# EFFICIENCY ANALYSIS OF HOSPITALS IN THE GREAT PLAINS:

# AN URBAN-RURAL COMPARISON

**by**

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## Efficiency Analysis of Hospitals in the Great Plains: An Urban-Rural Comparison

Expenditures for hospital care services was $341.7 billion in 1994. Between 1960 and 1980, hospital expenditures as a percentage of personal health care expenditures increased from 38.9 percent to 46.7 percent. Given the escalating costs of hospital services, and increased closing of both urban and rural hospitals, concerns have been expressed by the public, along with policy makers (Adams and Wright). Both rural and urban hospitals experienced a significant drop in inpatient utilization after the implementation of Prospective Payment System (PPS) in 1983. This fall in inpatient utilization is more prevalent among rural hospitals than urban hospitals. Consequently many rural hospitals are more dependent on outpatient and nonpatient sources of revenue such as donations and tax subsidies for their financial viability (Goody, Weisgrau).

Several differences exist between urban and rural hospitals. First, the composition of their respective markets are vastly different. Market competition characteristics in urban markets are notably different from rural health care markets (Ferrier and Valdmanis). Compared to urban hospitals, rural hospitals are generally smaller with lower occupancy rates, a declining and dispersed geographic patient base, face increased uncompensated care, offer fewer specialized services, and rely heavily on Medicare and Medicaid programs, and nonpatient revenue (Davis et al., Hatten and Connerton, Weisgrau, Rizzo).

The purpose of this study is to examine and compare the relative efficiency between urban and rural hospitals in the Great Plains using Färe's nonparametric approach. Applying Färe's approach allows the modeling of multiple outputs, which is a common feature of hospitals and it may add insights into the production practices of urban and rural hospitals. An additional objective of this study is to identify hospital characteristics correlated with efficiency. Variables correlated with respective efficiencies also may differ by hospital location. Therefore, comparison of respective efficiency measures may provide insight about their respective performance level. Identification of these differences may provide information that will help hospitals administrators, public policy makers, and third-party insurance agents make better decisions.

## The Nonparametric Approach

Several nonparametric methods have developed to measure the alternative types of efficiency proposed by Farrell. Under the nonparamentric approach, linear programs are used to search for the optimal combination of inputs for the given level of output in cost applications. The objective of this approach is to "envelop" the data. Nonparametric analysis provides quantitative insight into the technical and allocative inefficiencies of individual firms relative to the underlying best practice production frontier (the envelop) of the prevailing industry technology. This approach is useful for measuring and comparing the operational performance of hospitals, where all hospitals may not be profit maximizers, but where cost minimization is a more likely goal (Ferrier and Valdmanis).

The method used in this study is a nonparametric approach suggested by Färe et al. When estimating the production and cost frontier, the nonparametric approach does not impose restrictions on the functional form (Chavas and Aliber, and Featherstone, Langemeier, and Ismet). Further discussion of the nonparametric approach can be found in Chavas and Aliber or Featherstone, Langemeier, and Ismet. The nonparametric approach is applied to a sample of Great Plains hospital (urban and rural) data. Four linear programming models are solved for each of the Great Plains, urban, and rural hospitals, respectively.

## Data Source

The Hospital Cost Report Information system, Minimum Data Set, Form HCFA-2552-92, of the Health Care Financing Administration (HCFA) for reporting periods between October 1, 1991 and September 30, 1992 is used for this study. All general short term hospitals in the Great Plains are included in the primary data set. A total of 1,006 hospitals are in the primary data set. After screening for invalid and outlying observations the working data set contained information from 803 hospitals in the Great Plains. All MSA/NECMA hospitals are classified into urban hospitals, with the others classified as rural hospitals. Out of 803 hospitals in the Great Plains, 255 (31.8%) hospitals are located in urban areas and 548 (68.2%) hospitals are located in the rural areas. Further, there are 365 (45.5%) nonprofit hospitals, 330 (41.1%) public hospitals (Federal, State, County, community, etc.), and 108 (13.4%) private proprietary hospitals in the Great Plains.

Hospital inputs were placed into four categories: i) direct staff (salaried) hours, ii) direct cost, iii) physicians' hours, and iv) capital costs. Outputs were classified into three groups: i) inpatient revenue, ii) outpatient revenue, and iii) nonpatient revenue. Total staff salaries and physicians' remuneration is divided by the average hourly wage index of hospital financial wage index information from Form HCFA-2552-92, Worksheet S-3, Part II. Total direct cost is total cost (excluding staff and physicians' salaries) of the cost centers in the facility. Capital costs are total capital related costs in the facility (plant, equipment, building, etc.). The average hourly wage index is used as price vector for staff and physicians' hours, while prices for other inputs (direct costs, and capital costs) do not to differ between hospitals.

Inpatient revenue is the sum of all the revenue received from patients treated on an inpatient basis by all the units in the facility. Outpatient revenue consists of the ambulance, home health services, and patients treated on an outpatient basis. Nonpatient revenue consists of other income received, such as contributions, donations, bequests, investments, and governmental appropriations.

A pooled frontier for 803 hospitals, and separate frontier for urban (255) hospitals and rural

(548) hospitals is estimated. Measures of pure technical, allocative, scale, and overall efficiency were calculated for each of hospitals in the data set, under the pooled frontier, and separate frontier for urban and rural hospitals respectively. Pooled results are decomposed into urban and rural hospitals for the comparison of hospital performance between urban and rural. The Kruskal-Wallis nonparametric test is used to examine the statistical significance between efficiency measures of urban and rural hospitals. To identify the characteristics associated with the efficiency measures, Tobit regression was used.

## Results and Discussion

A hospital is efficient in a particular measure when that value is one. Subtracting the value from one represents the percent of inefficiency or by the cost could be reduced to produce the observed outputs (Grosskopf and Valdmanis). Summary statistics for the efficiency measures are found in Table 1. Efficiency measures are computed relative to the best practice frontier constructed from the sample. Therefore, these values represent a relative not an absolute measure of efficiency.

Pure technical efficiency ranged from 0.40 to 1 for the Great Plains as a whole with a mean level of 0.71. Pooled measures ranged from 0.43 to 1 for urban hospitals, and 0.40 to 1 for rural hospitals with a mean level of 0.72 and 0.71 respectively. On average the same output could be produced by hospitals using 29% less inputs in the Great Plains, 28% in urban set, and 29% in rural set if hospitals are technically efficient. Pure technical efficiency for the separate frontier ranged from 0.44 to 1 for urban and 0.43 to 1 for rural with a mean level of 0.75 and 0.78 respectively. When separate frontier efficiency measures are estimated, the input reduction that could be achieved for urban hospitals is 26% and 22% for rural hospitals.

Allocative efficiency ranged from 0.46 to 1 for both the Great Plains and pooled rural set, and

0.51 to 1 for the urban set with means of 0.83, 0.81, and 0.87 respectively. A cost savings of 17% in the Great Plains, 13% for urban hospitals, and 19% for rural hospitals could be achieved if hospitals optimally reallocated inputs. Allocative efficiency of separate frontiers ranged from 0.51 to 1 for urban set, and 0.50 to 1 for rural set with a means of 0.87 and 0.85, respectively.

Scale efficiency ranged from 0.34 to 1 for the Great Plains, 0.56 to 1 for the urban set, and 0.34 to 1 for the rural set with a mean level of 0.87, 0.90, and 0.85 respectively. These values show that an average increase in costs of 13% for Great Plains hospitals, 10% for urban hospitals, and 15% for rural hospitals are due to the non-optimal size of hospitals. Separate frontiers scale efficiency ranged from 0.36 to 1 for urban set, and 0.43 to 1 for rural set with a mean level of 0.87 and 0.90.

Overall efficiency, the product of technical, allocative, and scale efficiency measures the cost savings in the industry if every hospital is efficient in all three efficiency measures. Overall efficiency ranged from 0.14 to 1 for the Great Plains, 0.26 to 1 for the urban set, and 0.14 to 1 for the rural set, with mean level of 0.50, 0.56, and 0.48 respectively. Separate frontiers overall efficiency ranged from 0.26 to 1 for urban set and 0.18 to 1 for rural set with a mean level of 0.56 and 0.60, respectively.

To statistically test efficiency differences between urban and rural hospitals, a nonparametric Kruskal-Wallis test (Conover) was conducted for all efficiency measures for single frontier (pooled), and separate frontiers following Grabowski and Pasurka. The calculated single (pooled) frontier Kruskal-Wallis test is 11.7 for technical, 67.6 for allocative, 53.3 for scale, 29.0 for economic, and 67.1 for overall efficiency. Similarly, the calculated separate frontiers Kruskal-Wallis test is 12.7 for technical, 5.6 for allocative, 11.9 for scale, 4.4 for economic, 18.7 for overall efficiency. Kruskal-Wallis test results indicate that at the 1% level there is no statistically significant difference between urban and rural hospital performance with respect to all efficiency measures for both pooled and separate frontiers. While it appears that urban hospitals are more efficient with respect to all measures, these differences are not statistically significant.

**Returns to Scale Analysis**

Returns to scale results show that 13.4% of Great Plains (108 of 803), 39.6% of urban (101 of 255), and 1.3% of rural hospitals (7 of 548) are producing their services in a region of increasing returns to scale and could expand accordingly. About 85.9% of Great Plains hospitals (690 of 803), 58.8% of urban hospitals (150 of 255), and 98.5% of rural hospitals (540 of 548) are producing in the region of decreasing returns to scale and could contract their services accordingly. This analysis implies that most of the hospitals in the Great Plains are too large. Though, many urban hospitals face decreasing returns to scale, it is more severe among rural hospitals. The findings of this study are consistent with the hypothesis that the hospital sector in general and rural hospitals in particular suffer from an excess capacity problem (Maindiratta).

**Hospital Characteristics and Efficiency**

Identifying factors associated with the hospital performance helps to understand the relationship between omitted variables and efficiency. Tobit analysis of the efficiency scores is the appropriate analytical tool for censored variables (Ferrier and Valdmanis). To identify factors associated with the performance of hospitals, Tobit regression on a set of hospital characteristics which include: employees per inpatient day, type of ownership (nonprofit, public and excluded variable is private), urban, sole community hospital, number of beds, number of beds squared, bed days, bed turnover ratio (bed days/number of beds), inpatient days, Medicare discharges, and Medicaid discharges.

The Tobit regressions were used to estimate elasticity results of relationship for each of the above hospital characteristics on technical, allocative, scale, economic, and overall efficiencies. Following McDonald and Moffitt, the values shown in Table 2 represent the change in y of those above the limit, weighted by the probability of being above the limit.

The results indicate that the employees per inpatient day variable is statistically significant for allocative, scale, and overall efficiency measures. In addition, this variable has the expected negative sign with regards to each efficiency measure. The form of hospital ownership and the relationship to efficiency is consistent with property rights and public choice theory. Private proprietary hospitals' efficiency is higher than those of nonprofit and public hospitals for all efficiency measures. A possible explanation for these efficiency results may be due to the private hospital's self selection, the choice of location, objectives, levels of access to health care along with public choice theory. Private hospitals are usually located where it is more profitable to provide health care services. On the other hand, public hospitals are often located where no other facility is available, and probably the concept of social good may be more appropriate for public hospitals than the other two forms of ownerships (Ferrier and Valdmanis, Grosskopf and Valdmanis).

The difference between urban and rural hospitals' operational performance is statistically significant for allocative, scale, and overall efficiencies. Urban hospitals are relatively more efficient than rural hospitals perhaps due to the demographic differences, composition of their respective markets, competitive environment, proportion of nonpatient income and case mix. Rural demographics are not favorable to a rural hospital's efficiency or survival. Community hospitals' are negatively and statistically significantly related to technical, economic, and overall efficiencies.

Generally, financial distress for hospitals is associated with the size of the hospital (Ferrier and Valdmanis). To examine the impact of size, beds and beds squared are included in the analysis.

There is U-shape relationship between technical and allocative efficiency and size. This implies that small and large hospitals in the sample are relatively more technical and allocative efficient than medium sized hospitals. The inverted U-shape relationship between scale, and overall efficiency and size implies that hospitals may be too small or too large given the demand for services being offered.

The bed days variable embodies the level of usage of hospital beds. There is a positive relationship between bed days and allocative and scale efficiency, implying that hospitals with more bed days are more allocative and scale efficienct, i.e. face a reduced per unit cost of operation. Bed turnover rate is statistically significant for technical and allocative efficiency and its association is positive with technical efficiency and negative with allocative efficiency.

As stated earlier, the efficiency level of a hospital also depends on the mix of patients, services being offered, and resources available in the hospital. There is a negative correlation between inpatient days and allocative, scale economic, and overall efficiency, implying that inpatient days may not be as cost effective.

The negative relationship between efficiency measures and Medicare discharges are as expected for all variables but scale efficiency. The positive association between Medicare discharges and scale efficiency is not surprising, given the excess capacity problem among the hospitals.

Our results found a positive relationship exists between Medicaid discharges and efficiency measures. While the Medicaid discharges results are not as expected, observed results may be due to state differences in Medicaid Programs.

## Summary and Conclusions

This study examined the efficiency for a sample of hospitals in the Great Plains, using a nonparametric approach. Urban hospital efficiency was compared with rural hospitals in the Great Plains. Technical, allocative, scale, economic, and overall efficiency for 803 Great Plains hospitals was examined. Pooled results are segregated into urban (255 hospitals) and rural (548 hospitals) sets to compare their relative performance. Further, separate frontier efficiency measures for urban and rural hospitals were estimated.

Technical efficiency was relatively less than either allocative or scale efficiency in the Great Plains as a whole. On average, the Great Plains hospitals were 71% technically efficient, 82.6% allocatively efficient, 86.6% scale efficient, 58.2% economic efficient, and 50.2% overall efficient. Urban hospitals on average are 71.8% technically efficient, 86.8% allocatively efficient, 90.3% scale efficient, 62.1% economic efficient, and 55.5% overall efficient. Rural hospitals on average are 70.7% technical efficient, 80.6% allocative efficient, 84.9% scale efficient, 56.4% economic efficient, and 47.7% overall efficient. These results indicate that on average urban hospitals are relatively more efficient than rural hospitals with respect all efficiency measures. However, Kruskal-Wallis test results indicate that there is no statistically significant difference for efficiency measure between the pooled and nonpooled results. Results of this study are consistent with the literature (McGuire, Kooreman, Ferrier and Valdmanis).

In general, the majority of hospitals in the Great Plains are too large for their existing market, though there are a few hospitals that are too small for their respective markets. About 85.9% of hospitals are operating in the region of decreasing returns to scale, while 13.4% of hospitals are operating in the region of increasing returns to scale. These results are consistent with Maindiratta's results, where it was found that about 71% hospitals are larger than the most productive scale size.

Hospital characteristics were regressed on each of the efficiency measures using Tobit regression to identify the factors that are associated with the efficiency measures. Tobit analysis indicated that hospitals in general may be over staffed given the demand for services. Private hospitals are more efficient than nonprofit and public hospitals. This implies that private proprietary hospitals are managing their resources prudently given the prevailing conditions. Sole community hospitals are less efficient than other hospitals. Results of this study are consistent with other studies (Ferrier and Valdmanis, and Grosskopf and Valdmanis). Urban hospitals are relatively more efficient than rural hospitals, in general, due to their higher level of technical, allocative, and scale efficiency. However, urban hospitals superior performance cannot be associated solely due to better management strategies, but may be due to several factors discussed above.

## Policy Considerations

Continued presence of inefficiency in the health care sector leads to the increased cost of operation and reduced profit margins which leads to hospital financial distress and closure of hospitals. This study identified several hospital characteristics associated with hospital performance. For example, private hospitals were relatively more efficient than nonprofit and public hospitals. Nonprofit and public hospital administrators could replicate private hospital operational methods in terms of resource utilization, given their own objectives of operation, and other considerations.

As mentioned earlier, public and nonprofit hospital performance is poor. However, closing public and nonprofit hospitals may not be a good strategy in the interest of access to health care. Nonetheless, a joint-venture with different combinations of the three forms of ownership may be an alternative for administrators and policy makers. Merits of the three different structures (operational methods, management expertise, access to care, regulations, etc.), could be blended in the joint-venture structure to enhance the operational performance of the health care sector in general.

**Table 1. Summary Statistics of Efficiency Measures for a Sample of Hospitals in the Great Plains (Pooled and Separate)**

| | Technical | Allocative | Scale | Overall |
|---|---|---|---|---|
| **Great Plains (803)*** | | | | |
| Mean | 0.710 | 0.826 | 0.866 | 0.502 |
| Standard Deviation | 0.149 | 0.105 | 0.128 | 0.125 |
| Minimum | 0.404 | 0.459 | 0.340 | 0.138 |
| Maximum | 1.000 | 1.000 | 1.000 | 1.000 |
| **Pooled Frontier Efficiency Measures Disaggregated into Urban and Rural** | | | | |
| **Urban (255)*** | | | | |
| Mean | 0.718 | 0.868 | 0.903 | 0.555 |
| Standard Deviation | 0.154 | 0.092 | 0.114 | 0.123 |
| Minimum | 0.431 | 0.514 | 0.556 | 0.257 |
| Maximum | 1.000 | 1.000 | 1.000 | 1.000 |
| **Rural (548)*** | | | | |
| Mean | 0.707 | 0.806 | 0.849 | 0.477 |
| Standard Deviation | 0.147 | 0.105 | 0.130 | 0.119 |
| Minimum | 0.404 | 0.459 | 0.340 | 0.138 |
| Maximum | 1.000 | 1.000 | 1.000 | 1.000 |
| **Separate Frontier Efficiency Measures for Urban and Rural** | | | | |
| **Urban (255)*** | | | | |
| Mean | 0.745 | 0.868 | 0.874 | 0.555 |
| Standard Deviation | 0.158 | 0.095 | 0.125 | 0.123 |
| Minimum | 0.435 | 0.514 | 0.357 | 0.257 |
| Maximum | 1.000 | 1.000 | 1.000 | 1.000 |
| **Rural (548)*** | | | | |
| Mean | 0.782 | 0.847 | 0.903 | 0.596 |
| Standard Deviation | 0.141 | 0.107 | 0.107 | 0.144 |
| Minimum | 0.430 | 0.495 | 0.427 | 0.178 |
| Maximum | 1.000 | 1.000 | 1.000 | 1.000 |

* Values in parentheses represent number of hospitals in each group.

**Table 2. Estimated Elasticities Among Efficiency and Hospital Characteristics**

| Variable | Technical | Allocative | Scale | Overall |
|---|---|---|---|---|
| Employees/inpatient day | 0.0004 | -0.0010 [c] | -0.0008 [b] | -0.0011 [a] |
| Nonprofit | -0.0302 [c] | -0.0236 [c] | -0.0110 [a] | -0.0733 [c] |
| Public | -0.0191 [a] | -0.0214 [c] | -0.0199 [c] | -0.0646 [c] |
| Urban | 0.0016 | 0.0140 [c] | 0.0090 [b] | 0.0252 [c] |
| Community Hospital | -0.0127 [b] | -0.0013 | 0.0039 | -0.0122 [b] |
| Number of Beds | -0.0456 | -0.0356 | 0.0929 [c] | 0.1032 [a] |
| Number of $Beds^2$ | 0.0732 [c] | 0.0072 [a] | -0.0351 [c] | -0.0002 |
| Bed days | -0.1443 [c] | 0.0619 [b] | 0.0715 [b] | -0.0230 |
| Turnover Rate | 0.1017 [a] | -0.0748 [b] | 0.0147 | 0.0669 |
| Inpatient Days | 0.0361 [a] | -0.0361 [c] | -0.0896 [c] | -0.0907 [c] |
| Medicare Discharges | -0.0137 [c] | -0.0006 | 0.0054 [b] | -0.0071 |
| Medicaid Discharges | 0.0236 [c] | 0.0095 [c] | 0.0061 [b] | 0.0307 [c] |
| *Likelihood Ratio Test* | *129.63* [c] | *116.56* [c] | *258.76* [c] | *174.07* [c] |

Note: Superscripts a, b, and c denote significance at the 10%, 5%, and 1% level, respectively.

## References


Adams E. K. and G. E. Wright. (1991) "Hospital Choice of Medicare Beneficiaries in a Rural Market: Why not the Closest?" *The Journal of Rural Health*, 7(1): 134-152.

Chavas, J-P. and M. Aliber. (1993) "An Analysis of Economic Efficiency in Agriculture: A Nonparametric Approach." *Journal of Agricultural and Resource Economics*, 18:1-16.

Conover, W. J. (1980) Practical Nonparametric Statistics. John Wiley & Sons, New York.

Davis, R. G., T. C. Zeddies, M. K. Zimmerman, and R. A. McLean. (1990) "Rural Hospitals under PPS: A Five-Year Study." *The Journal of Rural Health*, 6(3): 286-301.

Färe, R., S. Grosskopf, and C. A. K. Lovell. (1985) The Measurement of Efficiency of Production. Boston, Mass: Kluwer-Nijhoff.

Farrell, M. J. (1957) "The Measurement of Production Efficiency. "*Journal of the Royal Statistical Society*, Series A, General, 125, Part 2: 252-67.

Featherstone, A. M., M. R. Langemeier, and M. Ismet. (1997) "A Nonparametric Analysis of Efficiency for a Sample of Kansas Beef Cow Farms." *Journal of Agriculture and Applied Economics,* 29(1): 175-184.

Ferrier, G. D. and V. Valdmanis. (1996) "Rural Hospital Performance and Its Correlates." *The Journal of Productivity Analysis*, (7): 63-80.

Goody, B. (1992) "Medicare Dependent Hospitals: Who Depends on Whom?" *Health Care Financing Review*, 14 (2): 97-105.

Grabowski, R. and C. Pasurka. (1988) "The Relative Technical Efficiency of Northern and Southern U.S. Farms in 1860." *Southern Journal of Agricultural Economics,* (54): 598-614.

Grosskopf, S. and V. Valdmanis. (1987) "Measuring Hospital Performance: A Nonparametric Approach." *Journal of Health Economics,* (6): 89-107.

Hatten, J. M. and R.E. Connerton. (1986) "Urban and Rural Hospitals: How do they differ?" *Health Care Financing Review*, 8(2): 77-85.

Hospital and Hospital Health Care Complex Cost Report, Form HCFA-2552-92, Chapter 28.

Kooreman, P. (1994) "Nursing Home Care in The Netherlands; A Nonparametric Efficiency Analysis." *Journal of Health Economics*, 13(3): 301-316.

Maindiratta, A. (1990) "Largest Size-Efficient Scale and Size Efficiencies of Decision-Making Units in Data Envelopment Analysis." *Journal of Econometrics*, (46): 57-72.

McDonald, J. F. and R. A. Moffitt. (1980) "The Uses of Tobit Analysis." *The Review of Economics and Statistics*, 62(2): 318-321.

McGuire, A.M. (1987) "The Measurement of Hospital Efficiency." *Social Science Medicine*, 24(9): 719-724.

Rizzo, J. A. (1991) "Has Medicare Been a 'Bad Deal' for Rural Hospitals?" *Journal of Rural Health*, 7(5): 599-617.

Weisgrau, S. (1995) "Issues in Rural Health: Access, Hospitals, and Reform." *Health Care Financing Review*, 17(1): 1-14.