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Data Envelopment Analysis Applications and US Hospital Policy

APPENDIX

TABLE 11.2 *Hospital efficiency/productivity studies*

Authors	Date	DEA model	Inputs/outputs	Data	Major findings
Sherman	1984	Input-oriented overall technical efficiency	Inputs included FTE non-physician labor and total dollar value of supplies plus purchased services. Outputs were patient days for patients 65 and older, patient days 64 and younger, number of nurses trained, and number of interns and medical residents trained.	1976 Massachusetts Rate Setting Commission and input from a panel of experts made up of administrators of the hospitals studied	DEA identified two inefficient hospitals. A panel of experts agreed on the choice of inputs and outputs. The director and chief financial officer of the inefficient hospital concurred that the DEA model used and the inputs and outputs that were included reflected their hospitals could improve efficiency along the lines suggested by the findings. DEA results were understood by administrators (panel of experts) and agreed findings from DEA could be used in taking managerial action.
Grosskopf and Valdmanis	1987	Input-oriented overall technical and pure technical efficiency	Inputs included net plant assets, number of FTE physicians, FTE registered nurses plus other staff, and number of admissions as a type of control variable. Outputs included acute inpatient days, intensive care inpatient days, number of surgeries, number of outpatient plus, ER visits.	1982 American Hospital Association Survey of Hospitals, California hospitals with 200 + beds in cities with a population of 50,000 or more	Comparing public hospitals and private NFP hospitals, public hospitals were relatively more efficient than NFP hospitals at a statistically significant level.

Valdmanis	1992	Input-oriented overall technical efficiency, pure technical efficiency, and scale efficiency	10 different specifications[33]	1982 American Hospital Association Survey of Hospitals. Michigan hospitals with 200 + beds in cities with a population of 50,000 or more	In all 10 specifications, public hospitals were statistically significantly (Mann-Whitney tests) more efficient than the NFP hospitals on all three efficiency measures: overall technical efficiency, weak technical efficiency, and scale efficiency.
Ozcan and Luke	1993	Input-oriented overall technical efficiency	Inputs included number of beds, number of diagnostic and special services, non-physician FTE staff, and operational expenses. Outputs included case-mix adjusted admissions, FTE teaching medical residents, nursing, and physical therapy.	1987 American Hospital Association Survey of Hospitals (3,000 Urban hospitals)	Using covariance analysis, public hospitals were relatively more technically efficient, and for-profit hospitals were the least efficient compared to public and NFP hospitals. Hospitals treating more Medicare patients were less efficient and payer mix was not statistically significantly related to efficiency.
Grosskopf and Valdmanis	1993	Input-oriented overall technical efficiency and pure technical efficiency	Same inputs and outputs as used in Grosskopf and Valdmanis (1987) with the inpatient outputs weighted by case mix.	Same data set as used in Grosskopf and Valdmanis (1987)	Public hospitals treated patients with a higher case-mix index (more seriously ill) and were statistically significantly more efficient than NFP hospitals.

[33]The outputs used in various combinations included acute inpatient days, intensive care inpatient day, number of ambulatory plus emergency room visits, number of surgeries, number of adult inpatient days, number of pediatric inpatient days, and number of Medicare inpatient days. Inputs used included various combinations of number of FTE physicians, FTE house staff, FTE nurses, FTE other nonphysician staff, number of beds, and net plant assets.

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TABLE 11.2 *(continued)*

Authors	Date	DEA model	Inputs/outputs	Data	Major findings
Wang, Ozcan, Wan, and Harrison	1999	Input-oriented overall efficiency and a comparison of efficiency in 1989 and 1993	Inputs included service complexity, non-physician FTE staff, and operating expenses. Outputs included case-mix-adjusted discharges and outpatient plus emergency room visits.	1989 and 1993 American Hospital Association Survey of Hospitals	Relatively small deviations from efficiency in medium and large hospital markets, and inefficiency and excess service capacity were related.
Kazley and Ozcan	2009	Input-oriented overall technical efficiency and a comparison of efficiency changes between efficiency scores in 2004 minus efficiency scores in 2001	Inputs included FTE non-physician staff, staffed beds, capital assets, and operating expenses. Outputs were case-mix-adjusted admissions and outpatient plus emergency room visits.	2001 and 2004 American Hospital Association Survey of Hospitals	The use of electronic medical records (EMR) was not statistically significantly more efficient between 2001 and 2004.
Grosskopf, Margaritis, and Valdmanis	2004	Input-oriented directional distance function (DDF)	Inputs included FTE physicians, FTE house staff (medical resident), FTE registered nurses, FTE licensed practical nurses, FTE other staff, and number of staffed beds. Outputs were number of patients, number of surgeries, and number of outpatients plus emergency room visits.	1995 American Hospital Association Survey of Hospitals	Stratifying teaching hospitals by number of managed care contracts, teaching hospitals treating more patients under HMO and PPO contracts were relatively more efficient at statistically significant levels.

TABLE 11.3 *Plant capacity utilization*

Authors	Date	DEA approach	Inputs/outputs	Data	Major findings
Färe, Grosskopf, and Valdmanis	1989	Output-oriented plant capacity utilization	Inputs included FTE physicians, FTE other staff, number of admissions, and number of staffed beds. Outputs were number of acute patient days, number of ICU patient days, number of surgeries, and number of outpatient visits plus emergency room visits.	1982 American Hospital Association Survey of Hospitals for the state of Michigan	Beginning with all inputs as variable and adding a fixed constraint on succeeding inputs, efficiency scores decreased as more inputs were permitted to vary. There was no statistically significant difference between nonurban and urban hospitals. However, urban hospitals overutilized FTE physicians and FTE staff, whereas these two labor inputs were underutilized in nonurban hospitals.
Ferrier, Leleu, and Valdmanis	2009	Output-oriented distance function plant capacity utilization	Inputs included FTE registered nurses, FTE licensed practical nurses, FTE medical residents, FTE administrative staff, and FTE trainees and staffed beds. Outputs were Medicare inpatient days, Medicaid, emergency room visits, outpatient visits, number of inpatient surgeries, and number of outpatient surgeries.	2002 American Hospital Association Survey of Hospitals	For-profit hospitals had the most excess capacity, whereas federal hospitals (including Veterans Affairs hospitals) had the least excess capacity. Among the 15 SMSAs examined, hospitals operating in St. Louis had the most excess capacity, whereas hospitals operating in New York City had the least excess capacity.

(*continued*)

TABLE 11.3 *(continued)*

Authors	Date	DEA approach	Inputs/outputs	Data	Major findings
Ferrier, Leleu, and Valdmanis	2010	Outpatient distance function plant capacity	Inputs included FTE registered nurses, FTE licensed practical nurses, FTE administrative staff, and staffed beds. Outputs were case-mix-adjusted admissions, emergency room visits plus, outpatient visits, number surgeries, and FTE medical residents and other trainees.	1994–2002 American Hospital Association Survey of Hospitals	Results indicate that states without CON in place (non-CON) had an industry inefficiency score of 33.7% compared to states with CON which had an inefficiency score of 31%. Similarly, aggregate technical inefficiency was 20.6% for non-CON states compared to 18.9% for CON states. Structural technical inefficiency was 13.1% for non-CON states and 12.1% for CON states.

TABLE 11.4 *Malmquist approach*

Authors	Date	DEA approach	Inputs/outputs	Data	Major findings
Färe, Grosskopf, Lindgren, and Roos	1994	Malmquist approach	Inputs included doctors, medical labor, service labor, and administrative labor. Outputs were defined as inpatient discharges and long-term bed care days.	1970–1985 Central Statistical Bureau (Sweden)	Results were mixed in terms of productivity as 13 of the 17 hospitals demonstrated a decrease in technical change (movement to a higher isoquant) and only five hospitals showed an improvement efficiency gains (catching up to the isoquant).
Roh, Park, and Moon	2011	Malmquist approach	Inputs included FTE doctors, assets, and beds. Outputs were patient days, emergency room visits, outpatient visits, the number of surgeries, and amount of charity care.	1999–2003 Merritt Research Services, LLC including data on hospital utilization data and financial statements	For this sample of hospitals, technical efficiency improved between 1999-2003.

TABLE 11.5 *DEA hospital efficiency/productivity studies including quality*

Authors	Date	DEA approach	Inputs/outputs	Quality measure
Clement, Valdmanis, Bazzoli, Zhao, and Chukmartov	2008	Output-oriented under assumptions of strong and weak disposability of outputs	Inputs include FTE registered nurses (RNs), FTE licensed practical nurses (LPNs), FTE other staff, and staffed Beds. Outputs were number of births, outpatient surgeries, ER visits, outpatient visits, and case-mix-adjusted admissions.	Risk-adjusted morality rates for acute myocardial infarction (ACI), congestive heart failure (CHF), stroke, gastrointestinal hemorrhage, and pneumonia
Nayar and Ozcan	2008	Input-oriented CRS DEA	Inputs included beds, operating expenses (excluding payroll, capital, and depreciation) FTE staff, and total assets. Outputs were outpatient visits, case-mix adjusted discharges, and number of FTE medical trainees.	Percentage of patients given antibiotic timing, percentage of patients given oxygenation, percentage of patients given pneumococcal vaccines.
Valdmanis, Rosko, and Mutter	2008	Output-oriented DEA including CRS, VRS, scale, and congestion (weak disposability of outputs)	Inputs included FTE RNs, FTE LPNS, FTE other staff, acute care beds, other beds, and FTE interns and residents.	Number of patients experiencing failure to rescue, infection due to medical care, postoperative sepsis, and postoperative respiratory failure

Ferrier and Trivitt	2013	Double-input-oriented DEA	Inputs included beds, FTE RNs, FTE LPNs, FTE other staff, and number of residents. Outputs were Medicare inpatient days, Medicaid, other payer inpatient days, ER visits, outpatient visits, inpatient surgeries, outpatient surgeries, and case-mix index.	Risk adjusted mortality rates for AMI, CHF, and gall-bladder surgery.
Du, Wang, Chen, Chou, and Zhu	2014	Slack-based additive super efficiency DEA under VRS	Inputs included total operating revenue, beds, FTE physicians and dentists, FTE nurses (RN or LPN). Outputs were total operating revenue and number of cases.	Survival rates
Onder, Cook, and Kristal	2022	Output-oriented DEA with bootstrap for second stage regression	Inputs included beds, employees, and discharges. Outputs were readmission tates and operating costs.	Readmission rates as an output. Included in the second-stage regression clinical care and experiential care

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TABLE 11.6 *DEA hospital efficiency/productivity studies including quality*

Authors and year	Data	Major findings
Clement et al. 2008	2004 Pennsylvania Hospitals American Hospital Association Survey of Hospitals, Agency for HealthCare Research and Quality (AHRQ), Inpatient Data Base, Healthcare Utilization Project (HCUP)	Acute myocardial infarction patients (AMI/Heart Attack) had better outcomes in teaching hospitals; Valdmanis et al. (2008) found that patients suffering from pneumonia had poorer outcomes in public hospitals, but overall congestion was not statistically significantly different among public, NFP, or for-profit hospitals.
Nayar and Ozcan, 2008	2003 Virginia Hospitals from American Hospital Association Survey of Hospitals, Center for Medicare and Medicaid Services, (CMS) Cost Reports, and Virginia Health Information Database	Including only the technical efficiency measure, results showed there was 16 efficient hospitals (mean score of 1.00) and 37 inefficient hospitals (mean score of 0.72). Results from the second model showed that 21 hospitals were deemed efficient as compared to 32 inefficient hospitals (mean score 0.78). By partitioning the sample by efficient and inefficient hospitals, 70.9% of efficient hospitals met the antibiotic timing as compared to 65.7%.
Valdmanis et al., 2008	2004 Urban Hospitals from American Hospital Association Survey of Hospitals, Patient Safety Indicator from AHRQ, and Quality Indicator from HCUP	Patients suffering from pneumonia had poorer outcomes in public hospitals, but overall congestion was not statistically significantly different among public, NFP, or for-profit hospitals

Ferrier and Trivitt, 2013	2005 American Hospital Association Survey of Hospitals, CMS, and HealthGrades	Findings for all hospitals were consistent with other studies, with mean efficiency scores ranging from 0.6547 to 0. 7941. Analysis also gauged differences by ownership form and teaching status. For-profit hospitals were statistically significantly more efficient than either NFP or public Hospitals. Teaching hospitals were statistically significantly more efficient than nonteaching hospitals at taking the ratio between process quality DEA model and the process efficiency. Hospitals were better at producing quality rather than reducing costs. This finding fits well with the theories of hospital behavior of quality maximization as an objective.
Du et al., 2014	2006 American Hospital Association Survey of Hospitals, The Pennsylvania Health Care Cost Containment Council	The benefits of this approach include the individual indication of which inputs can be increased and outputs decreased via nonnegative slacks without compromising efficiency. Inefficient hospitals had too many beds and staff given quality-adjusted outputs.
Onder et al., 2022	2014 CMS Cost Reports, Hospital Consumer Assessment	Findings included both patient experience and clinical treatment improve hospital efficiency for a relatively fixed volume of patients, improving quality lowers costs and readmission rates. Their insight is important to hospital managers and policymakers, focusing on quality, demonstrating that there may not be a trade-off between quality of hospital care and total economic costs.

TABLE 11.7 *DEA efficiency/productivity studies and geographical access*

Authors	Date	DEA model	Inputs/outputs	Data	Findings
Nedelea, Fannin, and Barnes	2010	Input-oriented DEA, two-stage model	Inputs included hospital beds, FTE employees, price of capital, and wages. Outputs were Total hospital admissions, total inpatient days, total outpatient visits, outpatient surgeries, inpatient surgeries.	2006 American Hospital Association Annual Survey of Hospitals and 2006 Medicare Hospital Cost Report	CAH hospitals were less efficient than non-CAH hospitals. By ownership type, public hospitals were the least efficient whereas for-profit CAHs were relatively the most efficient.
Bernet, Moises, and Valdmanis	2011	Input-oriented DEA	Inputs included FTE staff, FTE nursing hours, beds, total distance traveled for patients with diagnosis 143, total distance traveled for patients with diagnosis 182. Outputs were case-mix-adjusted admissions, number of patients with diagnosis 143, and number of patients with diagnosis 182.	The Florida Agency for Health Care Administration (data on hospital capacity), Hospital Inpatient Discharge Data (patient characteristics), and the Hospital Financial Data for Florida for specific service capabilities	Total resource use for urgent care patients is more efficient, which included the technical efficiency of hospitals including patients' travel distance. Patients enrolled in an HMO (Medicare, Medicaid, or private) traveled to closer hospitals at statistically significant levels.