

# Measuring Efficiency of Physician Practices Using Data Envelopment Analysis

STEVEN ANDES, PhD, CPA<sup>1</sup>; LAWRENCE M. METZGER, PhD, CPA<sup>2</sup>; JOHN KRALLEWSKI, PhD<sup>3</sup>; DAVID GANS, MSHA<sup>4</sup>

<sup>1</sup>Research Assistant and Professor at the University of Illinois at Chicago, Director of Physician Information and Research, American Osteopathic Association, Chicago, Ill.; <sup>2</sup>Professor of Accounting, Loyola University Chicago, Chicago, Ill.; <sup>3</sup>Wallace Professor of Health Research and Policy, School of Public Health, University of Minnesota, Minneapolis, Minn.; <sup>4</sup>Survey Operations Director, Medical Group Management Association, Englewood, Colo.

## ABSTRACT

**Purpose:** Medical-group practices are becoming increasingly commonplace, with more than a third of licensed physicians in the United States currently working in this mode. While previous studies have focused on physician practices, little attention has been focused specifically on the contribution of internal organizational factors to overall physician practice efficiency. This paper develops a model to help determine best practices of efficient physician offices while allowing for choices between inputs. Measuring how efficient practices provide services yields useful information to help improve performance of less efficient practices.

**Design:** Data for this study were obtained from the 1999 Medical Group Management Association (MGMA) Cost Report. In this study, 115 primary care physician practices

are analyzed. Outputs are defined as gross charges; inputs include square footage and medical, technical, and administrative support personnel.

**Methodology:** Data envelopment analysis (DEA) is used in this study to develop a model of practice outputs and inputs to help identify the most efficient medical groups. DEA is a linear programming technique that converts multiple input and output measures to a single comprehensive measure of efficiency. These practices are used as a reference set for comparisons with less efficient ones.

**Conclusion:** The overall results indicate that size of physician practice does not increase efficiency. There does not appear to be extensive substitution among inputs. Compared to other practices, efficient practices seem to manage each input well.

## INTRODUCTION

Medical-group practices are increasingly becoming the mode of practice for physicians. Currently, more than a third of licensed physicians in the United States work in group practices — a number that is expected to increase.<sup>1</sup> To a great extent, this growth results from the consolidation of solo and partnership practices into groups, as well as the merging of existing groups into larger and more diversified practices. While much has been written about the formation of medical-group practices and the social, economic, and professional factors that shape these practice forms, there have been far fewer publications focused on the ef-

fects of these organizations on physician practice styles — and even fewer on the economies of their practices.

Several studies have found that physician-practice styles in groups are influenced by structural organizational attributes, such as clinical information systems,<sup>2,3</sup> administrative demand-and-referral management programs,<sup>4,5</sup> and physician-profiling programs.<sup>6,7</sup> How physicians are compensated also has been shown to influence their practice styles including both their productivity and their use of resources to care for patients.

While these studies have made important contributions to a better understanding of group-practice organizations, they have focused largely on practice size without addressing internal organizational factors that contribute to efficiency. This paper is designed to address these issues.

The investigators in this study have developed a model that helps determine the best practices of efficient physician offices while allowing for choices between inputs. Best practice is defined as a proven service, function, or process that has been shown to produce superior results or to result in benchmarks that meet or set new standards. Efficiency relates outputs to inputs. In the general sense, output in a physician office means providing health care services. Inputs represent the resources needed to provide these services. By measuring how the most efficient practices provide services, information can be gathered to help less efficient practices improve performance.

### Author correspondence:

**Lawrence M. Metzger, PhD, CPA**  
Professor of Accounting  
Loyola University Chicago  
820 N. Michigan Ave.  
Chicago, IL 60611  
Phone: (312) 915-7107  
Fax: (312) 915-7224  
E-mail: lmetzge@luc.edu

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## METHODS

Data Envelopment Analysis (DEA) is a linear programming-based technique that converts multiple input and output measures into a single comprehensive measure of efficiency.<sup>8</sup> This is accomplished through the construction of an empirically based production-possibility frontier and identification of individual units sharing similar characteristics. These individual units are commonly called decision-making units (DMUs). In this study, the DMUs comprise individual medical-group practices.

As originally developed, DEA was used in the public, not-for-profit sector. In the not-for-profit area, DEA has been tested empirically as an efficiency measure in hospitals,<sup>9-13</sup> rural health care,<sup>14</sup> nursing home care,<sup>15</sup> and physician efficiency in hospitals.<sup>16</sup>

Practices that are determined to be the most efficient relative to the peer group of other practices are assigned an efficiency rating of 1.0. Less efficient practices are assigned an efficiency rating of less than 1.0. (The lowest possible value is zero.) DEA provides a technique for assessing relative efficiency in contexts where there are multiple incommensurate outputs and inputs, and also provides an indication as to how a physician practice should attempt to vary its inputs and outputs to achieve a performance comparable to that of the best observed. In this study, an efficient physician practice is defined as one that is able to produce the same level and mix of services as other practices in the peer group, using fewer inputs. A technical discussion and formulation of DEA is included in the appendix that is included at the end of this article.

### Measures of physician practice outputs and inputs

There are many ways to measure the output of physician practices. Examples include relative value unit (RVU) measures, total patient visits,

and/or total charges for a given period. For this study, the output measure is defined as the sum of the total charges for each practice's nonsurgical procedures conducted inside the practice's facilities, and surgery and anesthesia procedures conducted inside the practice's facilities.

Gross charges are listed as output measures on the Medical Group Management Association (MGMA) survey. Gross charges were chosen as the output measure, because gross charges had the highest response rate of all potential measures in the MGMA data set. Data values for RVU values, actual procedures, and patients seen had far fewer recorded responses than gross charges. Charges for activities performed outside the practice facilities (such as in the hospital) were not included, because those activities do not use physician-practice resources.

As with outputs, relevant inputs can be measured in many ways. The study used inputs that met three criteria: reasonably controllable by physician office management; significant correlation with the measured output, and; measurable from data received via the MGMA survey.

In this study, the investigators follow a basic labor and land/capital approach to measure inputs. The inputs used to measure efficiency were:

- The total square footage of the practice. Balance-sheet data is requested as part of the MGMA survey. The survey requests amounts for total current assets, noncurrent (property, plant, and equipment) and all other assets, current liabilities, noncurrent and other liabilities, and total equity. Response rate to this section of the survey was quite low, and discussions with MGMA staff led the investigators to the conclusion that the balance-sheet data that was reported, particularly the value of noncurrent assets, was suspect. Square footage data is also requested on the survey; this value has a much higher

response rate and is considered more reliable. Therefore, we included square footage as a proxy for capital costs.

- Office-support staff were divided into three categories: technical support, administrative support, and medical support.

Medical-support staff had direct patient clinical care. While technical-support staff provided or supported direct patient care, this staff did not consist of nurses or physician assistants. Administrative-support staff was not directly connected with patient care. The specific personnel categories for each group are listed below.

Medical-support staff included:

- Registered nurses
- Licensed practical nurses
- Medical assistants

Technical-support staff was defined as full-time employees (FTEs) connected with:

- Information services staff (data processing, programming, telecommunications, etc.)
- Medical records staff
- Clinical laboratory staff
- Radiology/imaging staff
- Other technical staff (services in all ancillary departments other than those listed such as optical, physical therapy, radiation oncology, electrocardiograph, etc.)

Administrative-support staff included employees in:

- General administrative staff (administrators, chief financial officer, medical director, human resources, marketing, and purchasing)
- Business office staff (business-office manager; billing, credit, accounting, bookkeeping, and collections)
- Managed care administrative (health maintenance organization (HMO)/preferred-provider organization (PPO) contract adminis-

trators, quality assurance and utilization review staff, actuaries, case management, etc.)

- Housekeeping, maintenance, security
- Medical receptionists
- Medical secretaries
- Other administrative support (mail room, cafeteria, laundry, etc.)

In total, four inputs are included in this model: square footage, medical-support staff, administrative-support staff, and technical-support staff.

**Data resources**

As previously noted data for this study were obtained from the 1999 MGMA Cost Survey. This survey is the most comprehensive annual survey of medical-group practices conducted in the United States. Detailed information as provided by the MGMA appears in this paper primarily as aggregate data. No specific physician practices have been identified in the results.

**Sample selection**

The investigators in this study focused on primary care practices, because these practices provide comparable data relative to practice sites. The following operational definition was used to identify primary care practices:

- Multispecialty practices with greater than 90 percent primary care
- Multispecialty practices with primary care only
- Single specialty: Family practice
- Single specialty: Pediatrics
- Single specialty: Internal medicine with greater than 90 percent primary care (This classification is used by MGMA)

The sample produced a total of 227 practices. Rather than a central-tendency method such as regression, DEA is an extremal method. Thus, data errors and outliers in the data can drastically alter results. Capéttini and colleagues<sup>17</sup> have suggested careful analysis to detect and remove outliers and/or unreasonable data.

**TABLE 1 Summary of descriptive statistics**

*All practices in the sample*

Statistic	Mean	Median
Gross charges	\$4,011,262	\$2,290,658
Square footage	21,474	12,250
Technical-support staff (FTE)	6.71	3.00
Administrative-support staff	23.70	14.89
Medical-support staff	16.13	10.00
Physicians (FTE)	12.19	7.00
Charges per physician	\$331,693	\$325,782
Charges per square foot	\$206	\$190
Charges per total support staff	\$80,330	\$74,557
Physician per square foot	1,888	1,717
Total support staff per physician	4.16	4.07

Therefore, once the practice type had been identified, the information provided to the MGMA by the individual practices was “cleaned” for missing and/or nonsensical data. This action reduced the sample size to 115 practices. Most of the reduction in practices can be traced to a lack of reported data on the survey. The investigators believe the sample permits reasonable generalizations with respect to primary care practices, however. The sample is diverse in terms of size and charges, and it includes practices from 34 of the 50 states.

**Results and interpretation**

Table 1 shows the descriptive statistics for these variables in the 115 practices. The DEA measures for each of the practices included in this study are shown in Table A. These measures range from most to least efficient. No individual practices are identified.

The results indicate that 7 of the 115 physician practices used in the model are relatively efficient, as shown by their DEA values of 1.00. The other practices are less efficient, with DEA values that range from 0.987 to 0.117. The ratings for the less efficient practices generally can be interpreted in terms of percentage of

inputs that could have been reduced, given the practices’ output to be relatively as efficient as the most efficient practices. Physician-practice number 12, for example, has a DEA-efficiency measure of 0.796 (or, rounded off, 0.80). This means that practice 12 could have reduced inputs by 20 percent (100-80) without reducing output, if that practice had been as efficient as those practices with a DEA value of 1.00.

**Comparisons of the DEA groups**

To analyze these differences further, the investigators divided the practices into five groups based on DEA ratings (Tables B-F).<sup>†</sup> The first group represents the data for all the practices that the DEA model determined to be efficient, i.e., their DEA-efficiency measure was 1.00. As noted above, there were seven such practices. The next group shows practices with efficiency measures that were between 0.99 and 0.75. There were nine of these practices. There were 32 practices having efficiency measures between 0.50 and 0.74; 47 were between 0.25 and 0.49; and finally,

<sup>†</sup> Tables B-F include the mean, median, minimum, and maximum for each of the model’s outputs and inputs for each of the five DEA categories.

**TABLE A DEA results**

Practice number	DEA value	Practice number	DEA value	Practice number	DEA value	Practice number	DEA value	Practice number	DEA value
1	1.000	26	.656	51	.494	76	.353	101	.235
2	1.000	27	.627	52	.493	77	.347	102	.234
3	1.000	28	.623	53	.492	78	.340	103	.223
4	1.000	29	.615	54	.492	79	.339	104	.220
5	1.000	30	.613	55	.487	80	.339	105	.213
6	1.000	31	.604	56	.477	81	.318	106	.212
7	1.000	32	.603	57	.461	82	.315	107	.211
8	.987	33	.603	58	.461	83	.313	108	.199
9	.979	34	.602	59	.459	84	.308	109	.198
10	.914	35	.591	60	.458	85	.307	110	.193
11	.909	36	.590	61	.449	86	.303	111	.160
12	.796	37	.574	62	.424	87	.297	112	.154
13	.782	38	.570	63	.415	88	.296	113	.137
14	.770	39	.555	64	.414	89	.293	114	.130
15	.765	40	.539	65	.411	90	.281	115	.117
16	.750	41	.534	66	.408	91	.272		
17	.743	42	.533	67	.404	92	.267		
18	.731	43	.524	68	.399	93	.257		
19	.709	44	.521	69	.392	94	.256		
20	.685	45	.521	70	.388	95	.253		
21	.676	46	.517	71	.378	96	.249		
22	.673	47	.509	72	.374	97	.248		
23	.670	48	.504	73	.373	98	.244		
24	.666	49	.498	74	.364	99	.241		
25	.664	50	.498	75	.355	100	.240		

there were 20 practices with efficiency measures that fell below 0.25.

Given the large values for the standard deviations for the mean values, it was determined that the median values would be better than the means to describe the “typical values.” A summary of these data, along with ratios comparing median gross charges (output) to each of the individual inputs for the model is shown in Table 2.

As the data indicate, increasing size does not increase efficiency, and, generally, smaller is better. This finding is consistent regardless of the way that size is measured. For example, Table 2 shows that the practices having DEA measures between 0.75 and 1.00 had fewer square feet and used a smaller support staff than did practices with efficiency measures below

0.75. These findings contradict previous research indicating that more office space and more staff per physician improve productivity.

Total charges are not directly connected to efficiency. If the practices are ranked by size with gross charges as the size measure, only two of the practices with a DEA of 1.00 and only one practice with a DEA measure between 0.75 and 0.99 would be included in the top 25 practices. With respect to total charges, the largest practices fall primarily in efficiency ranges between 0.25 and 0.74.

This finding that smaller is better also is evident if the practices are measured with respect to the number of physicians. Only one practice with a DEA measure of 1.00 and only two practices with a DEA measure between 0.75 and 0.99 are in the top 25

with respect to the number of physicians in the practice.

Table 3 shows median values for charges per square foot and charges per total support staff for each of the five DEA efficiency categories. There is a monotonic relationship for both measures. That is, the more efficient the practice is, as measured by DEA, the greater the ratio of charges per input.

Table 4 shows the ratio of FTE physicians to the outputs and inputs of the DEA model. The most efficient practices, i.e., DEA=1.00, do not have the highest charge per physician. Rather, these practices achieve higher efficiency by making better use of their inputs. The most efficient practices use less square footage per physician and also less total administrative staff per physician.

**TABLE B Practices with DEA measure of 1.000**

n=7

	Gross charges	Square footage	Technical-support staff (FTEs)	Admin support staff FTEs*	Medical support staff FTEs
Mean	\$4,833,615	13,931	2.01	13.30	8.07
Median	3,825,000	10,440	0.00	13.00	8.00
Minimum	3,036,912	3,984	0.00	0.00	0.00
Maximum	10,568,040	46,272	8.10	27.00	25.00

\* Full-time employees

**TABLE C Practices with DEA measures .75-.99**

n= 9

	Gross charges	Square footage	Technical-support staff (FTEs)	Admin support staff FTEs	Medical support staff FTEs
Mean	\$3,635,476	11,354	1.62	13.84	9.66
Median	2,229,884	6,000	1.00	9.95	6.25
Minimum	1,632,543	4,200	0.00	0.00	0.00
Maximum	8,679,800	33,602	8.00	47.25	36.00

**TABLE D Practices with DEA measures .5-.74**

n=32

	Gross charges	Square footage	Technical-support staff (FTEs)	Admin support staff FTEs	Medical support staff FTEs
Mean	\$5,814,889	26,230	7.03	29.35	21.06
Median	3,566,498	15,177	3.50	18.75	15.65
Minimum	1,167,360	5,500	0.00	7.23	0.00
Maximum	29,554,361	172,779	37.80	143.70	136.50

**TABLE E Practices with DEA measures .25-.49**

n=47

	Gross charges	Square footage	Technical-support staff (FTEs)	Admin support staff FTEs	Medical support staff FTEs
Mean	\$3,889,884	23,756	8.88	27.94	18.21
Median	1,933,957	11,500	3.25	15.00	9.25
Minimum	588,503	4,000	0.00	2.00	0.00
Maximum	25,192,890	120,000	70.00	263.00	131.00

Practices with efficiency levels of 1.00 (Table B) and those with efficiency levels between 0.75 and 0.99 (Table C) have less total square footage and tend to use fewer support staff than those practices that are less efficient. Median values for practices with levels falling between 0.75 and 0.99 show that these practices use less square footage and a smaller total support staff than the most efficient practices. Nevertheless, these practices are not able to generate enough total gross charges from their inputs to be considered relatively efficient with respect to the reference group. This becomes evident on examination of Table 3, which shows charges per square foot and per support staff. This is true of all practices with efficiency levels below 1.00.

Practices with a DEA measure of 1.00 have less square footage per physician and also use fewer support staff per physician (Table 4). Both square footage per physician and support staff per physician increase as efficiency decreases. This is a result that is outside the scope of the DEA model, as number of physicians was not included in the measure of practice efficiency in the DEA model that is used for this study.

Practices that are in the DEA efficiency range between 0.50 and 0.74 (Table D) have the highest average gross charges and the second-highest median value for gross charges. Yet they also have the highest median square footage and size of medical-support staff, technical-support staff, and administrative-support staff. This would indicate that the largest practices, at least with respect to gross charges, are using more inputs than are necessary. This could also indicate an excess-capacity issue. These practices may be able to handle more patients with the same level of inputs. It might also be the case that efficient practices maximize their outputs through greater individual productivity. A proxy for productiv-

ity would be charges per procedure. Statistical testing showed that the results for the charges per procedure were not statistically significant for the quintile categories of DEA efficiency. Excess capacity seems to be a better explanation for the results shown in Table 4.

There seems to be no direct relationship between medical-support staff and administrative-support staff. The most efficient practices make significant use of both categories. Between technical-support staff and efficiency, there appears to be a negative relationship. The trend is that the more efficient practices use fewer technical-support services. These practices may in fact be contracting these services out. Detailed information regarding contracted services is not available on the MGMA survey.

DEA can provide insight into possible substitution effects with respect to inputs of efficient practices. That is, is there any indication or evidence of a pattern that the most efficient practices are substituting one input for another? For example, is square footage being substituted for support staff? In this study, there appears to be no pattern of substitution in the most efficient practices. The study indications are that the most efficient practices use fewer of all inputs measured in the model. The results indicate that efficient practices carefully manage all inputs and that the road to efficiency seems to be managing all inputs well.

**Practice management implications**

These findings have important implications for practice managers regarding both practice size and the focus of management strategies. Size is an important management issue. On one hand, larger may be better. Physician practices have been urged to consolidate to take advantage of scale economies and to become increasingly able to seek out managed care contracts. Practices have been

**TABLE F Practices with DEA measures <.25**

	Gross charges	Square footage	Technical-support staff (FTEs)	Admin support staff FTEs	Medical support staff FTEs
Mean	1,291,980	15,695	5.06	12.82	9.10
Median	1,094,419	12,923	3.00	12.00	7.35
Minimum	408,080	4,844	0.00	3.00	2.93
Maximum	4,206,646	43,876	16.00	46.70	31.70

**TABLE 2 Summary of median data**

DEA	Gross charges (\$)	Square footage	Technical-support staff FTEs	Admin-Support staff FTEs	Medical-support staff FTEs	Total-support staff FTEs
1.00	3,825,000	10,440	0.00	13.00	8.00	21.00
0.75-0.99	2,229,884	6,000	1.00	9.95	6.25	16.20
0.50-0.74	3,566,498	15,177	3.50	18.75	15.65	39.88
0.25-0.49	1,933,957	11,500	3.25	15.00	9.25	30.00
<0.25	1,094,419	12,923	3.00	12.00	7.35	22.50

**TABLE 3 Median-value ratios**

DEA	Charges/square footage	Charges/total-support staff
1.00	\$440	\$109,229
0.75-0.99	367	103,785
0.50-0.74	241	90,539
0.25-0.49	164	63,415
<0.25	84	48,862

**TABLE 4 Median-value ratios**

DEA	FTE MDs	Charges/MD	Square footage/MD	Total admin staff/MD
1.00	8.74	\$434,262	1,030	3.71
0.75-0.99	5.00	480,183	1,433	4.07
0.50-0.74	10.00	386,845	1,595	4.15
0.25-0.49	5.50	299,390	1,876	3.99
<0.25	4.85	187,189	2,455	4.21

encouraged to increase square footage per physician to reduce the amount of time that is lost in waiting for patients to reach examining rooms. Similarly, practices have been encouraged to hire medical and non-

medical support personnel to reduce the demands on physicians' time.

Increasing the size of the administrative staff has been proposed as a way to meet the increased administrative responsibilities that come with

third-party payment, especially with managed care organizations. On the other hand, it has long been recognized that there is an optimal size for a medical practice, beyond which diseconomies of scale become more important. While there has been substantial attention devoted to the optimal size for some organizations, such as schools or hospitals, there has been surprisingly little attention devoted to the optimal size of professional businesses, such as those comprising physicians, accountants, or lawyers. These findings suggest that the optimal size (along several dimensions) may be much smaller than might have been expected.

Administrative staff and medical-support staff may be exceptions in that the most efficient practices (DEA=1.00) use more of these staff categories than do two categories of less efficient practices (DEA 0.50–0.74 and 0.25–0.49). Even for these two types of personnel, however, the most efficient practices still use a smaller staff than many practices that are less efficient.

Examining the results on a per-physician basis, rather than at the group-practice level, also supports these findings. The most efficient practices have the least square footage and the smallest number of staff members per physician.

Practice managers should examine how to increase charges, given the inputs that are already available. To a great extent, additional square footage and increased staff size are representative of fixed or semifixed costs. Additions to these inputs should be made with care, because they usually represent relatively long-term commitments to resources. One possible strategy might be to outsource technical services rather than to increase staff size.

#### Limitations

While this analysis provides valuable insights, it has limitations that future research can address. First, it is

important to note that DEA is not a measure of absolute efficiency or even maximum possible efficiency. It measures only relative efficiency, which may not suffice if the sample of practices as a whole is inefficient. Also, DEA does not measure effectiveness. The quality of the health care being provided is not being measured in the DEA model. Although some practices are deemed inefficient, that in no way implies that these practices are not providing quality care. Moreover, there are several important environmental factors, such as HMO penetration, that are not included in our model that might have greatly influenced our measure of efficiency. Clearly, better measures of outputs would improve DEA analysis.

#### Further research

These findings suggest that future research should address five major issues. First, such analyses should be replicated through time to see if consistent overall results are obtained. Second, the analyses should be expanded to include the effects of specific market conditions. Factors such as the percentage of patients in managed care within a given practice, the number of competing practices, the number of managed care contracts, and patient acuity could influence the findings relative to optimal size and staff mix. Third, further study of efficiency in physician practice could include a more detailed analysis of physician-practice patterns. Whereas this study focused on the inputs that are available, an examination of practice patterns might shed some light on how physicians use these differences. Fourth, the findings could be expanded to include multispecialty practices. Multispecialty practices might have higher coordination costs than single-specialty practices. They also have potential for an increased patient flow, however. Finally, differences between for-profit and not-for-profit practices should be investigated. The two types of practices have

different goals and therefore may have different optimal size and structures. The results of this study strongly suggest that DEA is an important management tool and that future studies are well worth conducting.

#### CONCLUSION

One of the most important challenges faced by both policymakers and health care administrators lies in improving the efficiency of medical-group practices. These practices quickly are becoming the preferred model for physicians who want a more stable organizational base for their clinical work in the rapidly changing health care system and for managed care organizations that seek to encourage higher levels of service integration. Unfortunately, group-practice administrators have few data available to assist in the process of increasing practice efficiency.

Physician-practice management is still a new field, and many practices are managed by personnel with limited experience. DEA provides a way to measure efficiency that reflects the multi-output, multi-input nature of physician practices and the possibility that local market conditions may change the optimal resource mix. These first findings suggest that the optimal practice size may be smaller than expected and that the key to increasing efficiency may be using and managing a smaller number of inputs rather than focusing on expanding the size and complexity of practices and their total charges.

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**APPENDIX**

**Data Envelopment Analysis Technical Formulation**

In technical terms, DEA is a mathematical program developed as an ex-postefficiency measurement for DMUs. The DEA-efficiency measurement is obtained as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the ratios for every DMU be less than or equal to 1.

The basic, simplified formulation is as follows:

$$\text{Max } E = \sum_r Y_{r_o} / \sum_i X_{i_o}$$

In other words, DEA seeks to maximize efficiency (E), which is the ratio of the sum of the total outputs (Y) to the total inputs (X) for each DMU<sub>i</sub> under consideration.

Subject to the constraint that  $\sum_r Y_{r_j} / \sum_i X_{i_j} \leq 1.00$

The Y<sub>rj</sub> and X<sub>ij</sub> values represent the known outputs and inputs for the jth DMU. The U and V values are the weights or virtual multipliers for each of the individual outputs and inputs (designated by the r and i subscripts respectively) in the ratio. The solution of the DEA formulation results in multipliers for each DMU such that E is maximized. If the DMU is efficient, the virtual multipliers will cause E to be equal to 1. For less efficient units, E will be less than 1. Thus, E is the efficiency rating assigned to the DMU under evaluation.

The above model involves a nonlinear nonconvex-programming formulation. Charnes and colleagues,<sup>8</sup> showed that the problem may be stated as a linear-programming model. This new formulation is as follows:

**Objective function:**

Maximize the sum of the weighted individual outputs ( $\sum_r Y_{r_o}$ ) for the DMU (practice) being evaluated.

**Subject to:**

1. The sum of the individual outputs ( $\sum_r Y_{r_j}$ ) minus the sum of the individual inputs ( $\sum_i X_{i_j}$ ) for each separate DMU must be  $\leq 0$ . This constraint will be entered for each DMU in the analysis.
2. The sum of the inputs ( $\sum_i X_{i_o}$ ) for the DMU being evaluated must equal 1.

In formula form, the model looks as follows:

$$\text{Max } (\sum_r Y_{r_o})$$

**Subject to:**

1.  $\sum_r Y_{r_j} - \sum_i X_{i_j} \leq 0$  (for each DMU in the model)
2.  $\sum_i X_{i_o} = 1.00$  (for the individual practice being evaluated)

The total number of constraints in the model is equal to the total number of DMUs (physician practices) plus 1 (for the specific practice being evaluated.)

In effect, each DMU can specify the set of weights to apply to its inputs and outputs to determine its maximum relative efficiency, subject only to no other DMU having



a relative efficiency  $>1$  having those weights. One can therefore use this approach to calculate the relative efficiency of each physician practice by solving the linear programming formulation. A numerical example of the model is shown in the model formulation section of the paper.

**Model formulation**

The DEA model for this study was run using the output and input measures as described above for the 115 practices fitting the description of primary care specialties that reported the requisite data. The model was run for each individual practice.

The objective function was set up to maximize the efficiency of the practices being analyzed. The total number of constraints is equal to the total number of practices plus 1. In this study, the total number of practices was 115; the total number of constraints was 116.

As an example of how the DEA model is set up, consider the following created data for a particular practice:

**Outputs: (O1)**

Total charges as described above: \$6,000,000

**Inputs:**

- Square footage (I1)                      13,000 sq. ft.
- Technical staff (I2)                      6 full-time employees (FTEs)
- Support staff (I3)                        12 FTEs
- Medical-support staff (I4)              13 FTEs

**Objective function:**

Maximize \$6,000,000(O1)

**Subject to:**

$$6,000,000(O1) - 13,000(I1) - 6(I2) - 12(I3) - 13(I4) \leq 0$$

The sum of the outputs minus the sum of the inputs used must be  $\leq 0$ . This constraint will be used for each practice in the model. There are 115 of these, including the practice being analyzed.

**Subject to:**

$$13,000(I1) + 6(I2) + 12(I3) + 13(I4) = 1.00$$

This constraint consists of the inputs of the specific practice being measured. It is used so as to limit the maximum efficiency value to 1. This constraint is changed for each practice so as to use the inputs for the practice being measured.

The practice being evaluated will have a derived efficiency rating of 1, if it is relatively efficient, or  $<1$  if it is relatively inefficient. If the efficiency rating calculated under DEA is 1, then the practice being measured is at least as efficient as any other practice in the analysis. If the value is  $<1$ , it is relatively inefficient compared to the other practices.