Determinants of Cost Inefficiency of Critical Access Hospitals: A Two-stage, Semi-parametric Approach

I.Cristian Nedelea
Graduate Student
Department of Agricultural Economics and Agribusiness
Louisiana State University
101 Ag. Administration Bldg.
Baton Rouge, LA 70803
Phone: 225.578.2595
Email: *inedel1@lsu.edu*

J. Matthew Fannin, Ph.D.
Associate Professor
Department of Agricultural Economics and Agribusiness
Louisiana State University Agricultural Center
101 Ag. Administration Bldg.
Baton Rouge, LA 70803
Phone: 225.578.0346
Email: *mfannin@agcenter.lsu.edu*

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Corpus Christi, TX, February 5-8, 2011

Introduction

The Medicare Rural Hospital Flexibility Program (Flex Program), introduced as part of the Balanced Budget Act of 1997, established a national limited service hospital program[1], namely the Critical Access Hospital (CAH) program. The CAH program was created to protect small, financially vulnerable rural hospitals that might be important for access to care in isolated rural areas by granting them Medicare cost-based reimbursement rather than reimbursement based on the prospective payment system (PPS) (Dalton et al. 2003).[2] While one of the goals of PPS system was to promote hospital efficiency, cost-based reimbursement has been historically associated with inefficiency in hospital operations (Gianfrancesco 1990; McKay et al. 2002/2003). Since CAHs receive Medicare cost-based reimbursement, there have been concerns that this type of reimbursement might have a negative impact on the cost efficiency of hospitals that converted to CAH status. In a 2005 report to Congress, the Medicare Payment Advisory Commission (MedPAC) agreed that the CAH program helped preserve access to health care in isolated rural areas, but questioned the efficiency of CAHs (MedPAC 2005).

In this study, we focus on estimating and explaining, post-conversion, cost efficiency of CAH hospitals using a two-stage, semi-parametric approach. In the first stage, a traditional data envelopment analysis (DEA) efficiency estimator is used to estimate cost efficiency of CAH hospitals. In the second stage, cost efficiency scores are regressed on a set of environmental variables expected to influence hospital efficiency using a bootstrapped truncated regression as suggested by Simar and Wilson (2007).

[1] The purpose of limited service hospitals was to provide basic health care services to rural communities where a full services hospital would not be financially viable.
[2] Under cost-based reimbursement, hospitals are paid the full cost of providing services to Medicare beneficiaries, while PPS pays a fixed fee based on diagnosis related group (DRG).

Since its creation, there has been a growing interest in evaluating the performance of CAH program. Previous research focused on evaluating financial performance and quality of care of CAHs (Pink et al. 2007; Li et al. 2007). In a recent article, Rosko and Mutter (2010a) compared the cost inefficiency of CAHs with that of non-converting, prospectively paid rural hospitals. They estimated a stochastic frontier analysis (SFA) model with a panel data set from 1997 to 2004 in which CAHs and non-converting rural hospitals were jointly used in the analysis. While the study also examined the factors that affected cost inefficiency of hospitals, the joint use of CAHs and non-converting rural hospitals in the empirical analysis made it difficult to separate the effects of these environmental variables on CAH cost inefficiency. Since CAHs and non-converting rural hospitals operate under different payment systems, an alternative approach would be to model them separately.

In hospital efficiency studies, it seems important to control for quality. However, poor data availability as well as a lack of agreement about how quality should be measured has increased the difficulty of controlling for quality in efficiency studies. While Rosko and Mutter (2010a) attempted to control for quality and patient burden of illness, the downside was a dramatic loss in the number of hospitals (especially CAH hospitals) that would had been eligible for use in empirical analysis otherwise.

Our study is different from Rosko and Mutter (2010a) in a couple of aspects. First, the focus in our study is on specifically identifying and explaining the factors that affect the cost efficiency of CAH hospitals. Second, we use a much larger sample of CAH hospitals (i.e., an unbalanced panel for 1999-2006) to draw inference on the efficiency of CAHs. Third, we take a different approach than Rosko and Mutter (2010a) to model cost efficiency, namely the two-stage approach suggested by Simar and Wilson (2007). There is evidence that the two-stage,

semi-parametric approach suggested by Simar and Wilson (2007) outperforms the usual parametric approaches (Simar and Wilson 2008, Demchuk and Zelenyuk 2009).

Policy Background

One of the most important changes in rural health care policy that has impacted rural hospitals dramatically has been the creation of Critical Access Hospital program which was introduced as part of the Balanced Budget Act (BBA) of 1997. The goal of the CAH program has been to preserve access to health care in isolated rural areas by improving the financial conditions of small rural hospitals and preventing closure. A hospital that converts to CAH status has the advantage of receiving Medicare cost-based reimbursement for inpatient and outpatient services, post-acute (swing-bed) care, and laboratory services delivered to Medicare beneficiaries.

Under the BBA, a rural hospital had to meet several requirements before being considered eligible for CAH designation. Most importantly, to qualify for CAH status a hospital needed to be classified as non-metropolitan for Medicare PPS payment purposes; be under government or non-profit ownership; be located at least 15 miles by secondary road or 35 miles by primary road from the nearest short-term general hospital, or be declared by the state as a "necessary provider"[3]. Most hospitals failed to meet the 35-mile criterion for being considered an isolated hospital and entered the program based on state criteria that declared them necessary providers. Center for Medicare and Medicaid Services (CMS) gave hospitals great flexibility in setting necessary provider criteria such that some criteria were not even related to access to care. MedPAC (2005) estimated that, due to the necessary provider requirement, only 20 percent of

[3] Under this provision, states could waive the distance requirement for hospitals that were considered important for the delivery of health care services, thereby qualifying them for CAH conversion.

CAHs were more than 35 road miles from another provider. Hospitals that converted to CAH status were also required to use no more than 15 acute care beds at any one time plus an additional 10 to be used only as swing beds for long-term care patients; provide a length of stay of 96 hours or less for acute care patients, and provide 24-hour emergency services.

The Balanced Budget Refinement Act (BBRA) of 1999 subsequently expanded CAH eligibility by allowing for-profit hospitals to participate, and by including facilities that were located in counties contained in metropolitan statistical areas but identified as rural by their own state regulations. The BBRA also replaced the 96-hour length of stay limit with the less restrictive requirement that the annual average length of stay could not be greater than four days.

The Medicare Prescription Drug, Improvement, and Modernization Act of 2003 (MMA) eliminated states' ability to declare a hospital as a "necessary provider" starting in January 2006 and states could no longer waive the distance requirement. As a result, few additional hospitals met the criteria and entered the CAH program. In addition, MMA introduced several changes in the CAH program. MMA increased the reimbursement for CAHs to 101 percent of reasonable costs for inpatient, outpatient and post-acute care; the number of acute care beds increased from 15 to 25 starting January 2004, and allowed CAHs to have distinct skilled nursing facilities as well as psychiatric units, rehabilitation units, and home health agencies.

Rural hospitals that converted to CAH status have generally experienced significant improvements in their finances due to cost-based reimbursement. MedPAC (2005) reports hospitals that converted to CAH status have dramatically increased their Medicare payments and improved their all-payer profit margins from -1.2 percent in 1998 to 2.2 percent in 2003. For similar rural hospitals that did not convert to CAH status and remained on PPS all-payer profit margins declined from 2.2 percent in 1998 to -0.2 percent in 2003. Holmes et al. (2006) also

found that conversion to CAH status was associated with improvements in profitability (i.e., ability to generate the financial returns to replace assets, meet increases in service demands, and compensate investors), liquidity (i.e., ability to meet cash obligations in a timely manner), and capital structure (i.e., ability to meet debt obligations). MedPAC also reports that Medicare payments to CAHs rose, on average, by 9.5 percent per year during the period 1998-2003, compared with a 3.3 percent rise for similar rural hospitals that did not convert to CAH status. Using the difference between CAH payment rates and PPS payment rates as a rough estimate of increased Medicare spending, MedPAC estimated that in 2003 payments per CAH hospital were roughly $850,000 higher under cost-based reimbursement than they would have been under PPS payment rates.[4]

Methodology

In this study, we use a two-stage approach where DEA is used in the first-stage to estimate cost efficiency of CAHs (as described by Coelli et al. 2005). A fundamental assumption in DEA estimation is that all firms within an industry have access to the same technology, which justifies the estimation of one frontier from the entire data. DEA measures cost efficiency in two steps. First, given input prices and output levels, the cost-minimizing input vector for the *i*-th hospital is calculated using linear programming. Then, cost efficiency is measured as the ratio of minimum cost to observed cost. The cost efficiency measures the factor by which the observed cost can be scaled down if the *i*-th hospital selects the optimal input bundle and operates at a technically efficient point. Failure to achieve cost efficiency may be due to (a) technical inefficiency in the form of wasteful use of inputs, and (b) allocative inefficiency due to the incorrect mix of inputs (Ferrier and Valdmanis 1996, Ray 2004).

[4] MedPAC found that this increase in Medicare spending comes from increased payments rates to CAHs rather than volume increases.

Our focus in this research is on making valid inferences about the impact of external-environmental factors on the CAH cost efficiency. For this, we follow Simar and Wilson (2007) and specify, at the second-stage, the truncated regression[5]:

$$\delta_i = z_i\beta + \varepsilon_i \qquad (1)$$

where $\delta_i$is true cost efficiency, z_i is a vector of k environmental variables which are thought to have an effect on hospital efficiency and β is a vector of parameters to be estimated. Because true cost efficiency is unobserved, DEA-estimated cost efficiency is used and the truncated maximum likelihood regression becomes:

$$\hat{\delta}_i = z_i\beta + \varepsilon_i \geq 1, \quad i = 1, 2, \ldots, n \qquad (2)$$

where $\hat{\delta}_i$ is the reciprocal[6] of DEA-estimated cost efficiency scores such that $\hat{\delta}_i \geq 1$, ε_i is assumed to be distributed N(0, σ^2) with left truncation at 1-$z_i\beta$, and z_i and β are defined as before. It has been shown that the DEA efficiency estimator is biased but consistent[7] and that efficiency estimates and, implicitly, ε_is in (2) are serially correlated in a complicated, unknown way (Simar and Wilson 2007). While the correlation among ε_is disappears asymptotically, Simar and Wilson (2007) showed that conventional methods for inference in the second-stage regression are invalid. To provide valid inference in the second stage analysis, they suggested a parametric bootstrap of the truncated regression in (2). In this paper, we use the bootstrap procedure referred to as Algorithm 1 by Simar and Wilson (2007) which is designed to improve on inference in the second stage regression.

[5] Many of the previous two-stage studies used a tobit (censored) regression in the second-stage. However, Simar and Wilson (2007) showed that this model has important drawbacks.
[6] Such a parameterization of efficiency scores will give us a dependent variable with only a lower bound at 1in the second stage truncated regression, unlike the original efficiency measures that are bounded by 0 and 1.
[7] Kneip et al. (1998) showed that the DEA estimator is a consistent estimator (and, thus, asymptotically unbiased).

Data

Using data from the American Hospital Association (AHA) Annual Survey, Medicare Hospital Cost Report and the Area Resource File, we examined the set of community, general rural hospitals in the U.S. classified as Critical Access Hospitals. Since 1999, the CAH program has grown rapidly from 41 hospitals on January 1, 1999, to 1,055 hospitals on January 1, 2005 (MedPAC 2005). A large number of hospitals converted to CAH status between 2001 and 2005, with the largest number of hospitals joining to CAH program in 2005 because of the intention of the federal government to stop allowing states to waive the distance requirement with "necessary provider" criteria (McNamara 2009). Since our primary goal is to analyze, post-conversion, cost efficiency of CAHs, we used an unbalanced panel data set of CAHs for the period 1999-2006.[8] Only hospitals converted to CAH status in a given year that are also present in our data set in the subsequent years are kept for analysis.[9]

The DEA model used in this study requires information on hospital outputs, inputs, and input prices. The choice of outputs was guided by previous literature (Rosko and Mutter 2010a, Clement et al. 2008). In their excellent review of hospital efficiency studies, Rosko and Mutter (2008) emphasize that virtually all of the hospital efficiency studies included both inpatient and outpatient outputs. We used the number of outpatient visits as a measure of a hospital's outpatient output. This measure has been consistently used in almost all of the hospital efficiency studies (Rosko and Mutter 2008). The number of admissions and postadmission days (inpatient days – admissions) were included as measures of the hospital's inpatient outputs. In

[8] The unbalanced panel data set was dictated by the data availability and constraints on CAHs over the period of study. Furthermore, this unbalanced panel data set allowed us to construct an important variable (i.e., number of years of a hospital in CAH program in a given year) used in the second stage regression.

[9] We excluded CAHs with embedded gaps in the data (i.e., missing from AHA Annual Survey in one or more years) and those with missing information for important variables.

addition, emergency room visits, outpatient surgeries, and total births were also included as hospital outputs.

Rosko and Mutter (2008) pointed out that, due to data constraints, the input price variables were similar in each national study of hospital efficiency. Following these past practices, two input prices were used in the analysis: the price of labor ((payroll expenses + employee benefits) / full-time equivalent facility personnel) and the price of capital ((depreciation expenses + interest expenses) / facility beds). The corresponding physical inputs used in this analysis consist of full time equivalent (FTE) personnel and staffed and licensed beds (Ferrier and Valdmanis 1996).

For the choice of external-environmental variables used in the second-stage truncated regression, we were also inspired from the previous literature (Rosko and Mutter 2010a and 2010b). The primary variables of interest are those associated with the type of hospital reimbursement policies, ownership status, and the degree of competition in a hospital's market. Medicare reimbursement policies have an impact on hospital profits and can create incentives for hospitals to operate more efficiently. It has been shown that reimbursement policies under Medicare PPS create incentives for reducing inefficiency while cost-based reimbursement gives hospitals few incentives to control their costs. We follow previous literature (Rosko and Mutter 2008, 2010a, 2010b; Mutter and Rosko 2008) and use two variables to reflect the external pressure for efficiency of public payers: Medicare percent of admissions (*mcrpct*) ((Medicare admissions / total admissions) × 100) and Medicaid percent of admissions (*mcdpct*) ((Medicaid admissions / total admissions) × 100). Since CAHs receive cost-based reimbursement, it is expected that *mcrpct* to be directly associated with CAH cost inefficiency.

The ownership status in this analysis is introduced by using dummy variables that define public/government owned hospitals (*gov*), private non-profit hospitals and for-profit hospitals (*fprofit*). Non-profit ownership is the reference category. Ownership variables are used to control for internal pressure for efficiency associated with ownership (Rosko and Mutter 2010a and 2010b). The effect of ownership on hospital efficiency should be consistent with Property Rights Theory (PRT) which argues that when property rights are not clearly specified, incentives to promote efficient behavior decline (Rosko 1999). We expect that for-profit hospitals will place a greater emphasis on earning profits and increasing efficiency than non-profit hospitals.

Another internal factor associated with hospital efficiency is membership in a multihospital system (*sys*). Using concepts from resource dependency theory and institutional theory, Rosko and Proenca (2005) argue that hospitals participating in a multihospital system can provide services at lower costs and with greater efficiency than the ones that do not.

Following Rosko (1999, 2001) and Mutter and Rosko (2008) we use a Herfindahl-Hirschman index (HHI) to measure external competitive pressure in a hospital's market.[10] HHI is a standard economic measure of industry concentration and was calculated by summing the squares of the market shares of admissions for all of the hospitals in the county. Higher HHI values reflect less competitive pressure, and hence increased efficiency should be inversely associated with HHI.

Another source of external pressure for efficiency is Health Maintenance Organization (HMO) penetration. Previous literature showed that HMO penetration is inversely associated with hospital cost inefficiency (Rosko 2001). Following Zinn, Proenca, and Rosko (1997) and Rosko and Mutter (2010a), we used Medicare HMO penetration (from Area Resource File) as a

[10] The market area is defined as the county, a definition used consistently in hospital efficiency studies.

proxy for general HMO penetration. Two other variables from Area Resource File that may be used to explain hospital cost inefficiency include the county unemployment rate (*unemployment*) and median household income of the county (*medinc*). The county unemployment rate is used as a proxy for uncompensated care provided by the hospital (Rosko 1999).

An important variable that is used to explain hospital efficiency is the hospital occupancy rate (*occup*), which is included as a measure of the demand for hospital services (Ferrier and Valdmanis 1996). It is defined as the number of inpatient days divided by the cumulative number of beds maintained during the year (number of hospital beds ×365 days). Ferrier and Valdmanis (1996) found a positive impact of occupancy rate on hospital cost efficiency.

To account for the potential trending in CAH cost efficiency or explanatory variables, we include a time trend. In addition, we include a counter for the number of years a hospital had been a CAH in a particular year. Following Rosko and Mutter (2010a), we also suspect that hospitals tend to be more cost inefficient the longer they are in the CAH Program.

Variable definitions and summary statistics for DEA as well as for the second-stage regression are presented in Table 1.

Results

Based on DEA-estimated cost efficiency scores, a kernel density estimator is used to obtain an estimate of density of true efficiency scores. To account for the issue of bounded support of the distribution of efficiency scores, the reflection method (Schuster 1985, Silverman 1986) and a bandwidth selected using Sheather and Jones (1991) method are used for kernel density estimation (for details, see Simar and Zelenyuk 2006). As a preliminary analysis, the estimated density for all CAHs is visualized and indicates that some outliers exist in the sample. Further investigation of some key variables revealed that hospitals with efficiency scores in the

tail of the distribution are much smaller than the rest of the hospitals in the sample. It may be the case that some of these outliers are hospitals with a different distribution of efficiency. Because such outliers can be very problematic for the convergence of likelihood function in the second stage, we follow Zelenyuk and Zeka (2006) and trim the 10% right tail of the distribution. Table 2 presents the distributions of CAHs, by year, before and after the trimming.

A particular problem in this study was adjusting outputs to control for case-mix variations. Unfortunately, there is no Medicare Case-Mix Index available for CAHs as these hospitals are not subject to the PPS system. Rosko and Mutter (2010a) controlled for case-mix by including thirty hospital-level rates of morbidities per admission in their SFA model but many of these variables came out insignificant or of an unexpected sign. While Rosko and Mutter (2010a) used these variables to control for variations in patient burden of illness, the downside was a dramatic loss in the number of hospitals (especially CAH hospitals) that would had been eligible for use in empirical analysis otherwise.

In this paper, we follow a different approach to control for case-mix. Following Pilyavsky et al. (2006), we used average length of stay and percent of admissions for surgery as case-mix proxies and tested the impact of controlling for case-mix variations on hospital efficiency. Using a bootstrap-based test[11] adapted from Li (1996) by Simar and Zelenyuk (2006), we tested the null hypothesis of equality of distributions of efficiency scores from two DEA models in which case-mix proxies were alternatively included and excluded and failed to reject it (Simar-Zelenyuk-adapted-Li test = 0.362, bootstrap *p*-value = 0.682). Thus, case-mix does not appear to decisively influence the empirical analysis.

[11] For this test, we used a Gaussian kernel and a bandwidth selected using Silverman (1986) (see Simar and Zelenyuk (2006) for details).

Table 2 shows summary statistics of DEA-estimated cost efficiency of CAHs by year and for the entire period. The average level of cost efficiency is low (39.4%) and is almost unchanged over the study period. It has been shown that the traditional DEA efficiency estimators are very sensitive to outliers and are biased (however, they are consistent). In addition, DEA assumes that deviations from the efficient frontier are entirely due to inefficiency, making no allowance for random noise (Worthington 2004, Greene 2008). All these suggest that one should use caution interpreting the results in Table 2 as they are not directly comparable to efficiency measures from studies using SFA.

Since our primary goal is to make valid inference about the effect of environmental variables on CAH cost efficiency, we follow Simar and Wilson (2007) and estimate, in the second stage, a bootstrapped truncated regression with cost inefficiency (i.e., reciprocal of DEA-estimated cost efficiency) as the dependent variable. As an interpretation rule, a positive coefficient indicates an increase in inefficiency (or a decrease in efficiency), while a negative coefficient indicates a decrease in inefficiency (or an improvement in efficiency). Using a similar approach, Blank and Valdmanis (2010) analyzed the effect of environmental factors on the cost efficiency of Dutch hospitals.

Table 3 summarizes the results of the second-stage bootstrapped truncated regression. To check the robustness of our results, we estimated two different models. Model 1 is based on a bootstrapped truncated regression of cost inefficiency on all environmental variables present in our dataset. In Model 2, we re-estimated the bootstrapped truncated regression with occupancy rate and unemployment rate dropped from the analysis. A remarkable fact is that both models produced similar quantitative results suggesting that the parameter estimates are robust to changes in model specification.

The estimated results show a positive and significant coefficient of government ownership (*gov*) suggesting that government CAHs are less cost efficient relative to non-profit CAHs. For-profit ownership (*fprofit*) has a negative and significant coefficient in both models, suggesting that for-profit CAHs are more cost efficient than non-profit counterparts, a result that is consistent with the predictions of PRT. These results are consistent with recent findings in the literature (Mutter and Rosko 2008, Rosko and Mutter 2010a).

We hypothesized that Medicare cost-based reimbursement for CAHs leads to an increase in the cost inefficiency of these hospitals. The results show that Medicare share (*mcrpct*) has a positive and significant effect on CAH cost inefficiency suggesting that Medicare cost-based reimbursement might lead to an increase in the cost inefficiency of CAHs. The coefficient of Medicaid share (*mcdpct*) is negative and significant suggesting that an increase in the percent of Medicaid admissions leads to improvements in the cost efficiency of CAHs. This result may be due to the fact that not all states provide cost-based reimbursement for Medicaid patients in CAH hospitals, and some states reimburse CAHs for services delivered to Medicaid beneficiaries using the PPS system or other approaches (Radford, Hamon and Nelligan 2010).

A negative and significant coefficient is found for the system membership variable suggesting CAHs that are members in a multi-hospital system are more cost efficient than the ones that are not, a result consistent with previous literature. We also found a negative and significant coefficient (even though small in magnitude) for county median household income, suggesting that higher median income is inversely associated with CAH cost inefficiency. The negative and significant coefficient of *mhmo* may suggest that Medicare HMO penetration creates pressure for CAHs to operate more cost efficiently, and this result is consistent with Rosko and Mutter (2010a). The coefficient of occupancy rate (*occup*) is negative and significant

suggesting that an increase in occupancy rate leads to a significant decrease in the CAH cost inefficiency, a result that is consistent with Ferrier and Valdmanis (1996). The trend variable has a negative but insignificant coefficient, while for the CAH counter the coefficient is positive and significant suggesting that longer participation in the CAH program is directly associated with increases in cost inefficiency, a result consistent with Rosko and Mutter (2010a).

Conclusions

The CAH program was created to protect small, financially vulnerable rural hospitals that might be essential for access to health care services in isolated rural areas by granting them Medicare cost-based reimbursement. However, there have been concerns that cost-based reimbursement might provide a disincentive for CAHs to control costs and operate efficiently.

In this paper, we focused on explaining, post-conversion, factors that may affect cost efficiency of CAHs. To achieve this objective, we used a two-stage approach where DEA was used, in the first stage, to estimate cost efficiency for each CAH hospital in each year. In the second stage, we employed procedures suggested by Simar and Wilson (2007) for making valid inference, and estimated a truncated regression with bootstrap in which cost inefficiency scores were regressed on a set of external-environmental variables expected to influence hospital performance.

Among the factors that were directly associated with CAH cost inefficiency, we found that Medicare percent of admissions had a positive and significant effect on CAH cost inefficiency. Historically, Medicare cost-based reimbursement has been associated with inefficiency in hospital operation (Gianfrancesco 1990). The rationale is that under cost-based reimbursement a hospital has an incentive to increase costs in order to receive higher revenues because Medicare pays for services on a cost basis (McKay et al., 2002/2003). These suggest

that Medicare cost-based reimbursement (as reflected by Medicare percent of admissions) for CAHs might lead to an increase in the cost inefficiency of these hospitals.

The results also show that longer participation in the CAH program (as indicated by CAH counter variable) is directly associated with hospital cost inefficiency. While this is consistent with Rosko and Mutter (2010a), the size of the coefficient is five times smaller in our case. That is, our results suggest that an additional year in the CAH program increases cost inefficiency by 3.3% while the corresponding coefficient in Rosko and Mutter (2010a) suggests an increase in hospital cost inefficiency by 16.55% for each additional year in the CAH program. This discrepancy may be explained by the differences in modeling strategies as well as data sets between our study and Rosko and Mutter (2010a). While we used a two-stage approach in the line of Simar and Wilson (2007) and analyzed, post-conversion, cost efficiency of CAH hospitals, Rosko and Mutter (2010a) used CAHs and non-CAH rural hospital jointly in a SFA model.

Among the factors that were inversely associated with CAH cost inefficiency, Medicaid share had a negative and significant effect on CAH cost inefficiency. This result might be explained by the fact that not all states provide cost-based reimbursement for Medicaid patients in CAH hospitals and that some states use PPS reimbursement (Radford, Hamon and Nelligan 2010). Other factors that can significantly contribute to improvements in CAH efficiency are occupancy rate, Medicare HMO penetration, for-profit ownership and membership in a multi-hospital system.

It should be noted that a limitation of this study (as well as of the vast majority of the previous hospital efficiency studies) is that we were unable to control for variations in quality. Poor data availability as well as a lack of agreement about how quality should be measured or

how it should be introduced in the model specification has increased the difficulty of controlling for quality in hospital efficiency studies.

The results have important implications for policy. Our results suggest that the federal government has paid a lower price (in terms of efficiency losses) as compared to the findings of Rosko and Mutter (2010a). In a related study by the authors (under review), we found that while CAH hospitals were becoming more allocatively inefficient due to their inability to substitute away from using increasingly higher healthcare labor costs, technical efficiency improved due to the compulsory change in mission of the hospital required by CAH conversion (reduced acute care beds, maximum average length of stay, etc). Consequently, the mission change may have dampened some of the efficiency losses due to cost-based reimbursement.

Cost efficiency is important as Congress weighs the tradeoff of increased costs versus rural in-patient health care access. Our results suggest as the CAH program ages, further efficiency analysis should be conducted to see if the rate of growth of cost inefficiency accelerates or slows down. These studies will be important as the federal government evaluates the costs and returns of this health care program to alternatives under increasing budget constraints.

References

Blank, J.L.T. and V.G. Valdmanis. (2010). "Environmental factors and productivity on Dutch hospitals: a semi-parametric approach." *Health care Management Science* 13: 27-34.

Clement, J.P., V.G. Valdmanis, G.J. Bazzoli, M. Zhao, and A. Chukmaitov. 2008. "Is more better? An analysis of hospital outcome and efficiency with a DEA model of output congestion." *Health Care Management Science* 11: 67-77.

Coelli, T., D. Rao, C. O'Dommell, and G. Battese. 2005. An introduction to efficiency and productivity analysis (2nd ed.). New York: Springer.

Dalton, K., R. Slifkin, S. Poley, and M. Fruhbeis. 2003. "Choosing to convert to critical access hospital status." *Health Care Financing Review* 25(1): 115-32.

Demchuk, P. and V. Zelenyuk (2009). Testing differences in efficiency of regions within a country: the case of Ukraine. *J. Prod. Anal.* 32: 81-102.

Erman, D.E. (1990). Rural health care: the future of the hospital. Medical Care Review 47:1.

Ferrier, G.D. and V. Valdmanis. 1996. "Rural hospital performance and its correlates." *The Journal of Productivity Analysis* 7: 63-80.

Gianfrancesco, F.D. 1990. "The fairness of the PPS reimbursement methodology." *Health Service Research* 25: 1-23.

Holmes, M., G.H. Pink, and R.T. Slifkin. 2006. "Impact of conversion to Critical Access Hospital status on hospital financial performance and condition." Finding Brief #1, November. http://www.flexmonitoring.org/documents/CAHFindingsBrief1.pdf.

Kneip, A., B.U. Park, L. Simar. 1998. "A note on the convergence of nonparametric DEA estimators for production efficiency scores." *Econometric Theory* 14: 783-793.

Li, Q. 1996. "Nonparametric testing of closeness between two unknown distribution functions." *Econometric Reviews* 15: 261-274.

Li, P. J.E. Schneider and M.M. Ward (2007). Effect of Critical Access Hospital Conversion on Patient Safety. *Health Services Research* 42(6): 2089-2108.

McKay, N.L., M.E. Deily, F.H. Dorner. 2002/2003. "Ownership and changes in hospital inefficiency, 1986-1991." *Inquiry* 39: 388-399.

Medicare Payment Advisory Commission (MedPAC). 2005. Report to Congress: Issues in a Modernized Medicare Program. Washington, DC.

McNamara, P.E. (2009). "Rural Hospitals, Reimbursement Policy, and Health care Reform". *Choices* 24 (4).

Mick, S. S. and L. L. Morlock (1990). "America's rural hospitals: a selective review of 1980s research." *J Rural Health* 6(4): 437-66.

Moscovice, I. and J. Stensland (2002). "Rural hospitals: trends, challenges, and a future research and policy analysis agenda." *J Rural Health* 18 Suppl: 197-210.

Mutter, R.L. and M.D. Rosko. 2008. "The impact of ownership on the cost-efficiency of U.S. hospitals" In *Advances in Health Economics and Health Services Research* 18: 113-138.

Newhouse, J. 1994. "Frontier estimation: how useful a tool for health economics?" *Journal of Health Economics* 13: 317-322.

Pilyavsky, A. I., W.E. Aaronson, P.M. Bernet, M.D. Rosko, V.G. Valdmanis, M.V. Golubchikov. 2006. "East-west: does it make a difference to hospital efficiencies in Ukraine?" *Health Economics* 15 (11): 1173-1186.

Pink, G., G. Holmes, C. D'Alpe, R.E. Thomson, R. Slifkin (2007). Variations in financial performance among peer groups of Critical Access Hospitals. Journal of Rural Health 23: 299-305.

Ray, S.C. 2004. Data envelopment analysis: theory and techniques for economics and operation research. Cambridge: Cambridge University Press.

Radford, A., M. Hamon, and C. Nelligan. 2010. States' Use of Cost-Based Reimbursement for Medicaid Services at Critical Access Hospitals. Findings Brief. North Carolina Rural Health Research and Policy Analysis Center. Online at: http://www.shepscenter.unc.edu/rural/pubs/finding_brief/FB94.pdf. Accessed 28 October, 2010.

Rosko, M. 1999. "Impact of internal and external environmental pressures on hospital inefficiency." *Health Care Management Science* 2: 63-74.

Rosko, M. 2001. "Cost efficiency of U.S. hospitals: a stochastic frontier approach." *Health Economics* 10: 539-551.

Rosko, M. D. and R. L. Mutter 2008. "Stochastic frontier analysis of hospital inefficiency: a review of empirical issues and an assessment of robustness." *Medical Care Research and Review* 65(2): 131-66.

Rosko, M.D. and R.L. Mutter. 2010a. "Inefficiency differences between Critical Access Hospitals and prospectively paid rural hospitals." *Journal of Health Politics, Policy and Law* 35 (1): 95-126.

Rosko, M.D. and R.L. Mutter. 2010b. "What have we learned from the application of Stochastic Frontier Analysis to U.S. hospitals?" *Med Care Research and Review* (http://mcr.sagepub.com/content/early/2010/05/24/1077558710370686).

Rosko, M.D. and J. Proenca. (2005). " Imapact of network and system use on hospital X-efficiency". *Health Care Management Review*, 30: 69-79.

Schuster, E. 1985. "Incorporating support constraints into nonparametric estimators of densities." *Communications in Statistics, Theory and Methods* 14: 1123-1136.

Sexton, T., A. M. Leiken, and S. Sleeper. 1989. "The impact of prospective reimbursement on nursing home efficiency." *Medical Care* 27 (2): 154-163.

Sheather, S. and M. Jones. 1991. "A reliable data-based bandwidth selection method for kernel density estimation." *Journal of Royal Statistical Society*, Series B 53: 683-690.

Silverman, B.W. 1986. Density Estimation for Statistics and Data Analysis. London: Chapman and Hall.

Simar, L. and P.W. Wilson. 2007. "Estimation and inference in two-stage, semi-parametric models of production processes." *Journal of Econometrics* 136: 31-64.

Simar, L. and P.W. Wilson. 2008. "Statistical inference in nonparametric frontier models: recent developments and perspective." In *The Measurement of Productive Efficiency and Productivity Growth* edited by Harold O. F., C.A.K. Lovell, S.S. Schmidt. : 421-521. Oxford: Oxford University Press.

Simar, L. and V. Zelenyuk. 2006. "On testing equality of distributions of technical efficiency scores." *Econometric reviews* 25(4): 497-522.

Worthington, A. 2004. "Frontier efficiency measurement in health care: a review of empirical techniques and selected applications." *Medical Care Research and Review* 61: 135-170.

Zelenyuk, V. and V. Zheka. 2006. "Corporate governance and firm's efficiency: the case of transitional country, Ukraine." *Journal of Productivity Analysis* 25: 143-157.

Zinn, J., J. Proenca, and M. Rosko. 1997. "Organizational and environmental factors in hospital alliance membership and contract management: a resource dependence perspective." *Hospital and Health Service Administration* 42: 67-86.

Table 1. Summary statistics and variable definitions.

		Mean	Std. Dev.
DEA Variables			
Outputs			
admtot	Total admissions	673.28	496.23
postdays	Postadmission days: inpatient days - admissions	8,154.59	10,208.74
opv	Total outpatient visits	25,269.07	25,297.88
erv	Emergency room visits	4,406.63	4,075.46
outsurg	Outpatient surgeries	497.37	759.96
birth	Total births	50.34	88.04
Inputs			
bdtot	Staffed and licensed hospital beds	41.88	33.88
fte	Full time equivalent (FTE) employees	133.55	97.24
Input Prices			
pk	Price of capital($): (depreciation + interest expenses) / bed	19,733.15	22,460.04
w	Price of labor($): (payroll expenses + employee benefits) / FTE employee	43,183.83	15,583.02
Second Stage Variables			
gov	Government hospital (binary variable 1,0)	0.47	0.50
fprofit	For-profit hospital (binary variable 1,0)	0.02	0.16
mcrpct%	% Medicare admissions: (Medicare admissions/Total admissions)×100	59.00	14.15
mcdpct%	% Medicaid admissions: (Medicaid admissions/Total admissions)×100	11.76	8.09
hhi	Herfindahl-Hirschman index	0.57	0.35
sys	Member of a multihospital system (binary variable 1,0)	0.34	0.47
mhmo%	% Medicare HMO penetration	3.12	6.36
medinc	Median household income	36,917.37	7,277.45
occup	Occupancy rate: (inpatient days / beds ×365 days)	0.46	0.23
unemploy	County unemployment rate	5.16	2.24
trend	Time trend: 1 in 1999, 2 in 2000,…….., 8 in 2006	5.79	1.83
CAHcount	Number of years in CAH program	3.21	1.83

Table 2. DEA-estimated cost efficiency of CAHs.

			Cost Efficiency	
Year	N_0	N_1	Mean	Std. Dev.
1999	65	57	0.393	0.132
2000	221	186	0.390	0.141
2001	403	348	0.387	0.128
2002	589	522	0.394	0.132
2003	723	649	0.390	0.125
2004	864	787	0.399	0.132
2005	1,023	942	0.395	0.128
2006	1,023	942	0.395	0.130
Total	4,911	4,433	0.394	0.129

Note: N_0 – CAHs before outlier deletion, N_1 – CAHs after outlier deletion.

Table 3. Results of truncated regressions estimation.

Variable	Model 1	Model2
constant	2.9452***	2.8713***
gov	0.1646***	0.1775***
fprofit	-0.1897**	-0.1582**
mcrpct	0.0051***	0.0052***
mcdpct	-0.0104***	-0.0113***
hhi	-0.0484	-0.0415
sys	-0.1541***	-0.1537***
medinc	-0.000009***	-0.000010***
mhmo	-0.0036*	-0.0039**
trend	-0.0053	-0.0062
CAHcount	0.0331***	0.0343***
occup	-0.2019***	
unemploy	0.0014	

***p<0.01, **p<0.05, *p<0.10

Note: Estimation based on Algorithm 1 of Simar and Wilson (2007), with 2000 bootstrap replications for confidence intervals of the estimated coefficients.