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# Use of Circular Malmquist Index (CMI) and Variable Returns to Scale (VRS-MI) in Productivity Measurement- a Comparative Study

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## Abstract

*This paper aims at comparing results between the circular Malmquist index (CMI) and the variable returns to scale Malmquist index (VRS-MI) from an even panel data. Based on the ground theory, the study purposefully uses comparative discussion on above mentioned methods. The contribution of the paper is on applied feature of using different methods at the same data set. The results of the study reveal that efficiency scores of VRS-MI is of higher value than that of CMI except major unit efficient Decision Making Units (DMUs). In case of some firms, the deviations are even in extreme points- highest gap is observed by 49.72%. From the perspective of the application, this paper focuses on deviate scores and therefore updates the relevant literature. The study covers data from 2009 to 2013 and uses one output- annual sales and three inputs; namely. (i) fixed asset; (ii) raw material; and (iii) salary expenses as variables.*

***Keywords:*** *Data Envelopment Analysis; Variable Returns to Scale; Circular Malmquist Index.*

## 1. Introduction

Performance analysis has become an expedient tool for evaluating a decision making unit (DMU) comparing with others. Technically, all DMUs are of generic and flexible in nature. A handful number of research efforts enriched productivity with many theories and models. Introduction of Malmquist productivity index (MI) by Caves et al. (1982), is one of them. Ability of using both multiple inputs and multiple outputs makes the tool even popular.

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Valuable Return to scale (VRS) and Circular are two major classifications of MI. Both methods share a common feature of non-redial input and output values. In doing so, Circular MI demonstrates compact results than VRS Approach. It assumes that productivity growth is a product of change in technical progress (Catch-up) and frontier shift. To test the sources of such changes, authors have emphasized on comparative evaluation of efficiency scores. Most of the literatures on manufacturing industry have been focused on output-oriented productivity viz. Sales. A unit of positive change in output indicates a unit increase in the efficiency of inputs. Thus, reduction of input cost may meet by producing higher level of output. This paper covers the literature only on efficiency, productivity of pharmaceuticals and manufacturing industry and Total Factor Productivity. Kirigia et al. (2004) analyzed technical efficiency of health organizations in Kenya. Based on the secondary data from 32 major health care centers, DEA has been examined. Their findings have revealed that 44% of total health care center are technically inefficient. Seminal paper of Hashimoto and Haneda (2008) has been examined technical efficiency of Japanese Pharmaceutical Industry using same technique. They used sales volume as single output and three inputs namely, patent or R&D, product innovation and process innovation cost. Their findings are summarized a consistent negative productivity change over the period of 1982 to 2001. Recently, Tripathy et al. (2013) examined 81 Indian pharmaceutical companies using Malmquist productivity index. A positive technical efficiency change has been observed over the period of the observation. The study has resulted with significant outcomes in determining firm-specific factors of productivity for any pharmaceutical company. For example; age of establishment, Research and development, ownership and foreign direct investment.

A recent work of Ramli and Munisamy (2013) on Technical efficiency and ecological efficiency also contributed the existing literature. They applied DEA and Directional Distance Function (DDF) on manufacturing industries over the period of 2001 to 2010. The study has used Operating Expenditure and Capital as input and sales as desirable output. In oppose to the findings of Jajri and Ismail (2007), Ramli and Munisamy (2013) checked the efficiency on state basis rather than sector basis. Mohamad and Said (2012)studied on efficiency measurement of 42 world economies on effect of technology innovation had revealed that only best practiced firms can adopt and make use of new technological adoption at higher rate rather than others. Decomposition of TFP also suggested that there was no significant difference in efficiency changes compared to technological innovation in economy. For the empirical evidence, the study uses 5 (five) years of data. This paper has four sections. Section 2 presents the method of the study, data source and model development for the analysis. Section 3 presents analysis of empirical results and section 4 presents conclusion and policy implications.

## 2. Methodology and Model specification

Malmquist total factor productivity (TPI) is used in the study. Byproducts of TPI are technical efficiency change (TEC) and technical change (TCH). Again, TEC can be said as product of scale efficiency (SE) and pure efficiency (PU). If the input and output vector of a production unit is presented by$x^t \, and \, y^t$and (t) stands for time period, the output set of the production process can be defined as:

$$P^t(X^t) = [Y^t : X^t \; produces \; Y^t] \tag{1}$$

This output set by Chou et al. (2012) satisfies notion of disposability of inputs and outputs since it assumed to be closed, bounded and convex (Coelli et al., 2005). A distance function for the output set can be designed as follow:

$$D^t(x^t, y^t) = \min(\theta : (y^t/\theta) \in P^t(x^t)) \tag{2}$$

Considering two consecutive time frames e.g. t and t+1, and combining the distance function of Eq. (2), TPI of Malmquist index can be shown as follow:

$$MI\,(y^t, x^t, y^{t+1}, x^{t+1}) = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \tag{3}$$

Eq. (3) can be transformed into;

$$MI - \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\right]\left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \tag{4}$$

Here,

$$Technical\ efficiency\ change\ (TEC) = \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\right] \tag{5}$$

$$Technical\ Change\ (TCH) = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \tag{6}$$

So, $Malmquist\ TPI = TEC \times TCH$ (7)

$$TEC = \left[\frac{D^{t+1}_{VRS}(x^{t+1}, y^{t+1})}{D^t_{VRS}(x^t, y^t)}\right]\left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^t_{VRS}(x^t, y^t)}{D^{t+1}_{VRS}(x^{t+1}, y^{t+1})}\right] \tag{8}$$

Here, $D_{VRS}$ is the output distance function for variable returns to scale. The first part of the Eq. (8) is named as pure efficiency (PE) that describes pure change in technical efficiency in a relative form of defined consecutive time period. And, remaining part of Eq. (8) stands for describing change in effect due to economics of scale and denoted by SE. Thus,

$$Pure\ efficiency\ Changes\ (PE) = \left[\frac{D_{VRS}^{t+1}(x^{t+1},y^{t+1})}{D_{VRS}^{t}(x^{t},y^{t})}\right] \quad (9)$$

$$Scale\ efficiency\ changes\ (SE) = \left[\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t}(x^{t},y^{t})} \times \frac{D_{VRS}^{t}(x^{t},y^{t})}{D_{VRS}^{t+1}(x^{t+1},y^{t+1})}\right] \quad (10)$$

Combining Eq. (4) and (8), it comes as TPI is the product of TCH, PE and SE. An extended version of Eq. (7) can be then,

$$Malmquist\ TPI = PE \times SE \ \times TCH \quad (11)$$

In contrast, the Circular indices of Meta-Mulmquist measurement are of easy to use. They also easier in explanation because of no restores like geometric average. Portela et al. (2004) first introduces the idea of Malmquist Index calculation using negative input and output values. They used Range Directional Distance Function for such calculation. Using a single frontier as reference, this method resulted in circular index. Based on the pooled panel data, a meta-frontier is referred through the model. Thus, dependency on meta-period is raised here by using circularity of the frontier shift. Following a linear programming model describes the issues;

$$\beta_k^* \left\{ \beta_k \middle| \begin{array}{l} \sum_{j=1}^{n} \lambda_j Y_{rj}^t \geq Y_{rk}^t + \beta_k R_{y_{rk}^t},\ r = 1, \dots\dots\dots\dots\dots, s; \\ \sum_{j=1}^{n} \lambda_j X_{ij}^t \leq X_{ik}^t,\ i = 1, \dots, m;\ \sum_{j=1}^{n} \lambda_j = a,\ \lambda \geq 0 \end{array} \right. \quad (12)$$

This model represents the range vector which will in turn influence the frontier to shift. A value of $\beta_k^* = 0$ signifies that the DMU is on the frontier. Keeping it as a benchmark, the model continues for the rest of the DMUs.

This study covers the pharmaceutical industry of Bangladesh. Three inputs have been selected for the analysis, namely fixed asset, cost of raw materials and cost of salary and wages with only one output namely annual sales (both Local and export). Despite having 200 pharmaceutical firms in the country, all 13 companies, operating in the country's capital market now, have been selected for the study due to unavailability of data. The study covers data from 2009 to 2013.

## 3. Results

Table 1 and 2 explain efficiency positions of all 13 listed pharmaceutical companies over a period of 2009 to 2013. Based on Malmquist Index analysis proposed by Fare et al. (1994), productivity of a decision making unit is evaluated based on one value. A more than one value explains the positive TFP growth of that Decision Making Unit (DMU) for the time (t+1) compared to time (t).

**Table 1:** Malmquist index summary of annual means

| year | Technical Efficiency Change | Technological Change | Pure Technical Efficiency Change | Scale Technical Efficiency Change | Total Factor Productivity Change |
|---|---|---|---|---|---|
| 2009 | 0.944 | 1.266 | 1.022 | 0.924 | 1.196 |
| 2010 | 0.761 | 1.347 | 0.926 | 0.822 | 1.024 |
| 2011 | 0.877 | 1.151 | 0.755 | 1.161 | 1.009 |
| 2012 | 1.427 | 0.696 | 1.319 | 1.081 | 0.994 |
| 2013 | 0.838 | 1.225 | 0.954 | 0.879 | 1.027 |
| mean | 0.969 | 1.137 | 0.995 | 0.973 | 1.05 |

Table 1 represents a summary of annual means of Technical Efficiency Change, Technological Change, Pure Technical Efficiency Change, Scale Technical Efficiency Change and Total Factor Productivity (TFP) Change for all 14 companies. It is seen from the table that all the companies have inefficiency within a range of 5.6% to 23.9% in case of Technical Efficiency Change throughout the study period except for the year 2012. In case of Technological Change, all companies have experienced a negative efficiency of 31.4% in the same year. Compared to other years, this deficiency is a major breakdown. Even though, in the following year, companies have restored the capacity and had a 22.5% upward TFP growth. Refer to Pure efficiency; companies have experienced a positive growth change in 2009 and 2012. In remaining years, negative efficiency within a range of 4.6% to 24.5% has been witnessed in the table. A similarly mixed result has also been observed in case of Scale Technical Efficiency Change of the companies over the study period. In total, the Total Factor Productivity (TFP) growth Change of the companies found to be positive except for the year 2012 and within a range of -0.6% to +19%. The overall TFP growth, change of the companies is resulted by 4.7% over the study period.

Table 2 reveals a nutshell of the Malmquist Index Summary of Firm Means which is based on geometric means over a period of 2009 to 2013. Here we used Constant Return to Scale (CRS) method for calculation. As previously, the TFP of all companies has been observed a positive growth of 4.7% yearly. This variation could be higher if Technical Efficiency Change of companies were somewhere in unit value or positive values. On an average, a total 5.5% negative efficiency has been seen in Technical Efficiency Change of all companies annually. ACI, GLAXOSMITH and RENATA scored unit efficiency change yearly. Only RECKITTBEN had a positive Technical efficiency change with a value of 3.3% annually among the companies. A total of 9 (nine) companies, however, experienced a positive change in technological efficiency with a range of 5.3% to 36% each year. And 5 (five) companies, namely AMBEEPHA, CENTRALPHL, MARICO, ORIONPHARM and RECKITTBEN have been found inefficient over the study period.

**Table 2:** Malmquist index summary of firm means Using Constant Return to Scale (CRS)

| Firm | Technical Efficiency Change | Technological Change | Pure Technical Efficiency Change | Scale Technical Efficiency Change |
|---|---|---|---|---|
| ACI( ACI Limited. ) | 1.000 | 1.360 | 1.000 | 1.000 |
| AMBEEPHA( AmbeePharma ) | 0.917 | 0.778 | 0.993 | 0.923 |
| BEACONPHAR( Beacon Pharma. Ltd.) | 0.866 | 1.358 | 0.880 | 0.984 |
| BXPHARMA( BeximcoPharma ) | 0.936 | 1.214 | 1.000 | 0.936 |
| CENTRALPHL( Central Pharma. Ltd. ) | 0.939 | 1.053 | 0.963 | 0.975 |
| GLAXOSMITH( Glaxo SmithKline ) | 1.000 | 1.300 | 1.000 | 1.000 |
| IBNSINA( The IbnSina ) | 0.940 | 1.180 | 0.941 | 1.000 |
| LIBRAINFU( Libra Infusions Limited ) | 0.976 | 1.085 | 0.984 | 0.992 |
| ORIONPHARM( Orion Pharma Ltd. ) | 0.878 | 1.075 | 0.915 | 0.959 |
| PHARMAID( Pharma Aids ) | 0.932 | 1.128 | 1.000 | 0.932 |
| RECKITTBEN( Reckitt Benckiser(Bd.)Ltd. ) | 1.033 | 0.951 | 1.054 | 0.980 |
| RENATA( Renata Ltd. ) | 1.000 | 1.245 | 1.000 | 1.000 |
| SQURPHARMA( Square Pharma. Ltd. ) | 0.915 | 1.123 | 1.000 | 0.915 |
| **Mean** | **0.945** | **1.108** | **0.979** | **0.965** |

Considering the technological efficiency change, all the companies have scored, on an average, 10.8% positive growth yearly. Inefficiency is observed in both pure efficiency and Scale efficiency scoring of about 3% annually. Based on the findings, it is to be recorded that a total of 9 companies has been observed with positive Total Factor Productivity (TFP) growth changes. Among them, ACI, GLAXOSMITH and RENATA have been found top ranked. Remaining 4 companies have scored negatively in TFP change with a range of -1.1% to 28.6% annually. The lowest and highest TFP changes have been observed for AMBEEPHA and ACI respectively.

**Table 3:** Comparative Score of MI (VRS-MI vs. CMI) over the study period of 2009 to 2013

| Year | 2009 | | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Model | VRS-MI | CMI | VRS-MI | CMI | VRS-MI | CMI | VRS-MI | CMI | VRS-MI | CMI |
| DMUs | | | | | | | | | | |
| ACI | 100 | **65.82** | 100 | **93.08** | 94.48 | **94.3** | 100 | 100 | 100 | 100 |
| BEACONPHAR | 100 | 100 | 77.86 | **73.71** | 100 | **96.23** | 65.58 | **65.58** | 91.48 | **91.48** |
| CENTRALPHL | 73.87 | **66.24** | 95.85 | **80.82** | 73.75 | **73.61** | 68 | **63.71** | 73 | **61.31** |
| GLAXOSMITH | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | **95.94** |
| IBNSINA | 89.87 | **88.87** | 93.64 | **93.64** | 79.17 | **78.89** | 100 | 100 | 100 | 100 |
| LIBRAINFU | 100 | 100 | 100 | **97.12** | 100 | 100 | 100 | **31.66** | 70.03 | **18.37** |
| ORIONPHARM | 95.03 | **72.02** | 95.85 | **80.82** | 73.75 | **73.61** | 57.62 | **31.66** | 70.03 | **34.73** |
| PHARMAID | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| RECKITTBEN | 76.91 | **60.22** | 100 | 100 | 69.37 | **69.33** | 100 | **75.5** | 54.55 | **35.22** |
| RENATA | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

CMI: Circular Malmquist Index
VRS-MI: Variable Return to Scale-Malamquist Index

Table 3 reveals the most attractive findings of the study. According to this, all the CMI scores of selected 10 (ten) DMUs have scored lower than that of VRS-MI scores except for the efficient DMUs. Among them, 2 (two) exceptions have been counted in case of deviation even if the VRS-MI scored unit efficient. In 2013, the changes have found in a range from 1% to 34.18%. The highest score is found in case of ACI which is One of the unit efficient DMU for both the cases. In case of 2010, Maximum deviation in the scores for the DMUs is found in a range of 2.88% to 15.32%. No deviation is observed for IBNSINA though this is not a unit efficient DMU. Last but not the least, in 2013, the range is found within a range of 12.69% to 49.27%. The highest gap is scored for LIBRAINFO. Throughout the years, Efficiency score of RENETA is never changed irrespective of method of Total Productivity calculation. A significant modeling gap is observed in the case of explaining the behavior and method of such deviation. The deviations are of random nature and theoretically, CMI scores give more appropriate results and VRS-MI explains the frontier shift even better.

Table 4 describes the basic understanding for the most efficient DMU/s for the study. In 2013, as it is seen from the table that the most efficient peer frequency is found in ACI with a score of 6 (six). Followed by, GLAXOSMITH and PHARMAID, with a score of 4 (four) for both DMUs. Frequency for RENATA scores only 2 (two). This table signifies that ACI is the most significant DMU for the calculation of efficiency of others.

**Table 4:** Peer Group of Mulmquist Index for the year 2013

| Name | ACI | GLAXOSMITH | PHARMAID | RENATA |
|---|---|---|---|---|
| (Frequencies) | 6 | 4 | 4 | 2 |
| BEACONPHAR | True | True | True | True |
| CENTRALPHL | True | True | | |
| IBNSINA | True | True | True | True |
| LIBRAINFU | True | | True | |
| ORIONPHARM | True | True | | |
| RECKITTBEN | True | | True | |

## 4. Conclusion

Malmquist productivity index (MI) is a tool for efficiency measurement of decision making units. Both VRS-MI and CMI methods of Malmquist index are of nonparametric approach. But a significant deviation in the values among the selected DMUs presents a second thought for the researchers. Sometimes, even the unit efficient DMUs sacrificed their unit efficiency. This distinguish feature may misguide audience and needs correct requirements to fulfill. Again, this study has contributed the literature by filling a gap between the knowledge of existing Industry growth and its true productivity. The findings suggest a poor but positive productivity change in the Bangladeshi Pharmaceutical industry over the study period. Authors argued that this negligible efficiency improvement is just because of technological efficiency changes. So, setting up sustainability of Pharmaceutical companies depends on "Product Patent" than "Process Patent".

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