AN APPLICATION OF THE TWO-STAGE, SEMI-PARAMETRIC APPROACH WITH DOUBLE BOOTSTRAP TO ANALYZE TECHNICAL EFFICIENCY OF CRITICAL ACCESS HOSPITALS

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Poster prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011.

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ABSTRACT

This study examines technical efficiency of Critical Access Hospitals (CAH) using a two-stage approach and bootstrap procedures for making valid inference about the impact of environmental variables on CAH efficiency. In the first stage, a data envelopment analysis (DEA) efficiency estimator is used to estimate technical efficiency of each hospital in the sample. In the second stage, efficiency scores are regressed on environmental variables using a truncated regression with bootstrap. Alternatively, a double bootstrap procedure is used, where bias-corrected DEA efficiency scores, obtained by means of bootstrap in the first stage, are used in the second stage bootstrapped truncated regression. While both procedures provide valid inference in the second stage analysis, the double bootstrap procedure has also been shown to improve statistical efficiency in the second stage truncated regression. Our results indicate that, while the two procedures yield in general similar and consistent results, only the double bootstrap procedure unveiled the direct association between Medicare cost-based reimbursement and CAH inefficiency.

INTRODUCTION

- The Critical Access Hospital program, introduced as part of the Balanced Budget Act of 1997, has offered Medicare cost-based reimbursement to small, isolated (and mostly) rural hospitals that meet certain eligibility criteria to improve their financial viability (and potentially prevent closure).
- Previous studies showed that Medicare cost-based reimbursement gave hospitals few incentives for cost control (McKay et al., 2002/2003).
- While there is a large consensus that the CAH program has helped preserve access to care in isolated areas, questions have been raised about the efficiency of CAH hospitals (MedPAC, 2005).
- The contribution of this research to the literature is twofold:
  - The first is analyzing the impact of Medicare cost-based reimbursement and other environmental factors on CAH technical efficiency.
  - The second is the application of more accurate techniques to hospital efficiency analysis, namely the two-stage DEA approach with both the single and double bootstrap procedures suggested by Simar & Wilson (2007).

DATA

- We focus on the set of 2005 and 2006 community, general hospitals in the U.S. classified as Critical Access Hospitals.
- Variable definitions and summary statistics for DEA as well as for the second stage truncated regression are presented in Table 1.

Table 1. Summary statistics and variable definitions.

DEA Variables	Mean	Std. Dev.
Outputs		
Total hospital admissions	761.27	549.35
Postadmission days	8,168.74	9,919.18
Total outpatient visits	28,750.82	27,346.64
Emergency room visits	5,096.16	4,217.28
Outpatient surgeries	590.11	599.78
Total births	60.90	102.96
Inputs		
Staffed and licensed hospital beds	41.43	31.85
Full time equivalent (FTE) registered nurses	29.12	20.74
FTE licensed practical nurses	8.28	6.93
Other FTEs	97.93	63.74
Second Stage Variables		
Government hospital (binary 1,0)	0.45	0.50
For-profit hospital (binary 1,0)	0.04	0.19
% Medicare admissions	59.02	14.11
% Medicaid admissions	12.36	8.48
Herfindahl-Hirschman index	0.56	0.34
Member of a multihospital system (binary 1,0)	0.36	0.48
% Medicare HMO penetration	3.97	6.91
Median household income	39,205.02	7,783.05
% Admissions for surgeries	16.47	64.55

METHODOLOGY

- We use a two-stage, semi-parametric approach with the single and double bootstrap procedures (Algorithm #1 and Algorithm #2) proposed by Simar & Wilson (2007) for making valid inferences about the impact of environmental factors on hospital efficiency.
- A data envelopment analysis (DEA) efficiency estimator is used in the first stage to estimate technical efficiency scores for individual CAH hospitals.
- An output-oriented DEA approach, assuming variable returns to scale, is used in estimation.
- We follow Simar & Wilson (2007) and specify, at the second-stage, a truncated regression model.
- To provide valid inference in the second stage analysis, Simar & Wilson (2007) suggest a parametric bootstrap of the truncated regression.
- Alternatively, Simar & Wilson (2007) suggest a bootstrap procedure to obtain bias-corrected technical efficiency scores used in the second stage truncated regression. Valid inference can be obtained by using a second bootstrap procedure applied to the truncated regression.
- In summary, in the two-stage approach with single bootstrap, technical efficiency scores are estimated in the first stage using DEA, and, in the second stage, the efficiency scores are regressed on environmental variables using a truncated regression with bootstrap.
- In the double bootstrap procedure, the DEA-efficiency estimator is corrected for bias, in the first stage, using a specific bootstrap procedure. In the second stage, bias-corrected efficiency scores are regressed on a set of environmental variables using a second bootstrap procedure applied to a truncated regression.

RESULTS

- Table 2 presents original and bias-corrected mean technical efficiency of analyzed CAH hospitals.
- Bias-corrected efficiency scores are, on average, lower than the uncorrected (original) DEA estimates suggesting that the uncorrected efficiency estimates are upward biased.

Table 2. Original and bias-corrected efficiency scores.

		Bias-corrected efficiency scores			
Year	Original DEA estimates	Mean	Std.Dev.	Min	Max
2005	0.717	0.651	0.159	0.279	0.930
2006	0.742	0.668	0.155	0.289	0.945
All	0.729	0.660	0.157	0.279	0.945

- Table 3 summarizes the results of the second stage bootstrapped truncated regression based on Algorithm #1. Table 4 presents the results of the second stage bootstrapped truncated regression based on Algorithm #2.
- As an interpretation rule, a positive coefficient suggests an increase in inefficiency, while a negative coefficient suggests a decrease in inefficiency (or an improvement in efficiency).
- The estimated results show that Medicare percent of admissions has an insignificant effect on CAH technical efficiency under Algorithm #1 while its coefficient is positive and significant, as expected, under Algorithm #2.
- For-profit CAHs are less technically efficient relative to non-profit CAHs which can be intuitively explained by the fact that for-profit CAH hospitals might take advantage of Medicare cost-based reimbursement to maximize their profit.
- The negative and significant effect of Medicaid share on the technical inefficiency of CAH hospitals is consistent with prior research which has shown that Medicaid typically underpays hospitals and exerts cost containment pressures.

Table 3. Results of bootstrapped truncated regression (Algorithm #1)

		95% Bootstrap C.I.		99% Bootstrap C.I.	
Variable	Coeff.	Low	Up	Low	Up
Constant	1.3914***	0.9084	1.8909	0.7751	2.0100
Government	0.3312***	0.2129	0.4405	0.1665	0.4829
For-profit	0.2926**	0.0531	0.5650	-0.0319	0.6475
Medicare %	0.0029	-0.0012	0.0069	-0.0023	0.0080
Medicaid %	-0.0270***	-0.0354	-0.0184	-0.0380	-0.0158
HHI	0.1509**	0.0119	0.2890	-0.0428	0.3373
System	-0.1592***	-0.2699	-0.0486	-0.3044	-0.0028
Income	-0.000009**	-0.000017	-0.000002	-0.000018	0.000001
HMO %	-0.0129**	-0.0217	-0.0029	-0.0238	0.0006
Surgeries %	0.0003	-0.0001	0.0013	-0.0003	0.0020
Y2006	-0.1121**	-0.2147	-0.0106	-0.2382	0.0169

Table 4. Results of bootstrapped truncated regression (Algorithm #2).

		95% Bootstrap C.I.		99% Bootstrap C.I.	
Variable	Coeff.	Low	Up	Low	Up
Constant	1.5069***	1.0911	1.9454	0.9607	2.0649
Government	0.3456***	0.2492	0.4429	0.2089	0.4698
For-profit	0.3495***	0.1356	0.5971	0.0504	0.6736
Medicare %	0.0046**	0.0012	0.0082	-0.0006	0.0095
Medicaid %	-0.0258***	-0.0334	-0.0187	-0.0355	-0.0169
HHI	0.1210*	-0.0103	0.2562	-0.0585	0.2997
System	-0.1517***	-0.2532	-0.0522	-0.2826	-0.0181
Income	-0.000009***	-0.000016	-0.000003	-0.000018	-0.000001
HMO	-0.0170***	-0.0248	-0.0085	-0.0269	-0.0058
Surgeries %	0.0003	-0.0002	0.0012	-0.0003	0.0018
Y2006	-0.0842*	-0.1746	0.0111	-0.2013	0.0339

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

CONCLUSIONS

- Our research suggests that, for future hospital efficiency studies, the two-stage DEA approach along the line of Simar & Wilson (2007) can be a viable alternative for analyzing the impact of environmental variables on hospital efficiency.
- When using the two-stage DEA approach, researchers at a minimum should consider using Algorithm #1 for making valid inference.
- While both the single and double bootstrap procedures provide valid inference, the double bootstrap procedure appears to improve on statistical efficiency in the second stage truncated regression relative to the single bootstrap procedure.

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