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Technical Efficiency and Productivity at the Community Clinics in Bangladesh: Using Data Envelopment Analysis

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Abstract

Scarcity of resources is a well-known fact in the healthcare industry. Ensuring optimal use of the resources can reduce waste. In this context, in a resource-poor developing country like Bangladesh, estimating technical efficiency is important. This study aimed at measuring the technical efficiency of primary public healthcare facilities, community clinics (CCs) in Bangladesh. Data Envelopment Analysis was applied to estimate technical efficiency using an input-oriented model. Primary data were collected from the 16 primary public healthcare facilities in 2013. The input variables used in the study were doctors, nurses, drugs, equipment, and the output variables used were the number of outpatient visits. It further compared efficiency gains/losses of the community clinics over time using the Malmquist index. Of the total 16, only one community clinic reached the frontier. The average efficiency score was 46 percent meaning that these facilities could produce the same outputs using 54 percent fewer inputs from their current input levels. The average amount of waste per CC was TK. 0.12 crore. All facilities, on average, experienced a gain of productivity during the study periods. However, the majority of the facilities were technically inefficient. As a result, the health sector is incurring a financial loss in a waste of resources. Decision-makers should identify the causes of low efficiency and adopt measures to increase efficiency and reduce waste.

Keywords: Technical efficiency, Data Envelopment Analysis, Community clinic, Malmquist productivity index (MPI), Bangladesh

Introduction

Bangladesh is a densely populated country (Ministry of Planning, 2017). Thus, providing quality healthcare to each citizen of the country remains a challenge. According to Health Bulletin 2019, the health system comprises primary healthcare below the Upazila (sub-district) level and targets the mass rural population and secondary and tertiary care at the district/urban areas (DGHS, 2019). The primary facilities comprise mainly three types of facilities- community clinics (CCs) at the lowest, union health and family welfare center (UH&FWC), and Upazila health complex (UHC) at the Upazila level. The community clinics (CCs)

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constitute the lowest tier of the primary public facilities of Bangladesh. The CCs provide a one-stop service to around 6,000-12,000 rural populations. As of December 2018, 13,907 CCs were functioning around the country. In addition, villagers, particularly the poor and the underprivileged community mothers and children, get services from their nearby CCs. On average, 9.5- 10.0 million seek health care each month in all the CCs (DGHS, 2019). A community clinic is the lowest tier of the health care system located at the grassroots level that provides essential services primarily emphasizing maternal and neonatal health. It also provides health education, treatment of minor ailments, and effective referral of emergency and complicated cases to higher facilities such as Union Health Center (DGHS, 2013).

For a developing country, achieving sustainable development goals (SDGs) require efficient use of currently available meager resources allocated for the health sector. Efficiency measures can help identify inefficient facilities, slacks in inputs and guide the policy makers and managers to adopt appropriate measures to reduce waste and improve facilities' performances (Kirigia et al., 2004). Several studies suggest that even a small amount of improvements inefficiency in the health sector can yield considerable savings of resources. Globally, economic loss due to inefficiency is estimated to be 20 to 40 percent of total healthcare expenditure, according to the World Health Report 2010 (WHO, 2010). Study shows that inefficiency is relatively high in Bangladesh health facilities (Mahmood, 2012).

Extensive literature is there on the efficiency of health care facilities using data envelopment analysis (DEA). However, most literature shows that these studies were conducted in developed countries. Although the number of studies on healthcare facilities' technical efficiency in developing countries has increased, no study has examined this issue in Bangladesh. The paper's objective was to identify levels of efficiency of CCs using the data envelopment analysis (DEA) model and detect efficiency gains/loss over time using the Malmquist index.

Method

This paper estimated the efficiency of CCs at ward levels in Bangladesh. The input-oriented constant returns to scale (CRS)[3] data envelopment analysis (DEA) model measured technical efficiency. It attempted to compare the CCs over time using the Malmquist index to detect efficiency gains/loss over time. Here, technical efficiency is concerned with a firm or production unit producing a large amount of output with a given amount of inputs or producing a given output with a low quantity of inputs using a given state of technology (Henderson and Quandt, 1980).

[3] CRS reflects the fact that output will change by the same proportion as inputs are changed (Charnes and Cooper, 1978.

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA), a non-parametric technique, develops an efficiency frontier by optimizing the ratio of weighted output to weighted input of firms, subject to the condition that this ratio can be equal, but never exceed, unity for any other firm. The technique helps in measuring the relative technical efficiency of the firms. Decision-Making Unit (DMU) refers to any production entity under evaluation. Here, each CC is considered as a DMU. The basic efficiency measure used in DEA is the ratio of total outputs to total inputs (Cooper et al., 2007). Let, 'x_i' represents the *i*th input, and 'y_r' represent the *r*th output of a DMU. Let the total number of inputs and outputs be represented by 'm' and 's', respectively, where 'm', 's' > 0 and 'v_i' and 'u_r' are the weights assigned to inputs and outputs respectively (Rao, 2003).

The mathematical program,

$$\max_{v_m u_s} \theta = \frac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i}$$

subject to,

$$0 \leq \frac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \leq 1 \; ; j= 1,2 \ldots.n$$

$$v_m, u_s \geq 0$$

One constraint is that the ratio ϴ should not exceed one for any DMU. The objective is to obtain the weights that maximize the ratio. The fractional programs are then converted to linear programming. A CCR-DEA linear program model is as follows (Cooper et al., 2007) –

$$\max_{v,u} \theta = \sum_{r=1}^{s} u_r y_r$$

Subject to,

$$\sum_{i=1}^{m} v_i x_i = 1$$

$$\sum_{r=1}^{s} u_r y_r - \sum_{i=1}^{m} v_i x_i \leq 0 \; ; \quad j=1,2,\ldots.n$$

$$v_m, u_s \geq \varepsilon \; ; i = 1,2,\ldots.m \text{ and } r= 1,2,\ldots.s$$

Where ε is an infinitesimal constant.

DEA has the advantage of managing multiple inputs and outputs (Rowena, 2001). According to Charnes and Cooper (1980), it has the advantage of measuring each input and output variable in any unit without being converted into a single one, but the same variables should be used for every DMU. Thus, DEA is a powerful technique for assessing performance. However, it has some limitations. Shetty and Pakkala (2010) mentioned that when dealing with a significantly large number of inputs and outputs and a small number of DMUs, the model's discriminatory power would be limited. This can be overcome by including only crucial inputs and outputs. The main weakness is that many DMUs can be efficient when the number of DMUs is less than the number of inputs and outputs. Several papers investigated the efficiency of the government hospitals mainly at the primary levels (Christian and Simon, 2013; Ahmad, 2012; Marschall and Flessa, 2011; Akazili et al., 2008; Zere et al., 2006; Osei et al., 2005; Bahumroz, 1999) which shows that the efficiency score varies between 70 to 80 percent. DEA was the most widely used measure of efficiency applied in both developing and developed countries.

Malmquist productivity index (MPI)

Productivity index measures change in a DMU's efficiency over time. MPI was introduced by Caves, Christensen, and Diewert to calculate productivity changes among different DMUs (Caves et al., 1982). MPI (also called total factor productivity changes (TFPC)) can be decomposed into technical efficiency changes (TEC) and technological changes (TC). TEC can also be decomposed into pure technical efficiency changes (PTEC) and scale efficiency changes (SEC).
TFPC = TEC X TC = (PTEC X SEC) X TC

Study design and data collection method

DEA is used to measure technical efficiency. It requires a large number of DMUs. The smaller the product of the number of inputs and outputs than the number of DMUs, the better the discrimination between efficient and inefficient DMU. A rough rule of thumb is to choose DMU equal to or greater than input times output (Charnes and Cooper, 1978). The study used one input and one output, and 16 CCs were selected to collect primary data. The UHCs were first selected using a crude performance ratio of provider–population. The ratio was calculated for all Upazilas of Bangladesh, and Local Health Bulletin 2014 was used (DGHS, 2014). The UHCs of each division were then grouped into three categories by level of performance: high, medium, and low performing. From divisions with a higher number of Upazilas- Dhaka, Sylhet, and Chattogram- a higher number of UHCs were chosen. A total of 16 UHCs were thus chosen for the survey. One CC was randomly selected from each Upazila. An envelopment input-oriented model with the assumption of constant returns to scale (CCR model) has been used employing the DEA Solver tool. Efficiency is very likely to vary by input combinations. The only input variable used in the study was human resources, and the output variable used was the number of outpatient visits. Data on inputs were collected through a facility survey using structured formats. Data on outputs were collected from the service statistics of the community clinics.

Results

Levels and determinants of resource use efficiency at the Community Clinics (CCs):

The input-oriented DEA efficiency score shows that only 1 out of 16 CCs scored 1 ($\Theta=1$). Figure 1 shows the results of DEA efficiency scores. The average efficiency score of all the facilities was 46 percent, while nine CCs scored below the average. Nizam Kha CC of Sundarganj Upazila was the best performing facility which scored the efficiency score one. The other 15 CCs scored an efficiency level of less than 1 ($\Theta<1$) and can become efficient by reducing their inputs.

Figure 1. DEA efficiency scores of the survey CCs

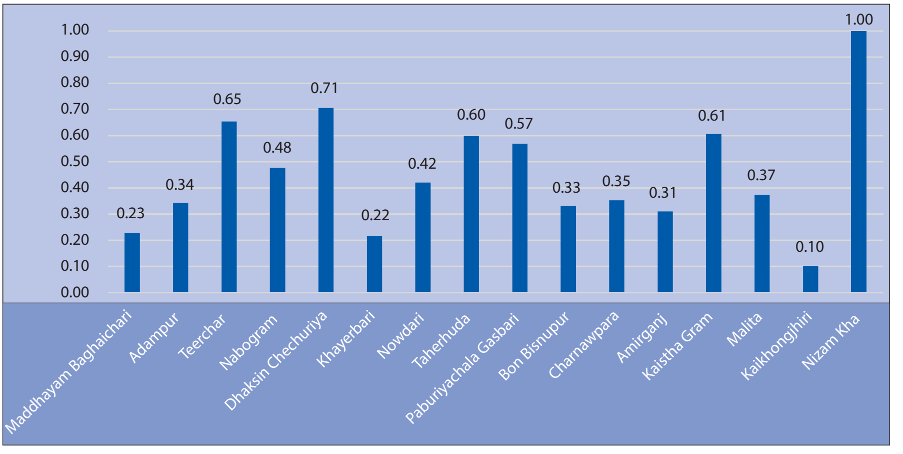

Table 1 shows the DEA efficiency scores of the CCs. Among the inefficient CCs, Dhaksin Chechuriya CC of Dhupchachia Upazila scored highest, 71 percent efficient. This CC can improve its efficiency by reducing inputs by only 29 percent. On the other hand, Kaikhongjhiri CC of Ruma Upazila obtained the lowest score. The efficiency level was only 10 percent. This CC can improve its efficiency by reducing inputs by 90 percent.

Table 1. DEA efficiency scores of the survey CCs

Upazila	CC	Efficiency score	Returns to scale	Benchmark/peer
Baghaichari	Maddhayam Baghaichari	0.23	Increasing	Nizam Kha(0.30)
Balaganj	Adampur	0.34	Increasing	Nizam Kha(0.38)
Chandina	Teerchar	0.65	Increasing	Nizam Kha(0.35)
Dhamrai	Nabogram	0.48	Increasing	Nizam Kha(0.47)
Dhupchachia	Dhaksin Chechuriya	0.71	Increasing	Nizam Kha(0.69)
Fulbari	Khayerbari	0.22	Increasing	Nizam Kha(0.24)
Fultala	Nowdari	0.42	Increasing	Nizam Kha(0.43)
Harinakunda	Taherhuda	0.60	Increasing	Nizam Kha(0.60)
Kaliakair	Paburiyachala Gasbari	0.57	Increasing	Nizam Kha(0.57)
Kamalganj	Bon Bisnupur	0.33	Increasing	Nizam Kha(0.33)
Madhukhali	Charnawpara	0.35	Increasing	Nizam Kha(0.38)
Mehendiganj	Amirganj	0.31	Increasing	Nizam Kha(0.34)
Nabiganj	Kaistha Gram	0.61	Increasing	Nizam Kha(0.64)
Palash	Malita	0.37	Increasing	Nizam Kha(0.37)
Ruma	Kaikhongjhiri	0.10	Increasing	Nizam Kha(0.09)
Sundarganj	Nizam Kha	1.00	Constant	Nizam Kha(1.00)

The amount of waste[4] due to the inefficiency of the CCs was calculated. Table 2 shows the amount of waste at the CCs. The Maddhayam Baghaichari CC had the highest amount of waste, and the lowest was in Teerchar CC. The average amount of waste per CC was TK. 0.12 crore. Therefore, to achieve the current efficiency level, the government could involve a lesser amount of inputs. The total amount of waste of all CCs in Bangladesh is estimated to be TK. 1,420.54 crores, and it is 11.2 percent of the total health budget from 2015-2016. It should be noted that the total amount of budget allocation per CC is significantly higher than the government allocation as there are many other sources of funds that the CCs receive, and it varies by CC. Therefore, the waste indicates that the current efficiency level could be achieved with a lesser amount of budget.

Table 2. The amount of waste at the survey CCs

Name of CC	Efficiency score	Input reduction %	Waste (in crore TK.)
Maddhayam Baghaichari	0.23	77	0.41
Adampur	0.34	66	0.29
Teerchar	0.65	35	0.07
Nabogram	0.48	52	0.21
Dhaksin Chechuriya	0.71	29	0.11
Khayerbari	0.22	78	0.35
Nowdari	0.42	58	0.23
Taherhuda	0.60	40	0.16
Paburiyachala Gasbari	0.57	43	0.17
Bon Bisnupur	0.33	67	0.27
Charnawpara	0.35	65	0.26
Amirganj	0.31	69	0.30
Kaistha Gram	0.61	39	0.17
Malita	0.37	63	0.25
Kaikhongjhiri	0.10	90	0.31
Nizam Kha	1.00	0	0.00

Table 3 presents slacks and targets of inputs and outputs at the survey CCs. The Input slack was highest in the Maddhayam Baghaichari CC, and the output slack was highest in the Kaistha Gram CC. All inefficient CC were operating under increasing returns to scale. As there was only one efficient CC, only one peer was prescribed for the inefficient facilities, Nizam Kha CC. The inefficient CCs can become efficient if the present value of the input and outputs are adjusted to the prescribed level. Among the inefficient CCs, the input and output targets were highest for Dhaksin Chechuriya CC of Dhupchachia Upazila.

[4] The amount of waste was the excess number of inputs existing in the facilities and if these inputs are reduced, the facility can become technically efficient. The amount of waste was calculated by multiplying the total value of inputs in the facilities with the percentage point of input reduction obtained from DEA efficiency scores (efficiency score 1). The amount of waste was multiplied by the total number of CC to get the total amount of waste.

Table 3. Slacks and targets of inputs and outputs at the survey CCs

Name of CC	Input slack	Output slack	Efficient input target	Efficient output target
Maddhayam Baghaichari	41085	4656	12055	6022
Adampur	28779	4923	14988	7487
Teerchar	7331	2396	13869	6928
Nabogram	20502	4885	18698	9340
Dhaksin Chechuriya	11494	4054	27606	13790
Khayerbari	35140	3806	9729	4860
Nowdari	23335	4902	16936	8460
Taherhuda	15954	4773	23823	11900
Paburiyachala Gasbari	17156	4876	22644	11311
Bon Bisnupur	26705	4423	13245	6616
Charnawpara	26044	4592	14206	7096
Amirganj	30207	4683	13593	6790
Kaistha Gram	16613	5033	25606	12791
Malita	24918	4654	14882	7434
Kaikhongjhiri	30950	1581	3525	1761
Nizam Kha	0	0	39838	19900

Results of time series data: Malmquist Index-DEA analysis for CCs

Monitoring performance over time can be insightful for health facilities. The Malmquist index is a method that helps to compare the performances of the health care facilities from one period to another. It is used to identify gains or losses of efficiency over time. The Malmquist index of total factor productivity change (TFPCH) over periods t and t+1 is the product of technical efficiency change (EFFCH) and technological change (TECHCH). The technical efficiency change measures the change in efficiency between these two periods (t and t+1), while the technological change shows the shift in the technology over time. The change in technical efficiency refers to getting closer to or further away from the efficiency frontier, and change in technology means a shift in efficiency frontier. A value greater than one in both changes indicates productivity growth, a positive factor value. The significant sources of productivity gains/losses can be measured by comparing EFFCH and TECHCH. If EFFCH > TECHCH, productivity gains are due to technical efficiency. If EFFCH < TECHCH, it is due to technological progress. Technical efficiency change (EFFCH) can further be decomposed into pure efficiency change (PECH) and scale efficiency change (SECH). If PECH > SECH, the technical efficiency is due to pure technical efficiency, and if PECH < SECH, the primary source of efficiency is an improvement in scale.

The Malmquist index (MI) results of total factor productivity change are summarized in Table 4. The table shows that the MI of the annual mean score of total factor productivity change was 1.85. The value of TFPCH greater than one indicates all facilities on average experienced a gain of productivity during both the periods, 2011/2012 and 2012/2013.

Table 4. Malmquist Index summary of annual means of the survey CCs

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
2011/2012	2.512	1.011	1.039	2.418	2.540
2012/2013	1.323	1.020	1.039	1.273	1.348
Mean	1.823	1.015	1.039	1.754	1.851

Table 5 summarizes the Malmquist index summary of the CCs, which compares the productivity change of the facilities and shows that all facilities except Teerchar CC experienced both technical efficiency improvement and technological improvement.

Table 5. Malmquist Index summary of facility means of the survey CCs

Name of CC	EFFCH	TECHCH	PECH	SECH	TFPCH
Maddhayam Baghaichari	1.721	1.015	1.000	1.721	1.747
Adampur	1.347	1.015	1.019	1.323	1.368
Teerchar	0.999	1.015	1.000	0.999	1.015
Nabogram	3.207	1.015	1.079	2.973	3.256
Dhaksin Chechuriya	4.550	1.015	1.210	3.759	4.620
Khayerbari	6.068	1.015	1.000	6.068	6.162
Nowdari	1.683	1.015	1.051	1.602	1.709
Taherhuda	6.478	1.015	1.156	5.603	6.578
Paburiyachala Gasbari	1.137	1.015	1.075	1.058	1.154
Bon Bisnupur	1.551	1.015	1.000	1.551	1.575
Charnawpara	1.083	1.015	1.006	1.077	1.100
Amirganj	1.201	1.015	1.000	1.201	1.220
Kaistha Gram	1.063	1.015	1.038	1.024	1.079
Malita	1.135	1.015	1.017	1.116	1.152
Kaikhongjhiri	2.398	1.015	1.000	2.398	2.435
Nizam Kha	1.000	1.015	1.000	1.000	1.015
Mean(all Malmquist index averages are geometric means)	1.823	1.015	1.039	1.754	1.851

Discussion

This study is the first attempt at measuring the technical efficiencies of CCs in Bangladesh using the DEA method. Among 16 facilities surveyed, only one CC was found efficient under the input-oriented CRS assumption. The efficient CC scoring one is Nizam Kha CC of Sundarganj Upazila. The average efficiency score of all the facilities was 46 percent. Studies from Kenya showed similar levels of efficiency, 44 percent in primary health facilities. Nine CCs scored below the average, of which one of the CCs scored as low as 10 percent. The efficiency scores vary from 0.10-1.00. This implies that there is a huge discrepancy in how resources are used among these CCs. The CCs scoring low are using excess inputs to produce the levels of output they are producing currently and hence can produce the same levels of output using fewer inputs. The analysis suggests that facility outputs could be increased significantly for the given level of resources along with additional input savings. Hence, the CCs are not working at their optimal level.

A study in China found that the average technical efficiency of rural township hospitals was as low as 50 percent (Cheng et al., 2016). Studies on the efficiency of the government hospitals, mainly at the primary levels, found that the average technical efficiency score of the facilities ranged from 70 to 80 percent (Christian and Simon, 2013; Akazili et al., 2008; Zere et al., 2006; Osei et al., 2005). The inefficiency indicated that the inadequate facilities were using excess inputs producing low outputs compared to the efficient ones. A low-efficiency score found in this study indicates a gap in efficiency levels of the CCs, which manifests the presence of waste of resource use. The average amount of waste per CC was TK. 0.12 crore. Input slack was highest in Maddhayam Baghaichari, and the output slack was highest in Kaistha Gram CC. If the inputs employed in the health care facilities are adequately utilized, waste will be minimum, and efficiency will be high. The slack analysis quantified the output increases or input decreases required for making inefficient CCs efficient. A significant scope is there for input saving or increasing outputs of the inefficient CCs.

The Malmquist Index measures the dynamic efficiency change of the DMU over some time. There was a productivity gain in both from 2011 to 2012 and 2012 to 2013. The productivity change of the facilities shows that 15 CCs experienced both technical efficiency improvement and technological improvement. These CCs were experiencing a reduced gap to the efficiency frontier and a shift in the efficiency frontier. The gains were because from 1997 and 2011, the availability of a crucial workforce and functional equipment improved under the health sector-wide approach, and as a result, there was a considerable increase in outpatient visits in public health facilities (Karar et al., 2016). These results suggested an increase in demand, which may have contributed to enhanced efficiency and total productivity.

Conclusions

The efficiency magnitudes can unravel how the sector can improve its performances with the available allocated resources. Resources at the inefficient CCs are not fully and properly utilized, creating waste. The health sector is incurring a financial loss in the form of a waste of resources. It was found that the average efficiency score of the inefficient CCs was 46 percent. The inefficient CCs need to enhance their performance. Improving efficiency will lead to lower costs, better utilization of resources. The results of efficiency estimates can help policymakers identify inefficient facilities and set up measures to improve their performance. The findings strongly indicate that if the efficiency of CCs is enhanced, it will save a huge amount of resources.

Efficiency measures and information on slacks could be helpful for policymakers. Knowledge of the technical efficiency and factors affecting the efficiency could help health policymakers to make informed decisions and adopt measures to improve the technical efficiency of the CCs. The presence of slacks suggests that inefficient CCs could improve their efficiency by reducing inputs and increasing outputs. Output augmentation can be done through increased demand created by campaigns. They could generate demand for services by improving the quality of care and staff behavior. Inefficient CCs can learn from benchmark facilities. Inefficient CCs should be investigated to understand their lacking of working at optimal.

The study has a few limitations. Firstly, the DEA results were obtained assuming that all inputs are employed. Therefore, the tool does not give an absolute score; instead, they are relative. Secondly, the tool requires many DMUs to give a better result; many facilities could not be included due to fund constraints. Only crucial inputs were included in the study. Thirdly, efficiency is measured assuming that inputs are fully and appropriately utilized and that the output produced is quality output. Quality-adjusted output is ignored while measuring efficiency, which is an important factor for the health sector. Without improved quality output, outcomes of the health sector will not be achieved. However, there is further scope for research, taking these limitations into account to better use the tools with more precision.

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