty. In 1988, they were 11 percent of practice costs, but have since fallen, e.g. to six percent in 1998. For the former see, Gonzalez, M.L., Socioeconomic Characteristics of Medical Practice 1995, American Medical Association, 1995: pp. 114 and 132. For the latter see Wassenaar, J. D. and S.L. Thran, Socioeconomic Characteristics of Medical Practice 2000-2002, American Medical Association, 2001: pp. 62 and 67.

3 Activity based costing at the practice level can be seen in Stuart, T.J. and J.J. Baker, in Baker, J.J., Activity-Based Costing and Activity-Based Management for Health Care, Aspen Publishers, Inc., Gaithersburg, MD: 1998. For a global approach see Dunn, D.L., and E. Latimer, Derivation of Relative Values for Practice Expense Using Extant Data (Final Report), A research for the Health Care Financing Administration, HCFA Contract No. 500-92-0023. Federal Project Officer: Paula Kolick. Submitted by the Rand Corporation, 1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138, April 1, 1996.

4 This survey was conducted under Health Care Financing Administration Cooperative Agreement NO.99-C-98526/1-08, 1992. For a description of the survey and its results, see Dayhoff, D.A., et. al., Handbook for Using the 1988 Physicians' Practice Costs and Income Survey (Final report) Center for Health Economics Research, 300 Fifth Ave, 6th floor, Waltham, MA 02154, April 1992. Prepared under Cooperative Agreement NO.99-C-98526/1-08 for the Health Care Financing Administration.

5 See Serlin, M.D., The Company Goes Commercial, The Government Executive, July 1999: 20-28; LaGrange, G.L., "Fort Riley Serves the Soldier and the Taxpayer with $6 Million in Savings", As Easy as ABC, Issue No. 39, Winter 2000, pp. 1, 8, 12; and Norwood, R.F. "Veterans Benefits Administration is Discovering the Cost of Doing Business Using ABC", As Easy as ABC, Issue No. 38, Fall 1999, pp. 2-3, 12.

6 Baker, J.J., Activity-Based Costing and Activity-Based Management for Health Care, Aspen Publishers, Inc., Gaithersburg, MD: 1998: p. 2.

7 American Medical Association, Physicians' Current Procedural Terminology, cpt 98, Standard Edition, American Medical Association, Chicago, 1997, or the same publication for other years.

8 Stuart, T.J. and J.J. Baker, The Bottom-Up Approach to Process by Northwest Family Physicians, in Baker, J.J., Activity-Based Costing

and Activity-Based Management for Health Care, Aspen Publishers, Inc., Gaithersburg, MD: 1998, chapter 13: pp. 147-170.

9 Dunn, D.L., and E. Latimer, Derivation of Relative Values for Practice Expense Using Extant Data (Final Report), A research for the Health Care Financing Administration, HCFA Contract No. 500-92-0023. Federal Project Officer: Paula Kolick. Submitted by the Rand Corporation, 1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138, April 1, 1996. Latimer, E.A., and E.R. Becker, Incorporating Practice Costs Into The Resource-Based Relative Value Scale, Medical Care, Vol 30 No 11, Supplement, November 1992: pp. NS50-NS60.

10 Physician Payment Review Commision. Practice Expenses Under the Medicare Fee Schedule: A Resource-Based Approach. No.92-1. Washington, DC: 1992.

11 Data for these latter two activities were used to support the direct practice expense values noted in footnote one, Health Care Financing Administration, Office of Strategic Planning.

12 For details of the survey and its results see Dayhoff, D.A., et. al., Handbook for Using the 1988 Physicians' Practice Costs and Income Survey (Final report) Center for Health Economics Research, 300 Fifth Ave, 6th floor, Waltham, MA 02154, April 1992. Prepared under Cooperative Agreement NO.99-C-98526/1-08 for the Health Care Financing Administration.

13 Legal, accounting, billing, practice management, etc.

14 In addition to REV, we tried controlling a number of other factors, which might be posited to affect OC, but none were germane empirically.

15 Stuart, T.J. and J.J. Baker, The Bottom-Up Approach to Process by Northwest Family Physicians, in Baker, J.J., Activity-Based Costing and Activity-Based Management for Health Care, Aspen Publishers, Inc., Gaithersburg, MD: 1998, chapter 13: pp. 147-170.

16 The PPCIS weights are "designed to inflate the final sample of 3,505 physicians to the [US] target population of 217,970 … the number of nonfederal patient care physicians (excluding interns, residents, and fellows) who were full- or part-owners of their main practice or employed by other physicians...". They adjust "for (1) over- and undersampling of selected groups of physicians; and (2) differential nonresponse rates rates between subgroups," Dayhoff, D.A., et. al., Handbook for Using the 1988 Physicians' Practice Costs and Income Survey (Final report) Center for Health Economics Research, 300 Fifth Ave, 6th floor, Waltham, MA 02154, April 1992, p II-4. Prepared under Cooperative Agreement NO.99-C-98526/1-08 for the Health Care Financing Administration.

17 The R^2 here, and in all our subsequent regressions, is the proportion of the sum of squared OC_is explained by the regression. While normally one would want to know the sum of squared deviations of OC_i from its mean, here we focus on how closely overall the predicted (fitted) values of OC, viz. the OC_{fi}s, explain the actual OC_is. OC_i can be divided into two parts, the fitted value OC_{fi} and an error term $u_i=OC_i-OC_{fi}$. In all our regressions,

explanatory power is seen as $R^2=1-[\Sigma u_i^2/\Sigma OC_i^2]$. Because we are interested in this explained proportion, moreover, we report the unadjusted R^2 (.7276) rather than the adjusted R^2 (.7275). In all instances, the large number of observations (at least 1,000) makes them all but identical.

18 As seen above, for all 2,737 observations, average OC was $43,986.47 and average PH was 2,533.7 so that OC per hour = $17.36. Thus to cover all overhead costs k should be inflated by ß = $17.36/$17.10.

19 The reader may note that this technique is a cumbersome way to simply refigure the weighted average cost per hour, $17.36. However, it will prove handy in the work below using multiple activities.

20 A general nonlinear functional form is preferable analytically over equation (5) because of its flexibility. However, the former generates non-constant unit costs (per hour or per dollar), which vary with the level and mix of activities, whereas equation (5)'s are constant (per hour for INH, OUTH, and SH and per dollar E&SD). Since it is necessary to pay unique prices for services, we assume constant unit activity costs. To see what is lost by doing this, we compared equation (6) results with a more flexible specification where OC_i is regressed on a second order Taylor series expansion of the right-hand-side variables, including an intercept (14 variables, 15 parameters). This was used instead of a translog so as not to take the log of 0. The Taylor series regression increased the comparable R^2 from .779 [equation (6)] to .793, only 1.8 percent. Heteroscedasticity continued to be a problem with the more flexible functional form; a White test is highly significant, $chi^2(76)=164.5$. Thus while the more flexible functional form gives a slightly better fit, the gain is slight.

21 Leibenstein, H., "A Branch of Economics is Missing: Micro-Micro Theory," Journal of Economic Literature, Vol. XVII (June 1979). pp. 477-502.

22 Friedman, M., A Theory of the Consumption Function, National Bureau of Economic Research, Princeton University Press, Princeton: 1957.

23 Peden, E.A., "Do hospitals behave like consumers? An analysis of expenditures and revenues," Health Care Financing Review/Winter 1992/ Vol. 14, No.2.

24 The weighting perspective is from Professor David Gillke of the University of North Carolina.

25 See Baker, J.J., Activity-Based Costing and Activity-Based Management for Health Care, Aspen Publishers, Inc., Gaithersburg, MD: 1998, p. 3; also Brimson, J.A., Activity Accounting: An Activity-Based Costing Approach, John Wiley & Sons, Inc., New York: 1991, p. 47; and Kaplan, R.S. and R. Cooper, Cost & Effect, Harvard Business School Press, Boston: 1998, p. 84.

26 See Friedman, M., A Theory of the Consumption Function, National Bureau of Economic Research, Princeton University Press, Princeton: 1957, and Peden, E.A., "Do hospitals behave like consumers? An analysis of expenditures and revenues," Health Care Financing Review/Winter 1992/ Vol. 14, No.2.

27 Results available from the authors.

28 This is analogous to getting equation (3) from equation (2).

29 Again comparing our result to that of a flexible functional form, the R^2 of equation (12), .817, is only 2.9 percent below the R^2 of a regression where the right-hand-side is a second order Taylor series expansion of the independent variables and an intercept (.841). Thus once again there is not a great loss of explanatory power from using the specification giving unique per unit activity costs. Moreover, heteroscedasticity is still a problem with the flexible form; a White test shows $chi^2(134)=277.8$.

30 We tried controlling for a number of other factors in addition to REV, but none proved germane empirically.

31 See Tukey, J.W., On the Comparative Anatomy of Transformations, Annals of Mathematical Statistics, 1957, pp. 602-632.

32 If $\alpha=1$, tREV=mREV. In the limit when α approaches 0, tREV=gREV (the geometric mean).

33 Another way to estimate typical REV would be to use regression to estimate a probability density function as a Taylor series expansion of REV and to find the REV which maximizes it.

34 A popular technique for separating requisite from inefficiency costs is frontier analysis, see Greene, W.H., Econometric Analysis (2nd ed), Prentice Hall, Englewood Cliffs, NJ, 1993: pp. 309-310. However, in exploratory work -assuming a half-normal or exponential distribution for the inefficiency errors- the inefficiency measure dominated the regressions; activity variables unrealistically accounted for less than half of total OC. Clearly another approach was needed.

35 Greene, W.H., Econometric Analysis (2nd ed), Prentice Hall, Englewood Cliffs, NJ, 1993: pp. 309-310.

36 The two-step heteroscedasticity correction from Fomby, T.B., R.C. Hill, and S.R. Johnson, Advanced Econometric Methods, Springer-Verlag, New York, 1984: pp. 176-183, is used as follows. After equation (18) was run, the absolute values of its errors were run OLS against a third degree Taylor series expansion of the regressors plus practice size (63 variables) and an intercept. The latter's inverse squared errors were then used to reweight the latter regression which was rerun generalized least squares (GLS). Results of this gave fitted values for the absolute values of the errors from equation (18). These were squared and inverted, and used to reweight the original regression. It was run WNLS to get equation (19).

37 Linear and lognormal error specifications do not exhaust our possibilities. We estimated the more general Box-Cox specification:

$$OC_i^q = [(a \cdot INHRS_i + b \cdot OUTHRS_i + c \cdot STAFFHRS_i + d \cdot E\&SDOLS_i) \cdot (REV_i/tREV)^e]^q, \quad (1f)$$

for q between 0 and 1 [q=0 gives equation (11)]; see Madalla, G.S., Econometrics, New York, McGraw Hill Book Co., 1977: pp. 315-317. In general the fit improves as q approaches 0, i.e. when assuming the lognormal errors of equation (16); positive error skewness also goes to 0 as q approaches 0. These factors all support the lognormal specification.

38 We questioned why the elasticity of REV fell from equation (15) to (18) and (19). Our best guess is that REV is the regressor most correlated with OC (rho=.59); equation (15) reflects this. But because both OC and REV are positively skewed, REV picks too much of the variation in OC. Equations (18) and (19) correct for this overfitting and the elasticity drops. In addition, the shift from STAFFHRS and E&SDOLS to INHRS, going from Tables 2 to 3 -based respectively on equations (7) and (15)- partially reverses itself going from (15) to (18) and (19); the reversal is reflected in Figure 4 below.

39 Spencer, D.E. and K.N. Berk, "A Limited Information Specification Test", Econometrica, vol.49, pp. 1079-1085, July 1981.

40 Regression results available from the authors.

41 Office expenses plus other professional expenses per self-employed physician as a percentage of revenue per self-employed physician, see Gonzalez, M.L. and P. Zhang, Physician Marketplace Statistics 1997/98, American Medical Association, 1998: pp. 70, 75, and 97.

42 Levit, K.R. et.al., National Health Expenditures, 1996, Health Care Financing Review/ Fall 1997/ Vol. 19, No. 1: Table 7, p. 179.

43 Respective asymptotic t's of its fitted values are 0.67 and -0.57.

44 They rose respectively to $chi^2(14)=88.3$ and $chi^2(14)=59.8$.

45 The z statistics of equation (20) and (21) coefficient differences are respectively: 1.13, -1.12, 0.35, -1.30, and 1.94.

Figures

Figure 1

Weighted Average Hours or Cost per Physician by
Activity Across 2,737 Practices Surveyed (1988 PPCIS)

Activity:	mINH	mOUTH	mSH	mE&SD
	1,423.5	1110.2	5,641.4	$18,734.40

Figure 2.

Estimated Overhead Costs per Physician
Distributed by Activity

Activity:	INH	OUTH	SH	E&SD	TOTAL
	$13,509	$11,613	$13,596	$5,283	$44,001*
	30.7%	26.4%	30.9%	12.0%	100.0%

*Doesn't total to $43,986.47 due to rounding.

Figure 3.

Estimated Average Overhead Cost per Physician and
Its Distribution by Activity

Part 1 [Assuming equation (13) results]

Activity:	INH	OUTH	SH	E&SD	TOTAL
	$24,029	$12,157	$6,375	$1,405	$43,965
	54.7%	27.7%	14.5%	3.2%	100.0%

Part 2 [Assuming equation (15) results]

Activity:	INH	OUTH	SH	E&SD	TOTAL
	$22,135	$11,202	$5,867	$1,293	$40,497
	54.7%	27.7%	14.5%	3.2%	100.0%

Figure 4.

Estimated OC per Physician Distributed by Activity
Uses Equation (19) and Sample Averages for 2,737 Observations

Activity:	INH	OUTH	SH	E&SD	TOTAL
	$19,772	$11,002	$6,713	$2,042	$39,529
	50.1%	27.9%	16.9%	5.2%	100.0%

Figure 5

Estimated OC per Physician Distributed by Activity
Uses the Full Data Set (2,737) Sample Averages

Odds Equation (20)

Activity:	INH	OUTH	SH	E&SD	TOTAL
	$18,790	$11,402	$6,600	$2,923	$39,715
	47.3%	28.7%	16.6%	7.4%	100.0%

Evens Equation (21)

Activity:	INH	OUTH	SH	E&SD	TOTAL
	$20,498	$10,303	$7,165	$1,574	$39,539
	51.8%	26.1%	18.1%	4.0%	100.0%

Figure 6

Weighted Average Hours or Cost per Physician for 1988
by Activity Across 1,362 Surveyed Practices with
odd ids and 1,375 Practices with even ids (PPCIS)

Activity:	INH	OUTH	SH	E&SD
Odds	1,422.4	1114.5	5,696.5	$19,060.36
Evens	1,424.7	1106.0	5,586.7	$18,410.78