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Provincial analysis of relative efficiency in Canadian hospitals using DEA

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C H R O N I C L E

Article history:
Received: October 1, 2024
Received in revised format: November 16, 2024
Accepted: December 17, 2024
Available online:
January 22, 2024

Keywords:
DEA
Data Envelopment Analysis
Canada
Healthcare
Efficiency
Hospitals

A B S T R A C T

Studying the efficiency of hospitals in Canada is very important for optimizing resource allocation and assuring equitable access to high-quality care in different provinces in Canada. The analysis could reveal issues in identifying best practices and areas of inefficiency, thereby informing policy decisions and shaping investment strategies. In this paper, we present a four data envelopment analysis methods, namely, CCR, BCC Input Oriented, BCC Output Oriented and Additive to measure the relative efficiency of 10 provinces in terms of offering different services including Discharges, Surgeries and Diagnostic Exams for their patients. The proposed study has implemented DEA technique and using three inputs, Beds in Operations, Hospital Staff (FTE) and Operating Expenses, and outputs, Dis-charges, Surgeries and Diagnostic Exams, measures the relative efficiencies for 10 provinces. The study also uses four DEA techniques for measuring the relative efficiencies of hospitals. The implementation of CCR for all four models yields lower scores compared with other methods. Overall, the method confirms that most hospitals across the country perform relatively well.

1. Introduction

Data Envelopment Analysis (DEA) (Charnes et al., 1978, 1985) has emerged as a powerful technique to evaluate hospital performance across the health care delivery system in Canada. DEA is a non-parametric method constructed on linear programming which allows many decision-making units (DMUs), to be compared with each other in relative terms based on input-output ratios (Banker et al., 1984). In Canada, DEA has extensively been implemented to measure technical efficiency, scale efficiency, and productivity changes in acute care hospitals, long-term care facilities, and diagnostic imaging units.

Hospitals in Canada work under diverse resource budgets and other constraints and service mandates, making DEA particularly suitable for performance measurement (Bagherzadi, 2024). Inputs basically include the number of beds, medical staff, operating expenses, and diagnostic equipment, while outputs encompass patient discharges, surgical procedures, diagnostic exams, and quality indicators (Chowdhury & Zelenyuk, 2016). DEA has helped identify best-practice hospitals and flag inefficient ones, guiding policymakers in resource allocation, funding models, and operational reforms (Allin et al., 2016).

In diagnostic imaging, DEA has been instrumental in assessing MRI and CT service delivery (Bagherzadi, 2024). By treating scanners and technologists as inputs and exam volumes as outputs, DEA models provide necessary information to identify provinces with optimal throughput and highlight areas for improvement (Bagherzadi, 2024).

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ISSN 3115-8269 (Online) - ISSN 3115-8250 (Print)

doi: 10.5267/j.he.2025.1.003

DEA's flexibility helps integration with various measurements, such as Malmquist indices for tracking productivity over time. Its application in Canada continues to expand, offering valuable insights for performance benchmarking, policy evaluation, and strategic planning (Wang, 2019).

2. The proposed study

The study of this paper implements Data Envelopment Analysis (DEA) to measure the relative efficiencies of 10 provinces in Canada. The data is at a **high-level (provincial)**, which averages out the performance of many individual hospitals. An analysis at the hospital level (DMU = hospital) would be more granular. The study doesn't include quality-of-care metrics.

Table 1, shown below, presents the data adapted for the proposed study of this paper.

Table 1
Canadian Hospital Inputs & Outputs by Province (2022–2023)

Decision Units	Beds in Operations	Hospital Staff (FTE)	Operating Expenses (B CAD)	Discharges	Surgeries	Diagnostic Exams
Ontario	33000	110000	35	1000000	900000	2500000
Quebec	22000	85000	22	800000	700000	2000000
British Columbia	11000	40000	10.5	400000	350000	1200000
Alberta	10000	38000	9.8	380000	340000	1100000
Manitoba	3500	13000	2.8	130000	110000	370000
Saskatchewan	3000	12000	2.5	120000	100000	350000
Nova Scotia	2500	10000	2.0	100000	90000	300000
New Brunswick	2000	8000	1.8	90000	80000	280000
Newfoundland & Labrador	1800	7000	1.6	85000	75000	260000
Yukon	150	600	0.2	5000	4000	12000

Sources: CIHI Quick Stats, Statista Hospital Data

For the implementation of the DEA method, we have ten decision units, therefore, we have some limitations on total number of inputs/outputs. The proposed study of this paper use Beds in Operations, Hospital Staff and Operating Expenses as the inputs and run DEA three times to get different perspective by considering each of Discharges, Surgeries and Diagnostic Exams as the output. Fig. 1 shows the structure of three models.

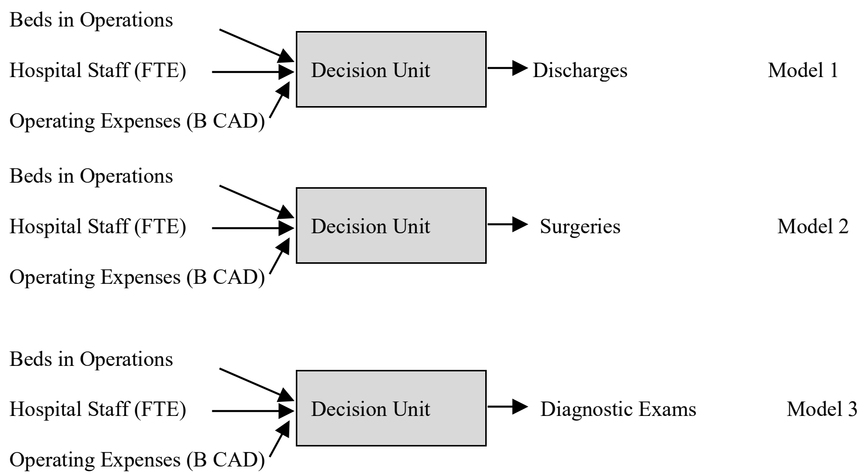

Fig. 1. The input/output factors used for Models 1-3

DEA is employed for efficiency measurement of hospitals in 10 Canadian provinces. When measuring inputs, the DEA model uses Inputs/output shown in Fig. 1. Next, the DEA will determine those provinces at the frontier and set the others against them. In other words, this nonparametric decision maker helps us make a comparison in the resource utilization pattern without the comparative assumption of a production function. These results may be used for decision-making related to scanner acquisitions, staff allocations, and planning for diagnostic capacity in provinces with somewhat lower efficiency scores compared to their peers.

The implementation of the proposed study uses four techniques of DEA, as follows (Bagherzadi, 2024),

CCR Model (Charnes et al., 1978) is a constant return to scale and measures the efficiency by comparing weighted inputs to outputs.
BCC Input-Oriented Model permits variable returns to scale and minimizes input usage while maintaining output levels (Banker et al., 2984).

BCC Output-Oriented Model also assumes of variable returns to scale but looks for maximizing outputs given fixed inputs (Cooper et al., 2007).
Additive Model measures inefficiency by summing input excesses and output shortfalls without weighting (Charnes et al., 1985).

3. The results

In this section, we demonstrate the summary of the implementation of the DEA method for measuring the relative efficiency of provinces.

Table 2
The results of the implementation of DEA methods for measuring the relative efficiencies of 10 province for Model 1

Province	CCR	Input oriented BCC	Output oriented BCC	Additive
Ontario	0.7487	1.0000	1.0000	1.0000
Quebec	0.7751	1.0000	1.0000	1.0000
British Columbia	0.8235	1.0000	1.0000	1.0000
Alberta	0.8235	1.0000	1.0000	1.0000
Manitoba	0.8739	0.9945	0.9956	0.9939
Saskatchewan	0.9035	1.0000	1.0000	1.0000
Nova Scotia	0.9412	0.9929	0.9945	0.9852
New Brunswick	0.9529	0.9695	0.9762	0.9736
Newfoundland & Labrador	1.0000	1.0000	1.0000	1.0000
Yukon	0.7059	1.0000	1.0000	1.0000

Table 2 presents the results of applying the DEA methods for measuring the relative efficiencies of 10 provinces for Model 1. As we can see from the results, the implementation of CCR yields lower scores compared with other methods since Efficiency under CCR = Technical Efficiency × Scale Efficiency. So CCR is always ≤ BCC. It is not a surprise that most provinces perform relatively well when our output criterion is “discharges”.

Table 3
The results of the implementation of DEA methods for measuring the relative efficiencies of 10 province for Model 2

Province	CCR	Input oriented BCC	Output oriented BCC	Additive
Ontario	0.7636	1.0000	1.0000	1.0000
Quebec	0.7686	1.0000	1.0000	1.0000
British Columbia	0.8167	0.9821	0.9844	0.9834
Alberta	0.8351	1.0000	1.0000	1.0000
Manitoba	0.8381	0.9380	0.9512	0.9483
Saskatchewan	0.8533	0.9269	0.9432	0.9412
Nova Scotia	0.9600	1.0000	1.0000	1.0000
New Brunswick	0.9600	0.9774	0.9820	0.9791
Newfoundland & Labrador	1.0000	1.0000	1.0000	1.0000
Yukon	0.6400	1.0000	1.0000	1.0000

Table 3 provides the results of the implementation of the DEA methods for measuring the relative efficiencies of 10 provinces for Model 2. As expected, like the results of the Model 1, CCR method provides lower efficiencies for most provinces except Newfoundland & Labrador. Most provinces appear to relatively perform well in terms of the number of surgeries.

Table 4
The results of the implementation of DEA methods for measuring the relative efficiencies of 10 province for Model 3

Province	CCR	Input oriented BCC	Output oriented BCC	Additive
Ontario	0.6119	1.0000	1.0000	1.0000
Quebec	0.6335	1.0000	1.0000	1.0000
British Columbia	0.8077	1.0000	1.0000	1.0000
Alberta	0.7794	1.0000	1.0000	1.0000
Manitoba	0.8132	0.9434	0.9567	0.9518
Saskatchewan	0.8615	0.9809	0.9858	0.9804
Nova Scotia	0.9231	0.9894	0.9926	0.9867
New Brunswick	0.9692	0.9976	0.9983	0.9974
Newfoundland & Labrador	1.0000	1.0000	1.0000	1.0000
Yukon	0.5538	1.0000	1.0000	1.0000

In model 3, when we consider Diagnostic Exams as the output of the DEA model, Newfoundland & Labrador appears to perform well for the implementation of all four models. Our analysis also shows Yukon to be performing relatively low when we look at the CCR results.

4. Discussion and Conclusion

This section needs more explanation for example what are the possible reasons certain provinces performed better than others. Is it because of their population size. In this paper, we have presented a four data envelopment analysis methods, namely, CCR, BCC Input Oriented, BCC Output Oriented and Additive to measure the relative efficiency of 10 provinces in terms of offering different services including Discharges, Surgeries and Diagnostic Exams for their patients. The proposed study has implemented DEA technique and using three inputs, Beds in Operations, Hospital Staff (FTE) and Operating Expenses, and outputs, Discharges, Surgeries and Diagnostic Exams, measured the relative efficiencies for 10 provinces. The study also has used four DEA techniques for measuring the relative efficiencies of hospitals. The implementation of CCR for all four models has yielded lower scores compared with other methods since Efficiency under CCR = Technical Efficiency × Scale Efficiency. So CCR is always ≤ BCC. Overall, the method has confirmed that most hospitals across the country performed relatively well.

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