An Application of Cost Malmquist Index: A Case Study of District Headquarters (DHQs) Hospitals of Sindh (Pakistan)

Majid Ali Rana

Introduction

- Estimation of efficiency and productivity establishes a significant task for policy-making and economic science (Peacock, 2001)
  - These methods are associated to cost-effectiveness and competitiveness of a certain production unit
- Concerning a cost-effective performance for public entities, the subject of the efficiency is an important element
- In less developed countries like Pakistan, public hospitals consume more resources of health sector (Khaliq, 2018)
  - Much of these resources are wasted through misallocation (allocative inefficiency) and by managerial (technical) inefficiency within hospitals
- Improvement in the efficient use of resources by the hospitals could yield tremendous benefits.
  - In this context, the analysis of efficiency and productivity is considered a useful tool.

Public Hospitals of Sindh

- Sindh is one of the four provinces of Pakistan, in the southeast of the country.
  - It has Pakistan's second largest economy after Punjab
  - It has highest population growth rate of 2.8% after Punjab with 53% of the population residing in rural areas and 47% in urban areas.
  - The rural population is, scattered over large distances, facing challenges of healthcare access.
  - There is the poor functionality of public sector facilities from frontline to DHQs hospitals level
  - Secondary care hospitals are poorly utilized due to chronic staff and drug shortages, and poor maintenance of facilities and equipment
  - There are large Tertiary and Teaching hospitals, which are utilized beyond capacity due to an insufficient primary healthcare system (Meghani, 2014).
  - Private providers are the predominant providers of primary, secondary, diagnostic, pharmacy and ambulance services while public sector dominates in the provision of tertiary care for low-income groups (Tanzil, 2014).

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- Sindh has 59% of Pakistan's private for-profit hospitals (Zaidi, et al., 2016)
  - Only 22% of its population uses public healthcare facilities as compared to 29% in Pakistan (Van de Poel, 2017).
  - Karachi, the country's largest city and the provincial capital, has the lowest ratio of using public sector health facilities (Hasan, 2015)
  - It indicates the distrust of people on public healthcare services and a severe shortage of healthcare resources in Sindh
  - In Sindh, due to poor access in rural areas, the infant mortality rate (IMR) is higher than the national average
  - The rural areas had well-designed district health systems but they are functioning poorly due to lack of facilities
  - The urban areas had an almost non-existent primary and secondary healthcare with reliance on the few tertiary hospitals that in turn get utilized beyond capacity
  - The less developed districts such as Tharparkar, Sanghar, and Khairpur districts had higher public sector utilization rates as compare to developed districts

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- Sindh government allocate Rs100.32 billion for health in 2017-18 (26 percent over 2016-17’ health budget)
  - The ratio of health developmental expenditure is lowest in Sindh as compare to other provinces
  - The 63 percent of health development budget goes to the tertiary level in place of primary or secondary levels.
  - Secondary level services are facing financial constraint.
  - The Financing 66% of total health expenditure in Sindh comes from households out of pocket expenditure and poorer income quintiles spending a higher proportion of household income on health expenses (PSLM, 2014-15).
- There is need such health system that enables the entire population to access their right to healthcare.
- the performance of the health system depends on the quality of its public hospitals
- The quality of the hospitals depends on the their economic performance.
- In this context, efficiency and productivity of the Public hospitals are needed to be examined

Efficiency and Productivity

- ***"Efficiency"*** suggests a level of performance that comparatively describes using the least amount of inputs to achieve the highest amount of output.
  - Efficiency refers to the comparison between observed and optimal outputs and observed and optimal inputs
    - ***Technically Efficiency (TE)*** if, firm produces the maximum of possible outputs at given inputs or produce given output level at minimum inputs (Atkinson and Cornwell, 1994).
    - ***Allocative Efficiency (AE)*** puts in relation the inputs utilizations at the current market prices (Rodriguez-Alves, et al. 2007).
    - ***Cost Efficiency (CE),*** product of TE and AE, is defined as the economic performance of the firm, that is, by its ability to make its operations profitable
  - The two influential techniques are commonly used for efficiency measurement:
    - DEA *non-parametric approach* that uses mathematical programming to identify the efficient frontier.
      - No need to specify functional form or distributional forms for errors
      - Easy to accommodate multiple outputs and easy to calculate
    - SFA is a *parametric approach* that hypothesizes a functional form and use the data to econometrically estimate the parameters of that function using the entire set of DMUs
      - Deal with single output and attempts to account for data noise
      - Can conduct hypothesis tests

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- ***"Productivity"*** is the ratio of the outputs to its inputs (Fried, et al., 2008).
  - It is a difference in productivity among producers in the same period, or variations in a given period of time (productivity growth).
  - In productivity, the performance of a production unit analyzes relative to the previous time periods as well as relative to other firms.
- For the ***measurement of productivity*** change.
  - Caves, et al., (1982), introduced the Malmquist Productivity Index (MPI) on basis of what Malmquist has proposed in 1953.
    - Efficiency change and technological change are the components of MPI.
    - Efficiency change is further composed by scale efficiency change and pure efficiency change.
  - Maniadakis and Thanassoulis (2004) developed a productivity index that is an extension of the work on Malmquist indexes, called ***Cost Malmquist Productivity Index (CMPI)***
    - A productivity Index which is applicable when input prices are known and producers are cost minimizers.
    - A productivity index that accounts not only for technical efficiency and technological variations but also for allocative efficiency and for the effects of input price variations.
- When the efficiency and productivity measures are evaluated, the DMU will come to know that how good or bad the performance is with reference to internal and external benchmarks. It can then take up steps to consume resources efficiently, improve the quality, ensure higher consumer satisfaction, and meet the strategic objectives (Al-Rashidi, 2016).

Objectives

- Cost restraint in public hospitals is one of the subjects of the current health care debate.
- With rising health care costs, an analysis of the efficiency of public hospitals is important to evaluate the tradeoff of increased hospitals costs versus health care condition.
- The basic objective of this study is to gain a better understanding of the dynamics of DHQs hospitals performance in Sindh.
- This study examines the patterns of cost efficiency and cost productivity of public (DHQs) hospitals of Sindh
- The study examines the entire and overall condition of the DHQs hospitals through measuring cost efficiency and cost productivity.
- This study informs the government about the level of wastage and misallocated resources in the DHQs hospitals.
- It also tells that how much resources are needed or how much in surplus?
- It also analyze the change in the performance of the hospitals after 18th constitutional amendment 2010
- Based on the finding of this study a policy is shaped for improving the performance of the DHQs hospitals in Sindh.

Data and Methodology

- The dataset comprises 11 selected DHQs in the Sindh Province from 2006 to 2015.
- Outputs
  - No. of inpatients
  - No of outpatients
- Inputs
  - Labor Input: total number of doctors, nurses and the total number of other paramedical and non-paramedical staff.
  - Capital Inputs: no. of beds
  - Cost: Salaries of hospitals staff, medicine cost, depreciation and current non-development expenditure
- The data of these variables are taken from the health department of Sindh and Account General Office Sindh for the period 2006-2015

Model

- Charnes, Cooper, and Rhodes (1978) introduced DEA which is called CCR model. It assumes that production units operates under constant returns to scale, and decomposes cost efficiency of a production unit into allocative efficiency and technical efficiency.
- Banker, Charnes, and Cooper (1984) have worked to develop a separate measure to determine pure technical efficiency assuming variable returns to scale, which is called BCC model.
- In this study, the BCC model is used to estimate the several efficiencies of the DHQs hospitals as their economic performance. First, technical efficiency and cost efficiency are estimated by using input oriented DEA model.

$$TEn = min\Upsilon i\Psi n\ \Psi n$$

$$s.t.$$

$$\sum_{i=1}^{I} \Upsilon i\, xij - \Psi nxjn \leq 0$$

$$\sum_{i=1}^{I} \Upsilon i\, yik - ynk \geq 0$$

$$\sum_{i=1}^{I} \Upsilon i = 1$$

$$\Upsilon i \geq 0.$$

$$\min_{\Upsilon_j x_{io}^*} \sum_{i=1}^{4} w_{io}\, x_{io}^*$$

$$sub.$$

$$\sum_{j=I}^{n} \Upsilon_j\, y_{rj} \geq y_{ro}$$

$$\sum_{j=1}^{n} \Upsilon_j\, x_{ij} \leq x_{io}^* 0$$

$$\sum_{j=I}^{n} \Upsilon_j = 1$$

$$\Upsilon_j \geq 0$$

Model of Cost Productivity

$$CM = \left[\frac{w^t x^{t+1} / C^t(y^{t+1}, w^t)}{w^t x^t / C^t(y^t, w^t)} \cdot \frac{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})}{w^{t+1} x^t / C^{t+1}(y^t, w^{t+1})} \right]^{1/2}$$

$w^t x^t / C^t(y^t, w^t)$ = how much aggregate cost of production in t time period can be reduced at the current level of output with giving prices w^t. This ratio estimates the distance between the observed cost and the cost boundary.

The CM index can be decomposed into Efficiency Change and CTC, as follows:

$$CM = \frac{w^{t+1}x^{t+1} \big/ C^{t+1}(y^{t+1}, w^{t+1})}{w^{t}x^{t} \big/ C^{t}(y^{t}, w^{t})} \cdot \left[\frac{w^{t}x^{t+1} \big/ C^{t}(y^{t+1}, w^{t})}{w^{t+1}x^{t+1} \big/ C^{t+1}(y^{t+1}, w^{t+1})} \cdot \frac{w^{t}x^{t} \big/ C^{t}(y^{t}, w^{t})}{w^{t+1}x^{t} \big/ C^{t+1}(y^{t}, w^{t+1})} \right]^{1/2}$$

- From outside the brackets depicts the OEC from the t to t+1 time span. It demonstrates how often the unit reaches the cost limit when it moves from t to t+1.
- The label within the square brackets is called the CTC. It evaluates the move of the cost limit evaluated at the xt and xt+ input mixes. The CTC deals with the cumulative impact of the change in input costs and technology over time.
- The cost of production relies on the technology and input prices in every other period and its overtime change highlights adjustments in these two components, the cumulative impact of which is seized by the CTC

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- The element of OEC can be disintegrated into technical (TEC) and allocative efficiency change (AEC):

$$OEC = \left[\frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} \right] . \frac{w^{t+1}x^{t+1} \Big/ (C^{t+1}(y^{t+1}, w^{t+1}) D_i^{t+1}(y^{t+1}, x^{t+1})}{w^t x^t \Big/ (C^t(y^t, w^t) D_i^t(y^t, x^t)} .$$

- The first element on the right side of is ‘‘catch-up’’ element in the Malmquist index. It processes input TEC between period t and t+1.
- Similarly, the second element in seizures input AEC and specifies the degree to which the component ‘‘catches-up’’ with the best input mix in light of the input cost in every period.

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- the CTC aspect can be further decayed as follows:

$$CTC = \left[\frac{D_i^t(y^{t+1}, x^{t+1})}{D_i^{t+1}(y^{t+1}, x^{t+1})} \frac{D_i^t(y^t, x^t)}{D_i^{t+1}(y^t, x^t)} \right]^{1/2} \left[\frac{w^t x^{t+1} / (C^t(y^{t+1}, w^t) D_i^t(y^{t+1}, x^{t+1})}{w^{t+1} x^{t+1} / (C^{t+1}(y^{t+1}, w^{t+1}) D_i^{t+1}(y^{t+1}, x^{t+1})} \cdot \frac{w^t x^t / (C^t(y^t, w^t) D_i^t(y^t, x^t)}{w^{t+1} x^t / (C^{t+1}(y^t, w^{t+1}) D_i^{t+1}(y^t, x^t)} \right]^{1/2}.$$

- Technical change (TC) is the first element in the right side of equation. It reveals the move of the production boundary between period t and t+1, assessed at x^t and x^{t+1}.
- The expressions in the second square brackets, detention the residual effect of comparative input price deviations on the move of the cost boundary.
- Specially, this term arrests the involvement of comparative input price variations on changes of the least cost at which output is produced.

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- The overall decomposition of the cost Malmquist productivity index is as follows:
  - $CM = \Delta PTE \times \Delta SE \times \Delta TC \times \Delta AE \times \Delta PE$
- where
  - ΔPTE = Pure Technical Efficiency Change
  - ΔCSE = Cost Scale Efficiency Change
  - ΔTC = Technological Change
  - ΔAE = Allocative Efficiency Change
  - ΔPE = Price Effect Change
- Values of the above five components greater than unity suggest deterioration, while values less than 1 suggest the improvement.

Results : Cost Efficiency of DHQs Hospitals

DHQs	TE		AE		CE	
DISTRICS	2006-10	2011-15	2006-10	2011-15	2006-10	2011-15
Badin	0.81	0.87	0.67	0.76	0.6	0.65
Dadu	0.8	0.94	0.81	0.98	0.71	0.93
Ghotki	0.72	0.97	0.84	0.82	0.63	0.8
Jacobabad	0.72	0.84	0.71	0.57	0.5	0.47
Mirpurkhas	0.76	0.79	0.51	0.7	0.41	0.56
N. Feroz	0.67	0.87	0.77	0.85	0.53	0.77
Sanghar	0.48	0.97	0.65	0.7	0.35	0.67
Shikarpur	0.67	0.99	0.62	0.62	0.41	0.62
Tharparker	0.97	1	0.81	0.85	0.79	0.85
Thata	0.98	0.87	0.79	0.64	0.78	0.59
Umer kot	0.91	1	0.97	0.79	0.89	0.79
Mean	0.77	0.92	0.74	0.75	0.6	0.7

Relationship Between Efficiencies

		Spearman Rank Correlation		
	2006-10		2011-15	
Relation	rs	p-value	rs	p-value
TE-AE	0.485127	0.1304 > 0.05	0.32872	0.32364>0.05
TE-CE	0.826089	0.00173 < 0.05	0.65904	0.02741<0.05
AE-CE	0.872146	0.00046 < 0.05	0.89955	0.00016<0.05

Change in Efficiencies after 2010

	Change in Efficiencies after 2010					
Change	TE		AE		CE	
Improved	10	91%	7	64%	8	73%
Fall	1	9%	4	36%	3	27%
No change	-	-	-	-	-	-
Frequency	11		11		11	

Wilcoxn Rank Test

			Wilcoxon Signed Rank Test		
EFFICIENCIES	TIME PERIOD		Z	p-value	
TE	2006-10-2011-15		-1.9303	(0.00173<0.05)	Change
AE	2006-10-2011-15		-0.3016	(0.073120>0.05)	No Change
EE	2006-10-2011-15		-2.4711	(0.00125<0.05)	Change

Cost Productivity Growth

GROUP	EFFCH	TECH	SECH	TECCH	MPI	GROWTH	AECH	CEC	PCH	CMI	C.GROWTH
2006-10	0.919	0.947	0.97	0.978	0.899	10%	1.476	1.397	0.657	0.872	13%
2011-15	0.984	0.937	1.05	0.93	0.916	8%	1.212	1.136	0.840	0.938	6%
2006-15	0.908	0.909	0.908	0.910	0.910	9%	0.915	0.918	0.916	0.913	9%

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Districts	CMI	GROWTH
Thata	0.814	18.6
Jacobabad	0.869	13.1
Shikarpur	0.874	12.6
Badin	0.899	10.1
Ghotki	0.902	9.8
N. Feroz	0.921	7.9
Umer kot	0.936	6.4
Sanghar	0.944	5.6
Mirpurkhas	0.954	4.6
Dadu	0.968	3.2
Tharparker	0.979	2.1

Conclusion

- In the DHQs hospitals of Sindh the wastage of healthcare resources are found 23% in 2006-10 while after 2010 by reducing 15% the wastage of resources is found 8% during the period 2011-15.
- It is also observed that in the DHQs hospitals, 26% resources are misallocated in 2006-10 and 25% in 2011-15.
- While 40% of healthcare resources in the DHQs hospitals of Sindh are found as cost increasing inputs level in 2006-10 and 30% in 2011-15
- The DHQs hospitals of districts Umer Kot, Tharparker, and Ghotiki are found most economical while the DHQs of Jacobabad and Mirpurkhas are most costly.

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- Misallocation is found as a major source of increasing cost in the DHQs hospitals of Sindh.
- It is also observed that after fiscal decentralization the performance of the DHQs hospitals of Sindh is improved in the sense of utilization of the resources at minimum cost but not in the case of allocation of the resources.
- It means allocation of resources in the DHQs hospitals of Sindh are found major problem.
- Therefor government of Sindh should make effort to improve the optimal allocation of resources at minimum cost in the DHQs hospitals of Sindh.

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- The cost productivity of the DHQs hospitals is grew with the rate of 9 percent over the period (2006-15).
- During 2006-10, 13 percent growth is observed in the cost productivity of the hospitals while 6 percent growth is found in 2011-15.
- In both time period, there is deterioration in allocation efficiency and cost efficiency which reflects the bad performance of the managements due to which cost of these hospitals is increased.
- The government of Sindh should make effort to improve the optimal allocation of resources at minimum cost in the DHQs hospitals of Sindh.
- There are not only the limitation of resources but also the ghost employ along with political interference in the appointment of the government employee or transfers are consider the major problem of the misallocation of the resources in the DHQs hospitals of Sindh. Government should overcome this issues through autonomous monitoring system