Applying non-parametric methods measuring economic performance: a case of community hospitals in the State of New York

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Background: Community hospitals in New York State hold a unique position in turbulent era, while community hospitals are the hub of healthcare delivery in State of New York .The primary purpose of this study is to measure the economic performance of community hospitals in the State of New York that provide general and acute healthcare services from 2001 to 2014 applying non-parametric approaches.

Methods: To estimate the efficiency of community hospitals, this study uses data envelopment analysis (DEA) that corporate three input (total expenses, beds and FTEs) and three output ones (admissions, daily census and outpatients). Data is extracted from Annual Survey of Hospitals from 2001 to 2014.

Results: The average efficiency score of the community hospital in the State of New York is 0.882 and the average of scale efficiency is 0.925, respectively, for the 14 years. This study reports that rural community hospitals are more efficient than urban community hospitals for the 14 years, and large-size community hospitals are more efficient than medium and small-size hospitals. This study also confirms that public community hospitals in the State of New York are more efficient than non-profit hospitals.

Conclusions: To improve hospitals' competitiveness and find an alternative business model, the healthcare stockholders who include hospital administrators, creditors, healthcare consultants, and policy makers, need to pay careful attention to the economic performance of community hospitals in relation to their capacity. This study is the first one to evaluate the economic efficiency of community hospitals applying non-parametric approaches and explore the factors that influence the performance of community hospitals in the State of New York.

Keywords: Performance measurement; data envelopment analysis (DEA); community hospitals

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Introduction

Prospects for the hospital industry in the State of New York do not seem optimistic. Hospitals confront shortages of healthcare professionals, rising healthcare costs, and increasing barriers to accessing capital. Since 2007, eight hospitals in New York City have closed, and it is reported that nearly one-third of surviving voluntary nonprofit hospitals—most of them safety net hospitals—are in jeopardy (1). Hospitals are often considered vital to local economies, as they provide jobs, stimulate local purchasing, bring outside dollars into the community via third-party payers, and help attract industry and retirees (2,3). As such, the closure of a hospital can have detrimental effects on a community.

Community hospitals in New York State hold a unique position in turbulent era. While community hospitals are the hub of healthcare delivery in State of New York, competition has intensified among hospitals as well as between hospitals and physician-owned facilities. Advances in healthcare technology have enabled a large number of complex procedures to take place in an outpatient service setting. Physician groups, which compete with hospitals, have used these advanced technologies to enhance their capability and to increase their incomes. Therefore, to improve hospitals' competitiveness and find an alternative business model, hospital administrators, creditors, healthcare consultants, and policy makers need to pay careful attention to the productivity of community hospitals in relation to their capacity (4).

The primary purpose of this study is to investigate the economic performance of community hospitals in State of New York that provide general and acute healthcare services from 2001 to 2014. This study measures the performance of community hospitals in State of New York using data employment analysis (DEA) that incorporate multiple input and output variables. This study is structured as follows. A literature review of the related empirical studies on hospital performance using DEA is followed by the model specification of DEA models. The data and variables section presents the input variables and output ones and data sources in this study. The results section explores the factors that determine the performance of hospitals in State of New York. The discussion section presents the conclusion and suggestion for future research.

Previous studies

DEA has been applied as a critical analytical method for comparing the relative efficiency of different hospitals based on multiple input variables and output ones. Fare *et al.* [1989] measured the organizational capacity in analyzing the performance of 39 Michigan hospitals in different market environments (5). This study applied non-parametric DEA in using four input variables (physicians, beds, admissions and non-physicians) and four output ones (acute care, intensive care, surgeries and ER) 4nd found the locations where hospitals provide healthcare services is not significantly different in the performance. Harrison *et al.* [2004] evaluated the technical efficiency of federal hospitals in USA using DEA methodology with four input variables (operating expenses, beds, FTE and services complexity) and two output ones (admission and output visits) (6). The findings indicated the significant inefficiency over the years and the potential to increase efficiency through the management. The efficiency improved 11 percent from 68 percent in 1998 to 79 percent in 2001. This study suggested to establish more specialized policies to improve efficiency in the federal hospitals.

To explore the effect of new healthcare policy, Sulku [2012] employed DEA to measure the efficiency of 81 Turkish hospitals with three input variables (beds, specialists and general practitioners) and three output ones (outpatient, inpatients and total surgery) (7). Results showed the average technical efficiency was improved due to significantly increase scale efficiency, as the average pure technical efficiency slightly improved.

Ferrier *et al.* [2006] employed DEA to measure the efficiency of 170 acute care hospitals in Pennsylvania using five input variables (beds, nurses, LPNs, residents and other labors) and six output ones (inpatient surgeries, outpatient surgeries, ER visits, outpatient visits, inpatient days and charity care) (8). This study found that the Pennsylvania hospitals have produced 7% more output without using any additional inputs and rural hospitals is more efficiency than their urban counterparts. Also this study confirmed that teaching hospitals and non-profit hospitals are more efficiency than teaching and for-profit hospitals in Pennsylvania.

Watchararirој and Tang [2004] employed DEA to measure the technical efficiency of 92 public hospitals in Thailand using three input variables (beds, physicians, nurses) and four output variables (inpatients, outpatient, surgeries and IT investment) (9). This study found that large hospitals (500 beds or more) were more efficient than hospitals with less than 500 beds.

Helal and Eliman [2017] evaluated the technical efficiency of the public hospitals in various districts of the Kingdom of Saudi Arabia employing DEA with four input variables (beds, physicians, nurses and allied health professionals) and four output variables (outpatients, inpatients, patient benefiting from lab tests and patient benefiting from radiology) (10). This study found that the public hospitals failed to achieve the relative efficiency as 92.3 percent in 2014 and 90.2 percent in 2006, respectively and suggested to reduce input variables and to increase output variables for inefficient hospitals to reach efficiency.

Roh *et al.* [2013] examined the impact of ownership, location, size and network of hospitals on the efficiency of 144 acute care hospitals in Tennessee for the 2002–2006 period using DEA with three input variables (current assets, beds and FTEs) and five output variables (procedures, outpatient, inpatient, charity and profits) (11). This study found that hospitals with 126–250 beds are more efficiency than other size of hospitals in Tennessee, public hospitals are more efficient than private and non-profit ones, urban hospitals are less efficient than rural ones and hospitals with network with other healthcare organizations are more efficient than hospitals with non-network. This study suggested public policy should induce hospitals to downsize or upsize into optional size and private and non-profit hospitals should change their organizational goals from profit-driven to quality-driven.

Methods

Study design

DEA is a non-parametric linear programming method for estimating relative technical efficiency; it uses input and output variables of each decision making unit (DMU) to construct a piece-wise linear frontier over the data points (12-15). This linear frontier is made possible for an efficiency indicator to be generated without the need to parameterize the production functions. This method is developed from the relative efficiency of Farrell's concept that indicates the maximum possible efficiency, and provides an efficiency score for each DMU.

Since Charnes and his colleagues coined DEA, the scope of DEA has been applied to both input orientations and output ones. The typical DEA can be either a CCR-DEA model or BBC DEA model. Cooper *et al.* [2006] argued CCR-DEA model forms the possibility production set *P* with four assumptions (16). The first assumption is that each observed point (*xn*, *yn*) belongs to *P*: (*xn*, *yn*) ϵ *P*. The second one is the constant return to scale assumption states the point (*xn*, *yn*) ϵ *P*, then the point (*kxn*, *kyn*) *P* for any positive *k*. The third one relates to any point (*x*, *y*) ϵ *P*, if there is a positive point (x, ȳ) where x ≥ *x* and ȳ < *y* then (x, ȳ) ϵ *P*. Finally, for any linear combination of the points located in P belongs to *P*. P can be defined as an expression of:

$$P = \{(x, y) \mid x \geq \lambda X, y \leq \lambda Y, \lambda \geq 0\} \quad [1]$$

Charnes and his colleagues developed the input oriented DEA method (CCR-DEA model) that measures the efficiency of input to obtain the constant output (15). In other words, CCR-DEA model presumes the frontier surface in pursuing the maximum possible proportional reduction in input with output to be held constant for each DMU. This model assumes efficiency for the DMU as the weighted linear combination of its outputs divided by the weighted linear combination of its inputs, subject to the constraint that the efficiency is between 0 and 1 for each DUM. All weights are restricted to be nonnegative. The linear programming problem that is solved for the j-th hospital in input-oriented DEA model is as follows:

$$Max\ \theta = \sum_{m=1}^{M} u_m y_{m0}$$

$$s.t.\ \sum_{n=1}^{N} v_n x_{n0} = 1,\ \sum_{m=1}^{M} u_m y_{mj} - \sum_{n=1}^{N} v_n x_{nj} \leq 0, v_n, u_m \geq 0 \quad [2]$$

where x_n is vector of input quantities for j-th DMU, y_m is vector of output quantities for j-th DMU, v_n is vector of weight of input, u_m is vector of weight of output.

The CCR-DEA model refers to the constant return to scale (CRS) DEA model, because the scale will be a CRS technology.

Later, Banker *et al.* [1984] proposed the BBC-DEA model to extend and further to elaborate the CCR-DEA model by adopting variable returns to scale (VRS) assumption that increases or decrease return to scale (17). Cooper *et al.* [2006] defined the BBC-DEA model's possibility production set *P* as:

$$P = \left\{ (x, y) \middle| x \geq \lambda X, y \leq \lambda Y, \sum_{n=1}^{N} \lambda_n = 1, \lambda \geq 0 \right\} \quad [3]$$

BBC-DEA model seeks the maximum proportional increase in output production with the constant input (16). When all DMUs do not optimize the scale, the use of CRS specifications results in measures of technical efficiency that is described by scale efficiencies. Therefore, the BBC-DEA model calculates technical efficiency devoid of these scale efficiency effects (18).

The linear programming for BBC-DEA model is follows:

$$Max\ \theta = \sum_{m=1}^{M} u_m y_{m0} - \eta_0$$

$$s.t.\ \sum_{n=1}^{N} v_n x_{n0} = 1, \sum_{m=1}^{M} u_m y_{mj} - \sum_{n=1}^{N} v_n x_{nj} - \eta_0 \leq 0, v_n, u_m \geq 0 \quad [4]$$

where x_n is vector of input quantities for j-th DMU, y_m is vector of output quantities for j-th DMU, v_n is vector of weight of input, u_m is vector of weight of output. η_0 is return to scale.

Data and variables

For the analysis, this study extracts hospitals that provide acute care services in the State of New York from 2001 to 2014 from Annual Survey of Hospitals. After all the hospitals with missing data were deleted, the rich dataset covers 136 community hospitals in the State of New York and retains hospitals information on clinics and utilization,

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Table 1 Descriptive statistics of efficiency variables for individual period, means (standard deviation)

Years	Annual admissions	Daily census	Outpatients	Total expenses ($000)	Staffed beds	FTEs
2001	13,218.1 (12,948.5)	266.5 (267.3)	259,170.6 (250,643.4)	205,849.0 (271,078.5)	338.3 (307.0)	1,902.8 (2,111.0)
2002	13,534.8 (12,858.7)	266.4 (262.0)	254,144.6 (235,249.6)	217,085.9 (266761.9)	342.1 (306.3)	1,930.2 (2,140.8)
2003	13,714.1 (13,247.9)	268.5 (252.2)	266,210.5 (284,565.1)	226,535.0 (284,565.1)	340.2 (300.4)	1,956.7 (2,157.7)
2004	13,848.9 (13,837.7)	263.6 (245.6)	264,895.9 (238,505.1)	234,083.5 (297,689.8)	336.8 (293.7)	1,970.6 (2,175.2)
2005	14,080.0 (13,806.9)	270.5 (253.6)	280,339.6 (265,814.9)	254,508.1 (324,402.9)	335.3 (292.3)	2,035.1 (2,316.9)
2006	14,238.6 (13,951.6)	267.1 (250.0)	292,038.5 (271,911.9)	270,461.0 (350,563.2)	333.2 (296.7)	2,036.1 (2,257.0)
2007	15,472.6 (14,573.3)	272.1 (260.5)	305,735.2 (305,774.9)	282,804.8 (371,048.2)	335.3 (303.9)	2,072.6 (2,324.4)
2008	14,528.3 (14,555.4)	274.6 (271.1)	290,310.5 (294,553.7)	295,819.4 (392,227.9)	344.4 (307.1)	2,149.9 (2,411.9)
2009	14,832.7 (15,055.9)	273.7 (261.3)	306,307.3 (307,293.9)	314,309.1 (422,072.9)	342.2 (308.0)	2,208.9 (2,527.7)
2010	15,100.6 (15,676.9)	275.8 (276.8)	316,887.8 (316,823.7)	332,232.9 (451,460.1)	346.2 (311.4)	2,328.1 (2,708.4)
2011	15,220.6 (15,938.4)	275.1 (276.0)	325,102.8 (325,534.2)	347,068.0 (474,067.4)	346.7 (312.2)	2,322.9 (2,715.8)
2012	151,180.5 (15,848.2)	273.2 (268.9)	332,976.1 (327,147.8)	365,940.8 (503,966.9)	343.8 (303.1)	2,444.4 (3,077.1)
2013	15,117.0 (15,784.4)	275.1 (270.4)	341,240.9 (344,015.6)	390,671.0 (534,686.9)	343.9 (306.1)	2,482.4 (3,144.4)
2014	14,619.8 (15,767.6)	268.5 (271.3)	352,805.5 (368,265.8)	412,342.1 (573,602.4)	341.7 (312.3)	2,534.4 (3,304.6)
2001/14	14,479.7 (14,560.8)	270.8 (262.1)	299,154.7 (295435.7)	296,407.9 (394,156.7)	333.6 (304.4)	2,169.7 (2526.7)

as well as financial and organizational information. Since this study uses secondary institutional data sets, the approval by the Institutional Review Board (IRB) is not required. This study is based on data from the fiscal year 2001 to 2014 and the unit of analysis is the hospital.

The selection of input variables and output variables for the estimation of technical efficiency is important. The proper selection of variables influences the results as well as the utility of the method to provide useful and meaningful information (19). Input variables have to incorporate all necessary resources, while output variables need to reflect the managerial goals of organizations estimated. To measure the relative technical efficiency of acute care hospitals in State of New York, this study selects three input variables (beds, FTEs and total expenses) and three output ones (outpatients, admission and census). As a major input category, beds can be used a proxy for capital investment (20). It also indicates hospital size. Hospital with more beds should realize economies of scale more easily than hospital with fewer beds. Previous studies (21-23) used beds as input variable for measuring the technical efficiency of hospitals. The labor is the critical resources for delivering healthcare services in hospital (24). The FTEs is intended to reflect the volume and range of services undertaken by healthcare professionals in hospitals. The previous studies (25-27) also adopt FTEs as input variable. The total expense is to estimate the degree of the financial resources in relation to the healthcare service produced. Several studies used total expenses as input variable (28-30).

Regarding the output variables, annual admission is a patient accepted for inpatient service in a hospital. It is the main care output, at the same time, the basis for the development of clinical research and care technologies in the hospitals. Two studies use outpatient visit as output variable. It indicates a broad measure of outpatient workload of hospital (11,28). As an official count, census is the total number of patients admitted to the hospital by midnight, or sometimes at another time during the day or evening. Input and output variables in this study are consistent with output and input measures used in the DEA studies.

The descriptive statistic demonstrates the data set that consists of three input variable and three output ones with a variation in these variable over 14 years (*Table 1*). The averages of mean and standard deviation are more proper to allow for hospital size. Overall, two input variables (total expenses and FTEs) increased steadily during the period, and standard deviations of two input variables (total expenses and FTEs) also steadily increased. Two output variables (admissions and outpatients) demonstrate a similar pattern, except census. The standard deviation of census

Table 2 Comprehensive averages of hospital efficiency [136]*

Years	OTE	PTE	SE
2001	0.839	0.899	0.933
2002	0.727	0.803	0.911
2003	0.857	0.899	0.955
2004	0.882	0.928	0.952
2005	0.845	0.910	0.931
2006	0.822	0.900	0.917
2007	0.807	0.885	0.915
2008	0.865	0.906	0.956
2009	0.860	0.910	0.947
2010	0.825	0.893	0.928
2011	0.830	0.896	0.930
2012	0.779	0.855	0.916
2013	0.750	0.844	0.895
2014	0.707	0.824	0.868
Means	0.812	0.882	0.925

*, the number of hospitals. OTE, technical efficiency from CRS DEA; PTE, technical efficiency from VRS DEA; SE, scale efficiency = crste/vrste.

is steady during the period. Since the ranges among input and output variables indicate large variation between large hospital hospitals and the small ones, this study expects the significant variance of technical efficiencies.

Results

Table 2 reports the overall technical efficiency estimates of 136 community hospitals from 2001 to 2014, in terms of their ability to provide output with minimum input utilization, using the BBC-DEA model. The overall technical efficiency is to determine inefficiency due to input and output configuration as well as the size of operation. Pure efficiency and scale efficiency are mutually exclusive and non-additive components. This decomposition provides insight into the source of inefficiencies. Pure technical reflects the managerial performance to organize the inputs in providing healthcare services. So, pure technical efficiency is used as index to capture the managerial performance. Scale efficiency is to indicate the ability of management to choose the optimum size of resource (11).

This study reports a pure technical efficiency to measure scale efficiency to overcome the errors from DEA-BBC model. It is found that out of 136 community hospitals, 19 ones are efficient (efficiency score =1) in 2001, 8 ones in 2002, 20 ones in 2003, 25 ones in 2004, 16 ones in 2005 and 2006, 17 ones in 2007, 19 ones in 2008 and 2009, 13 ones in 2010 and 2012, 17 ones in 2011 and 9 ones in 2013 and 2014, respectively. The average efficiency scores for all the hospitals in the sample are 0.839 in 2001, 0.727 in 2002, 0.857 in 2003, 0.882 in 2004, 0.845 in 2006, 0.822 in 2007, 0.865 in 2008, 0.860 in 2009, 0.825 in 2010, 0.830 in 2011, 0.779 in 2012, 0.750 in 2013 and 0.707 in 2014, respectively. The average overall efficiency score is 0.812, the average of pure technical efficiency is 0.822.

In using DEA-CCR model, it is found that out of 136 community hospitals, 39 community hospitals are efficient in 2001, 24 ones in 2002, 39 ones in 2003, 42 ones in 2004, 48 ones in 2005, 44 ones in 2006, 41 ones in 2007, 45 ones in 2008, 37 ones in 2009, 35 ones in 2010, 41 ones in 2011, 33 ones in 2012, 35 ones in 2013 and 27 ones in 2014, respectively. The average efficiency scores of the inefficient hospitals are 0.899 in 2011, 0.803 in 2002, 0.899 in 2003, 0.928 in 2004, 0.910 in 2005, 0.900 in 2006, 0.885 in 2007, 0.906 in 2008, 0.910 in 2009, 0.893 in 2010, 0.896 in 2011, 0.855 in 2012, 0.844 in 2013 and 0.824 in 2014, respectively. The average efficiency score of the inefficient hospitals is 0.882 and the average of scale efficiency is 0.925 for the 14 years.

The location where a hospital provides healthcare services is the critical factor to determine the hospital performance, but there is no consensus on the effect of location (11). Staat [2006] reports urban hospitals are more efficient than rural hospitals (31), while Gruca and Nath [2001] and Roh *et al.* [2013] confirm rural hospitals are more efficient than urban ones (11,32). Kazley and Ozcan [2007] find there is no difference of technical efficiency between urban and rural hospitals (33). Out of 136 community hospitals in State of New York, 105 community hospitals are classified into urban hospitals, while 31 ones are classified into rural ones (*Table 3*). Like previous studies (11,32), this study finds that the efficiency of rural community hospitals is higher than urban community hospitals. From overall technical efficiency, this study finds that 19 urban hospitals are efficient in 2001, 7 ones in 2002 and 2014, 17 ones in 2003 and 2007, 26 ones in 2004, 16 ones in 2005 and 2013, 15 ones in 2006 and 2012, 14 ones in 2008 and 2009, 11 ones in 2010 and 12 ones in 2011, respectively. The average overall efficiency score of the urban hospitals is 0.848 for the 14 years. In the pure technical efficiency, this study finds that 35 urban hospitals are efficient in 2001, 2003,

Table 3 The averages of community hospital efficiencies by locations

Years	OTE	PTE	SE
Urban hospitals [105]			
2001	0.851	0.912	0.933
2002	0.736	0.828	0.893
2003	0.862	0.915	0.944
2004	0.895	0.940	0.952
2005	0.873	0.929	0.940
2006	0.857	0.920	0.932
2007	0.832	0.904	0.922
2008	0.886	0.928	0.955
2009	0.874	0.928	0.942
2010	0.831	0.909	0.916
2011	0.838	0.911	0.922
2012	0.863	0.911	0.949
2013	0.867	0.911	0.953
2014	0.812	0.885	0.919
Means	0.848	0.909	0.934
Rural hospitals [31]			
2001	0.905	0.945	0.954
2002	0.899	0.945	0.949
2003	0.938	0.962	0.976
2004	0.914	0.975	0.938
2005	0.881	0.958	0.922
2006	0.893	0.966	0.925
2007	0.912	0.964	0.947
2008	0.892	0.955	0.936
2009	0.905	0.962	0.942
2010	0.911	0.972	0.938
2011	0.896	0.967	0.929
2012	0.886	0.970	0.914
2013	0.888	0.973	0.913
2014	0.838	0.953	0.881
Means	0.897	0.962	0.933

OTE, technical efficiency from CRS DEA; PTE, technical efficiency from VRS DEA; SE, scale efficiency = crste/vrste.

2007, 2008, 2009 and2011, 20 ones in 2002, 44 ones in 2004, 36 ones in 2005, 39 ones in 2006, 31 ones in 2010 and 2012 and 34 ones in 2013, respectively. The average pure technical efficiency is 0.909 and the average of scale efficiency is 0.934 for the 14 years.

This study also finds that 11 rural community hospitals are efficient in 2001 2005, 2007, 2010, and 2012, 12 ones in 2002 and 2004, 15 ones in 2003, 9 ones in 2006 and 2011, 10 ones in 2009and 2014, 14 ones in 2008 and 13 ones in 2013 in the overall technical efficiency, and 18 rural community hospitals are efficient in 2001 and 2009, 19 ones in 2002, 2004 and 2005, 21 ones in 2003, 2006, 2008, 2011, 2012 and 2013, 20 ones in 2007, 2010 and 2014 in the pure technical efficiency, respectively. The average overall technical efficiency of rural community hospitals is 0.897, the average pure technical efficiency is 0.962 and the average of scale efficiency is 0.933, respectively, for the 14 years.

The proxy of hospital size is the number of beds. Some studies (9,11,34) argued that the economy of scale exists in the hospital industry with larger hospitals being more efficient than smaller one, while other studies (4,35,36) report that small hospitals are more efficient than large ones. Out of 136 community hospitals, 55 hospitals are classified into large hospitals, 49 ones medium and 32 ones small ones, respectively.

From DEA-BBC model, it is found that 20 large hospitals are efficient in 2001 and 2003, 19 ones in 2002, 2004 and 2006, 21 ones in 2005, 17 ones in 2007, 16 ones in 2008, 12 ones in 2007, 18 ones in 2010 and 2012, 13 ones in 2012, 15 ones in 2013 and 10 ones in 2014, respectively. From DEA-CCR model, it is found that 28 large hospitals are efficient in 2001, 2003 and 2012, 29 ones in 2002, 30 ones in 2004, 2005, 2009 and 2011, 31 ones in 2006, 27 ones in 2009 and 2010 and 26 ones in 2013 and 2014, respectively. The average efficiency score of the large-size inefficient hospitals is 0.925, the average of pure efficiency is 0.954 and the average of scale efficiency is 0.970, respectively, for the 14 years.

Out of 49 medium-size hospitals, it is found that 19 hospitals are efficient in 2001 and 2003, 14 ones in 2002, 2005 and 2007, 13 ones in 2004 and 2011, 11 ones in 2006 and 2014, 12 ones in 2008 and 2012, 15 ones in 2009, 9 ones in 2010 and 10 ones in 2013, respectively, using DEA-BBC model (*Table 4*). From DEA-CCR model, it is found

Table 4 The average of community hospital efficiencies by size

Years	OTE	PTE	SE
Large hospitals [55]			
2001	0.936	0.955	0.980
2002	0.912	0.951	0.959
2003	0.910	0.944	0.963
2004	0.932	0.963	0.966
2005	0.939	0.958	0.980
2006	0.930	0.965	0.963
2007	0.928	0.956	0.970
2008	0.931	0.956	0.974
2009	0.926	0.963	0.961
2010	0.937	0.957	0.978
2011	0.935	0.952	0.982
2012	0.920	0.943	0.976
2013	0.919	0.948	0.969
2014	0.909	0.945	0.962
Means	0.925	0.954	0.970
Medium hospitals [49]			
2001	0.911	0.939	0.971
2002	0.892	0.931	0.958
2003	0.929	0.964	0.963
2004	0.911	0.948	0.961
2005	0.898	0.940	0.955
2006	0.874	0.933	0.937
2007	0.892	0.941	0.948
2008	0.900	0.949	0.949
2009	0.900	0.937	0.962
2010	0.856	0.914	0.939
2011	0.866	0.901	0.963
2012	0.894	0.922	0.970
2013	0.887	0.919	0.966
2014	0.855	0.883	0.970
Means	0.890	0.930	0.958

Table 4 (*continued*)

Table 4 (*continued*)

Years	OTE	PTE	SE
Small hospitals [32]			
2001	0.882	0.933	0.938
2002	0.789	0.860	0.913
2003	0.888	0.923	0.963
2004	0.922	0.978	0.943
2005	0.903	0.966	0.937
2006	0.890	0.947	0.941
2007	0.858	0.919	0.937
2008	0.903	0.953	0.948
2009	0.889	0.952	0.936
2010	0.922	0.977	0.944
2011	0.902	0.967	0.935
2012	0.872	0.923	0.947
2013	0.888	0.940	0.945
2014	0.824	0.912	0.910
Means	0.881	0.939	0.938

OTE, technical efficiency from CRS DEA; PTE, technical efficiency from VRS DEA; SE, scale efficiency = crste/vrste.

that 26 medium-size hospitals are efficient in 2001 and 2004, 23 ones in 2002, 2008 and 2013, 32 ones in 2004, 24 ones in 2005 and 2007, 22 ones in 2006, 27 ones in 2009, 20 ones in 2010 and 2012, 19 ones in 2012 and 15 ones in 2014, respectively. The average efficiency score of the medium-size inefficient hospitals is 0.890, the average of pure technical efficiency is 0.930 and the average of scale efficiency is 0.958, respectively, for the 14 years.

Among 32 small-size hospitals, it is found that 11 hospitals are efficient in 2001, 2003 and 2007, 8 ones in 2002and 2014, 15 ones in 2003, 12 ones in 2005 and 2008, 13 ones in 2006 and 2013, 14 ones in 2009, 2010 and 2011, respectively, using DEA-BCC model, while this study finds that 21 hospitals are efficient in 2001, 11 ones in 2002, 15 ones in 2003, 18 ones in 2004, 2008 and 2009, 20 ones in 2005, 2006, 2010 and 2011, 16 ones in 2007 and 2012, 19 ones in 2013 and 16 ones in 2014, respectively, using DEA-

Table 5 The averages of community hospital efficiencies by organizations DEA

Years	OTE	PTE	SE
Nonprofit hospitals [117]			
2001	0.859	0.918	0.936
2002	0.739	0.822	0.903
2003	0.870	0.918	0.949
2004	0.893	0.944	0.947
2005	0.857	0.926	0.927
2006	0.838	0.920	0.914
2007	0.822	0.904	0.912
2008	0.868	0.917	0.948
2009	0.861	0.916	0.942
2010	0.834	0.907	0.923
2011	0.838	0.910	0.924
2012	0.853	0.907	0.943
2013	0.862	0.912	0.947
2014	0.743	0.854	0.878
Means	0.838	0.905	0.928
Public hospitals [19]			
2001	0.905	0.947	0.955
2002	0.913	0.951	0.959
2003	0.889	0.938	0.947
2004	0.922	0.967	0.954
2005	0.946	0.969	0.977
2006	0.915	0.954	0.958
2007	0.919	0.957	0.960
2008	0.930	0.959	0.970
2009	0.948	0.972	0.975
2010	0.900	0.964	0.934
2011	0.922	0.972	0.949
2012	0.831	0.938	0.887
2013	0.854	0.938	0.909
2014	0.863	0.927	0.931
Means	0.904	0.954	0.948

OTE, technical efficiency from CRS DEA; PTE, technical efficiency from VRS DEA; SE, scale efficiency = crste/vrste.

CCR model. The average efficiency score of the small-size hospitals is 0.881, the average of pure technically efficiency is 0.939 and the average of scale efficiency is 0.938, respectively, for the 14 years. Like previous studies (4,35,36), this study confirms large-size community hospitals in State of New York are more efficient than any other size hospitals.

The unique characteristic of healthcare services is that it is delivered by various sectors: public, non-profit and private organizations. The type of ownership is a critical factor that explores the variations of hospital performance. Previous studies (13,37) indicate that hospital ownership influences hospital performance. The result of hospital efficiency by ownership is mixed.

Grosskopf and Valdmanis [1987], Roh *et al.* [2013] find that public hospitals are more technically efficient due to better resource management and a better best practice production frontier (13,37). Ozcan and Bannick [1994] confirms that federal owned hospitals (Army, Navy and Air-Force) are much more technically-efficient compared to the civilian hospitals (38), while some studies (39-41) find that private hospitals perform more efficiently than non-profit and public hospitals. Other studies (8,42) find non-profit hospitals are more efficient than private and public hospitals.

Out of 136 community hospital in State of New York, 117 community hospitals are classified into non-profit hospitals, while 19 community hospitals are classified into public hospitals (*Table 5*). Among 117 non-profit hospitals, this study finds that 20 non-profit hospitals are efficient in 2001 and 2009, 7 ones in 2002, 19 ones in 2003, 23 ones in 2004, 15 ones in 2005, 2006, 2007 and 2011, 18 ones in 2008 and 2013, 12 ones in 2010, 17 ones in 2012 and 9 ones in 2014 in the overall technical efficiency, respectively, for the 14 years, while this study finds 38 non-profit hospital are efficient in 2001, 2005, 2006 and 2011, 25 ones in 2002, 35 ones in 2003, 2009 and 2012, 45 ones in 2004, 39 ones in 2007, 41 ones in 2008, 34 ones in 2010, 40 ones in 2013 and 27 ones in 2014 in the pure technical efficiency, respectively, for the 14 years. The average overall technical efficiency of non-profit hospitals is 0.838, the average pure technical efficiency is 0.905 and the average of scale efficiency is 0.928, respectively.

Among 19 public community hospitals, this study find that 7 public community hospitals are efficient in 2001, 2006, 2007, 2009 and 2011, 9 ones in 2002, 2003 and 2004, 8 ones in 2005 and 2014 and 6 ones in 2008, 2010, 2012 and 2013, respectively, in the overall technical efficiency, while 13 public community hospitals are efficient in 2001, 2002 and 2005, 12 ones in 2003, 2009, 2010, 2011 and 2014, 13 ones in 2005, 11 ones in 2006, 2007 and 2013, 10 ones 2008 and 2012, respectively, in the pure technical efficiency for the 14 years.

Discussion

This study is to examine the performance of 136 community hospitals in State of New York during the period 2001 to 2014. DEA methods do not require any assumption in regard to the functional forms on hospitals as well as not to require any assumptions that relate to organization specific effects to avoid to impose a wrong functional form on hospitals, and the capabilities that accommodate multiple input and output variables and do not require input price data make the DEAs the desirable methods to estimate the performance of hospitals. The selection of input and output variables for this study is based on variable choice from previous studies, the availability of data and the opinions from healthcare managers. This study selects three input (total expenses, beds and FTEs) and three out ones (admissions, daily census and outpatients).

The results of this study show that the average of pure technical efficiency of 136 community hospitals in State of New York is 0.882 during the 14 years. This score implies that there are considerable possibilities for increasing the level of technical efficiency by 11.8 percentages. Moreover, the results indicate the averages of pure technical efficiency are relatively stable for the first three years and reach its highest level, 0.928, in 2004. Out of 136 community hospitals, 42 community hospitals are efficient in 2004. This study finds that large-size community hospitals (over 301 beds) in State of New York are more efficient than their counterparts, suggesting medium-size (151–300 beds) and small-size (1–150 beds) community hospitals should consider alternative options to improve their efficiency, such as upsizing beds. It needs policy implementation that state government utilizes the Certificate of Need (CON) to control the number of beds for hospitals.

Conclusions

This study finds that rural community hospitals are more efficient than their urban counterparts in the State of New York. It implies urban community hospitals intensify medical arm race that results in lower level of performance to recruit top-tier healthcare professionals as well as to attract patients. The major insurance companies and local and state government can press to urban hospitals either to eliminate any remaining X-inefficiency or to cooperate with other urban ones to get rid of the negative effects of competition. This study finds non-profit community hospitals in State of New York are less efficient than public community hospitals during the analysis period. This finding implies that non-profit community hospitals focus on maximizing net profits, while public community hospitals, which should have relatively fewer resources, make more efficient of input variables to ensure the best performance with limited resources.

From this study, the usefulness of DEA methods is verified as a methodology for the sectorial analysis of community hospitals in State of New York. In addition, DEAs are utilized to estimate the performance of hospital industry in detail and to identify the policy implications for improving the performance.

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Footnote

Conflicts of Interest: The author has completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jhmhp.2019.08.03). The author has no conflicts of interest to declare.

Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was waived due to the nature of the study. This study only used institutional secondary data sets and does not require the approval by the Institutional Review Board (IRB).

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