EFFICIENCY OF HEALTH CLINICS USING DATA ENVELOPMENT ANALYSIS: A REVIEW OF ENVIRONMENTAL VARIABLES

Arinah W.D.S.¹,², Muhamad Hanafiah Juni³*.

¹DrPH Candidates, Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.
²Training Management Division, Ministry of Health Malaysia
³Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.

*Corresponding authors: Dr. Muhamad Hanafiah Juni, Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia
Email: hanafiah4660@gmail.com

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ABSTRACT

Background: Primary care services are delivered through health clinics. Issue of resource scarcity and wastage cannot be denied in health care. Evaluating efficiency of health clinics will provide information on resource utilization, therefore optimization of resources used can be carried out. Several techniques used to measure efficiency including data envelopment analysis (DEA). Environmental variables have been documented to have impact on values of efficiency score and rank of units. Knowledge on the environmental variables used in measuring efficiency of health clinic to equip policy makers with more accurate results and subsequently assist in decision making. The aim of this manuscript is to review literature on environmental variables used in measuring efficiency of health clinics with DEA.

Materials and Methods: A review was conducted using online databases namely Pub Med, Science Direct, CINAHL and MEDLINE to identify articles and publications that were related to measuring efficiency in health clinics using DEA.

Result: 423 studies were obtained from the initial search. After excluding non-English literature, limiting publication from year 2007 and applying inclusion and exclusion criteria, a total of 11 publications were selected for review.

Conclusion: This review identified different environmental variables used in measuring efficiency of health clinics. The variables can be categorized into staff characteristics, patient characteristics, facility characteristic and others. Many variables were also found to be significant in affecting efficiency of health clinics regardless of the stage of DEA used. Taking into consideration the importance of environmental variables, they should be included in measuring efficiency of health clinic. It will help health managers to make an informed decision.

Keywords: data envelopment analysis, efficiency, health clinic, primary care, environmental variables

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1.0 Introduction

Primary care is a multidimensional system and serves as the first contact between healthcare system and the community. Primary care plays a vital role in improving health outcomes, economic stability and quality of health care delivery (Pelone et al., 2015). Primary care services are delivered through health clinics. Issues of resource scarcity are common in healthcare. Increasing fund allocation alone will not solve the problem (Akazali et al., 2008). Hence, it is crucial to evaluate efficiency of health care. Efficiency of health care system can be measured to identify potential improvement areas in the present system (Ibrahim & Daneshvar, 2018). Efficiency of health care can also be measured at health clinics level to identify strategies to cut down wastage and reduce expenditure (Marschall & Flessa, 2009).

There are a few methods used to measure efficiency in primary care namely data envelopment analysis (DEA), stochastic frontier analysis (SFA), Cobb-Douglas model and Trans log model. These methods can be divided into non-parametric and parametric methodology. Data envelopment analysis falls under non-parametric while the other three methods are parametric methodology. Among the four, DEA is an attractive tool in measuring efficiency in health clinics. Based on the setting of the health clinics, DEA is able to handle existence of multiple inputs and outputs and is able to combine them to obtain a single summary of an efficient unit (Razzaq et al., 2013). It also does not require strong assumptions about the technology linking the variables (Pelone et al., 2015).

However, performance or efficiency has been known to be affected by variables beyond managerial control, such as environmental variables. Studies have found adjusting for this variable may affect efficiency in terms on the values of efficiency score and ranks of units (Pelone et al., 2012, Ferrera et al., 2011). The aim of this study is to systematically review the environmental variables used in measuring efficiency of health clinics with DEA. Knowledge on the influence of these variables used in measuring efficiency of health clinics will help us to identify strategies to improve environmental performance and assist policy makers in decision making on resource and budget allocation.

2.0 Materials and methods

Methods conducted for literature review starting from search term used, database included, inclusion criteria and analysis process were outlined as follows.

2.1 Search strategy

2.1.1 Database

Journal articles between the years 2007-2018 related to DEA in measuring efficiency in health clinics were compiled using a series of keywords. The main keywords used were data envelopment analysis, efficiency, efficient, health care, health clinic, clinic, health centre and primary care. Four databases (Pub Med, Science Direct, CINAHL and MEDLINE) were searched. The searches were papers published in English regardless of the availability of full-text.
2.1.2. Search terms

Based on the objectives of the study, the search strategy was developed. The following search terms were used.

(1) Data envelopment analysis
(2) Efficiency
(3) Efficient
(4) Health care
(5) Health clinic and/or clinic
(6) Health centre
(7) Primary care

2.1.3. Selection of studies

a) Type of Studies

All studies related to measurement of health clinics efficiency using DEA were included but limited to year 2007 – 2018 to ensure relevance of study.

b) Language

Only English language literatures were selected.

c) Outcome of interest

The environmental variables used in measuring efficiency of health clinics with DEA.

d) Exclusion Criteria

Studies that did not taking into considerations of environmental variables.

2.1.4 Literature collection

All results were exported to EndNote for screening and selection. Duplicated studies were removed using EndNote. Screening was initially done based on the title and abstract review from EndNote and those that meet the criteria were selected. Shortlisted studies were then screened for full text review. Full text was retrieved through the UPM library. Studies that met all the inclusion criteria were then finalized.

2.1.5 Data extraction and synthesis

Data were then extracted from the studies included the author, year and country where the study was done. The themes of analysis are decision making units (DMUs), input, output, DEA, efficiency score and environmental variables. The data were later narratively synthesized and listed individually.
3.0 Results

This section outlines the result of the study which includes result of study selection process and main findings of the studies.

The entire database was accessed on 1 December 2018 from Pub Med, Science Direct, CINAHL and MEDLINE. A PRISMA flow diagram of the search strategy is presented in Figure 1. Refined search strategy identified 423 studies from the 4 databases. After excluding non-English literatures and limited to publications of year 2007 and above, duplicates were eliminated and only 240 articles assessed and all screened for relevance. The abstracts of 240 publications were read and after applying inclusion and exclusion criteria on titles and abstract, 180 publications were excluded. Full-text articles were assessed for eligibility and 11 articles of these publications were selected for final review as shown in Figure 3.1. Main findings of the studies are presented in Table 3.1.

![PRISMA Flow Diagram](https://example.com/prisma-diagram.png)

**Figure 3.1 PRISMA Flow Diagram of the Review on Environmental Variables Used in Measuring Efficiency of Health Clinics.**
Table 3.1: Summary of Systematic Review on the Environmental Variables Used in Measuring Efficiency of Health Clinics Using DEA.

<table>
<thead>
<tr>
<th>Authors, Year, Country</th>
<th>DMU</th>
<th>Analysis</th>
<th>Efficiency measured</th>
<th>Environmental variable</th>
<th>Effect of Environmental Variable on Efficiency</th>
<th>Significant Environmental Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kontodimopoulos et al., 2007, Greece</td>
<td>194 health clinics</td>
<td>2-stage DEA</td>
<td>Technical efficiency, Scale efficiency</td>
<td>Provider, catchment population, location</td>
<td>TE: lower score, SE: lower score</td>
<td>TE, predictors: Provider (Social Security Foundation (p&lt;0.001)) and size (medium size (p&lt;0.001), large size (p=0.028)), SE: Provider not significant</td>
</tr>
<tr>
<td>Marathe et al., 2007, USA</td>
<td>493 health clinics</td>
<td>2-stage DEA</td>
<td>Technical efficiency, Cost efficiency</td>
<td>% Medicare eligible, % poverty, % Medicaid eligible, % Hispanic, crude death rate, population/physician ratio, urban, region or rurality</td>
<td>TE: higher efficiency, CE: higher efficiency</td>
<td>TE: % Hispanic, % Medicare eligible, % Medicaid eligible were significant ((p&lt;0.05)), CE: initial technical efficiency, staffing mix, payer mix, % Medicare eligible, % Hispanic were significant ((p&lt;0.05))</td>
</tr>
<tr>
<td>Sebastian &amp; Lemma, 2010, Ethiopia</td>
<td>60 health clinics</td>
<td>2-stage DEA</td>
<td>Technical efficiency, Scale efficiency</td>
<td>HEW from Tabia, HEW married, HEW pregnant last year, number of children, support from Tabias’ chief, Tabia population, distance to health post</td>
<td>Higher efficiency</td>
<td>None significantly affect TE</td>
</tr>
<tr>
<td>Marschall &amp; Flessa, 2011, West Africa</td>
<td>25 health clinics</td>
<td>2-stage DEA</td>
<td>Technical efficiency</td>
<td>Distance, number of household members, livestocks, durable household goods, ethnic groups, religion</td>
<td>Lower efficiency</td>
<td>All were significant ((p&lt;0.05))</td>
</tr>
<tr>
<td>Miliken et al., 2011, Canada</td>
<td>109 health clinics</td>
<td>2-stage DEA</td>
<td>Technical efficiency</td>
<td>Proportion of patients with self-reported fair or poor health, proportion of patients over age 65, proportion of patients who have been in Canada less than five years, proportion of patients whose education level is less than high school</td>
<td>Lower efficiency</td>
<td>Poor health was significant ((p&lt;0.05))</td>
</tr>
<tr>
<td>Ferreira et al., 2013, Portugal</td>
<td>22 health clinics</td>
<td>2-stage DEA</td>
<td>Scale efficiency</td>
<td>Population, population density, percentage of patients aged 65 years old or older, mortality rate, percentage of patients without a designated doctor, distance to the nearest hospital and purchasing power</td>
<td>Higher and lower efficiency</td>
<td>Not mentioned</td>
</tr>
<tr>
<td>Authors, Year, Country</td>
<td>DMU</td>
<td>Analysis</td>
<td>Efficiency measured</td>
<td>Environmental variable</td>
<td>Effect of Environmental Variable on Efficiency</td>
<td>Significant Environmental Variable Affecting Efficiency</td>
</tr>
<tr>
<td>------------------------</td>
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<td>-----------------------------------------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Ferrera et al., 2013, Spain</td>
<td>94 health clinics</td>
<td>4-stage DEA</td>
<td>Technical efficiency</td>
<td>Crude birth rate, elderly ration, dependency rate, replacement rate, population density, percentage of population employed in agriculture</td>
<td>Higher efficiency &amp; some become efficient</td>
<td>Elderly ratio, population density have significant effect (&gt;95%)</td>
</tr>
<tr>
<td>Deidda et al., 2014, Spain</td>
<td>130 health clinics</td>
<td>4-stage DEA</td>
<td>Technical efficiency</td>
<td>Mortality index, percentage of patients over 65</td>
<td>Lower mean efficiency score</td>
<td>Not mentioned</td>
</tr>
<tr>
<td>Ruiz-Rodriquez et al., 2016, Columbia</td>
<td>21 health clinics</td>
<td>4-stage DEA</td>
<td>Technical efficiency</td>
<td>Women’s average age, proportion of women 18 or older with high school degree, proportion of population in Unidos program, proportion of families with women as family head</td>
<td>ANC program: educational level and women’s age result in lower efficiency. EDCC program: women’s age result in lower efficiency. FP program: higher educational level result in higher efficiency.</td>
<td>None significantly affect TE</td>
</tr>
<tr>
<td>Obure et al., 2016, Africa</td>
<td>40 health clinics</td>
<td>2-stage DEA</td>
<td>Technical efficiency</td>
<td>The extent of integration, labor input mix, catchment population, facility ownership, geographic location, facility type and demand for integrated SRH and HIV services</td>
<td>Higher and lower efficiency</td>
<td>Number of HIV/STI services in the MCH unit, number of HIV/STI services provided per room, public health facilities and other health facilities (health centres and clinics), proportion of clinical staff were significant</td>
</tr>
<tr>
<td>Bobo et al., 2018, Ethiopia</td>
<td>16 health clinics</td>
<td>2-stage DEA</td>
<td>Technical efficiency, Scale efficiency</td>
<td>Catchment population, age, outpatient visit, clinical staff, nonclinical staff</td>
<td>Higher efficiency</td>
<td>Catchment population, clinical staff and nonclinical staff significantly affect TE (p&lt;0.05).</td>
</tr>
</tbody>
</table>

4.0 Discussion

4.1. Characteristics of Studies

Out of the 11 studies, 5 studies were from African countries (Sebastian & Lemma, 2010, Marschall & Flessa, 2011, Obure et al., 2016, Bobo et al., 2018) and 2 were from Spain (Ferrera et al., 2013, Deidda et al., 2014). The DMUs used in all studies were health clinics ranging from 16 to 493 DMUs. All studies used a minimum of 2-stage DEA apart from three studies which used 4-stage DEA (Ferrera et al., 2013, Deidda et al., 2014, Ruiz-Rodriquez et al., 2016). Majority of studies measured technical efficiency (TE) except for a study in Portugal that measured only scale efficiency (SE) (Ferreira et al., 2013).

4.2. Environmental Variables

Environmental variables are also known as exogenous variables. These variables are not involved directly in production process (Deidda et al., 2014). Nevertheless, they affect performance of DMUs (Charalambous et al., 2013). Therefore, they are used as independent variables. These studies measured different efficiency of health clinics and various environmental variables were identified. In view of the wide range of variables, they are further categorised as staff characteristics, patient characteristics, facility characteristics and others for a better overview, as shown in Table 4.1.

Table 4.1: Categories of Environmental Variables

<table>
<thead>
<tr>
<th>Staff characteristic</th>
<th>Patient characteristic</th>
<th>Facility characteristic</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Origin</td>
<td>• Age</td>
<td>• Provider type</td>
<td>• Population</td>
</tr>
<tr>
<td>• Marital status</td>
<td>• Citizenship</td>
<td>• Facility type</td>
<td>• Poverty</td>
</tr>
<tr>
<td>• Pregnancy status</td>
<td>• Duration of stay</td>
<td>• Region</td>
<td>• Mortality</td>
</tr>
<tr>
<td>• Number of offspring</td>
<td>• Ethnicity</td>
<td>• Location</td>
<td>• Crude death rate</td>
</tr>
<tr>
<td>• Social support</td>
<td>• Religion</td>
<td>• Distance</td>
<td>• Crude birth rate</td>
</tr>
<tr>
<td>• Labor input mix</td>
<td>• Education</td>
<td>• Catchment population</td>
<td>• Dependency rate</td>
</tr>
<tr>
<td>• Population/physician ratio</td>
<td>• Employment</td>
<td>• Integration of services</td>
<td>• Replacement rate</td>
</tr>
<tr>
<td></td>
<td>• Head of family</td>
<td>• Types of visit</td>
<td>• Purchasing power</td>
</tr>
<tr>
<td></td>
<td>• Health of patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• With/without designated doctor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Insurance eligibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Household members</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Household goods</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Livestocks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3. Efficiency of Health Clinic

Typically, DMUs with efficiency score of 1 (100%) were labelled as efficient. Score less than 1 (100%) was considered as inefficient. Yet, when environmental variables are included in the analysis, efficiency of DMUs can be altered regardless of the stage of analysis of DEA as obtained from this review (Kontodimopoulos et al., 2007, Marathe et al., 2007, Sebastian & Lemma, 2010, Marschall & Flessa, 2011, Miliken et al., 2011, Ferrera et al., 2013, Ferreira et al., 2013, Deidda et al., 2014, Ruiz-Rodriquez et al., 2016, Obure et al., 2016, Bobo et al., 2018).

4.3.1. Technical Efficiency

Technical efficiency (TE) allows DMUs to obtain maximum output with a given set of input or to obtain maximum input with a given set of output. In a 4-stage DEA analysis conducted in Spain, after environmental variables were included, it was noted that many health clinics obtained higher efficiency score (Ferrera et al., 2013). Based on the result, elderly ratio and population density have significant effect on TE (>95%). Another study achieved higher efficiency when staffs were not locally born, both married and had been pregnant last year (Sebastian & Lemma, 2010). Though, these did not significantly affect TE. Another author found that, percentage of the population that is Medicare eligible, percentage of the population that is Medicaid eligible and percentage of population that is Hispanic affects TE positively and significantly ($p<0.05$) (Marathe et al., 2007).

On the other hand, a study of 194 primary care centres in Greece reported to have different efficiency after including environmental variables (Kontodimopoulos et al., 2007). The study showed providers under National Health System (NHS), medium-sized/ large-sized centres and urban/ semi-urban areas resulted in lower efficiency. The significant predictors for this study were provider (IKA/Social Security Foundation $p<0.001$) and size (medium size $p<0.001$, large size $p=0.028$). In a similar study, lower mean efficiency score of 0.613 (SD=0.017) was noted after inclusion of environmental variable (Deidda et al., 2014). However, no determinants were mentioned.

In addition, after including environmental variable, some studies noted to have negative impact on efficiency (Marschall & Flessa, 2011, Miliken et al., 2011, Bobo et al., 2018). Longer distances to rural primary care facilities have a clear negative impact (Marschall & Flessa, 2011). This study also revealed that distance to the next health centre, number of household members, livestock, durable household goods, ethnic groups and religion were all significantly affects efficiency ($p<0.05$). A study in Canada exposed poor health effect efficiency negatively (Miliken et al., 2011). The variable of health status was based on patient self-reported and appeared to be significant ($p<0.05$).

Although it may seem apparent, environmental variables can have both positive and negative effect on TE as proven in two studies (Obure et al., 2016, Ruiz-Rodriquez et al., 2016). In
Columbia, a study analysed 3 different programs in health clinics namely family planning, antenatal care and early detection of cervical cancer program. It discovered that higher educational level of women had a positive effect on efficiency in family planning program. Meanwhile, women’s education level and average age had a negative effect in antenatal care program. Women’s age also had a negative effect in early detection of cervical cancer program (Ruiz-Rodriquez et al., 2016). In Africa, environmental variables namely number of HIV/STI services in the MCH unit, number of HIV/STI services provided per room, public health facilities and other health facilities (health centres and clinics), proportion of clinical staff were significant and yet have both positive and negative effect on efficiency with mean inflation factor of 2.81 (Obure et al., 2016). Similarly, catchment population and clinical staff number were reported to have significant positive effect on efficiency while nonclinical staff has significant negative effect on efficiency (Bobo et al., 2018).

### 4.3.2. Scale Efficiency

Scale efficiency (SE) refers to the notion of return to scale and are assessed in production term (Kontodimopoulos et al., 2007). There were 3 studies took into consideration SE (Ferreira et al., 2013b, Sebastian & Lemma, 2010, Ethiopia, Kontodimopoulos et al., 2007). Both positive and negative effects on the SE after including environmental variables, but none were found to be significant. Distance to reference hospital had a positive effect on SE but increased population, increased % of patient aged 65 years old or older and purchasing power had negative effect on efficiency (Ferreira et al., 2013). Similarly, in another study, lower efficiency score of health clinics was found if the clinics were located in remote/island and if they were smaller facilities (Kontodimopoulos et al., 2007). On the other hand, environmental variables did not effect SE in a study in Ethiopia (Sebastian & Lemma, 2010).

### 4.3.3. Cost Efficiency

Only one study in 2007 measured cost efficiency (CE). The findings showed an inverse ratio of total cost over encounters (Marathe et al., 2007). Author believes CE is affected by TE and by optimizing TE, CE will be improved as well. There were 4 environmental variables which have been found to have a significant positive effect on the CE, namely higher initially TE such as poor staffing mix in terms of number of professional providers relative to total staff, poor payer mix where grant dollars relative to total revenue, percentage of the population that is Medicare eligible and percentage of Hispanic population affects CE positively. These four variables were found to be significant ($p<0.05$).
5.0 Conclusion and recommendation

The review included 11 studies on the environmental variables used in measuring efficiency of health clinics with DEA. The DMUs range from 16 to 493 health clinics. The knowledge on the influence of these environmental variables used helps improve health clinic’s performance. From the studies, different environmental variables have been identified, and they can be categorized as staff characteristics, patient characteristics, facility characteristic and others. In relation to the staff characteristics, the environmental variables were staff origin, marital status, and pregnancy status, number of offspring, social support, labour and population to physician ratio. In terms of patient characteristics, the variables were patient’s age, citizenship, duration of stay, ethnicity, religion, education, employment, head of family, health of patient, with or without designated doctor, insurance eligibility, household members, household goods and livestock’s. As for facility characteristics, variables were facility based on provider type, facility type, region, location, distance, catchment population, integration of services and types of visit. Other environmental variables used were population, poverty, mortality, crude death rate, crude birth rate, dependency rate, replacement rate and purchasing power. Most of the environmental variables were beyond the control of decision makers. Many variables were also found to be significant in affecting efficiency in health clinics regardless of the stage of DEA used. However, from this review, significant environmental variables were found to affect only the technical efficiency. Taking into consideration the impact of environmental variables, they should be included in measuring efficiency particularly technical efficiency of health clinic. It will help health managers to make an informed decision.

Author’s contribution

Author 1: information gathering, preparation and editing of manuscript
Author 2: initiation of idea, and final review of manuscript

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Declaration

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