Author's response to reviews

**Title:** Investigating health system performance: An application of data envelopment analysis to Zambian hospitals

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**Author's response to reviews:** see over
RESPONSE TO REVIEWERS’ COMMENTS

Dear Editor,
Please find below my point-by-point responses to the comments raised by the reviewers to an earlier draft of my paper entitled: Operating efficiency in Zambian hospitals: implications for the success of global health initiatives.

Thank you

Felix Masiye

Typographical and grammatical errors
The manuscript has been duly edited and all spelling and grammatical errors removed. Further table numbering and positioning, acronyms, equation, as well as the references have been reviewed.

Title
I got the impression that the title might elicit, inadvertently, an interpretation that inefficiencies in African health systems should be dealt with before more global initiatives can be supported. The idea was to alert health policy officials within Zambia to the problem of health system weaknesses and the potential consequences they have for health care delivery. I have decided to change the title to:

Investigating health system performance: An application of data envelopment analysis to Zambian hospitals

Background: Paragraph two page 1
Three reviewers raised an issue about the lack of clarity in connection between the performance of global health initiatives (e.g. DDT) and hospital efficiency. I have agreed with the reviewers that this was unclear for the following reason. Financial resources, labour and other inputs are used to produce health services. These health services are in turn offered to needing populations with a view to improving health status. However, the link between service availability and health status improvement is determined by a complex set of issues. Efficient production of health services along cannot affect issues such as access, which was the main point from the reviewers.

In addressing this point, I make the distinct point that if health service production is inefficient, then resources that could be going to serve other beneficiaries are being lost. Thus, I attempt to link health care needs with resource availability and resource us or performance assessment.

To this end, the whole background has been re-written with the paragraph two removed and the following paragraphs, among other things, included:
In recent years, the debate about the growing financing needs for health care in Zambia has focused almost exclusively on mobilising additional resources, particularly from outside. While this focus is truly important, the ultimate solution has to include a broader analytical perspective. Performance weaknesses that run pervasive in many health systems in Africa render additional money necessary but perhaps not sufficient. A recent study illustrates how organisational and operational aspects of a health system can affect service coverage. The World Health Report 2000 framework recognised technical efficiency as important in achievement of greater effectiveness and efficiency of health systems.

Hospitals are at the centre of implementing interventions and policies which are key to the attainment of the recently articulated health targets for Zambia. In particular, hospitals provide the largest share of services in antiretroviral therapy (ART), prevention of mother to child transmission of Human Immuno-deficiency virus (PMTC), Tuberculosis treatment, safe deliveries and many other services. Besides their political clout, hospitals are consumers of a substantial proportion of health sector resources. When hospitals consume excess resources in producing their services this invariably results in misallocation and loss of potential care to other beneficiaries. This raises important sustainability and equity implications. Thus, improving efficiency would increase the service potential of existing health infrastructure and provide opportunities for re-allocating resources to other areas.

Expanded Context in section 2
All reviewers raised an issue about the lack of descriptive information about the Zambian health system. I have now re-written this section in that light.

Methods
Sample size
Reviewer 2 has raised an important point regarding sample size. The ‘commonly used’ threshold for sample size in DEA is that the sample size should be at least equal to twice the product of number of inputs and number of outputs (Dyson RG et al: European Journal of Operational Research 2001, 132: 245-259.). In this study we had hoped to achieve that with the initial 32 hospitals selected. However, as indicated, data from two of the hospitals were found to be incomplete in key variables, leaving us with a sample size of 30 hospitals. Nonetheless, the ratio of sample size to the product of 1.9, (as opposed to 2), is boarder-line, and the potential limitation (curse of dimensionality) of this is fully acknowledged.

More information on hospitals and sampling
All reviewers requested for further information about the hospitals in the sample and how they were selected. This has now been addressed under a new section 4.1 with a full discussion of the sample characteristics and the sampling process. The composition of the sample is described. And in specific response to reviewer 2’s point 6, I have expanded the discussion of the composition of the sample and the data in further detail.

Adjustment for case mix and quality
Reviewer 2 raised concern about the lack of case-mix and quality adjustment in outputs. The methods for doing this are truly available but we could not find any usable data to implement this. There are still papers in many top journals published recently which are still reporting crude output measures where no data on quality was available. Besides, even outpatient outputs need to be adjusted. Approaches for using intermediate outputs even when adjusted for quality is still a debatable issue in the literature. Nonetheless, this limitation is acknowledged. Although this is
not an excuse, I point out that several recent applied studies in the BMC journals and elsewhere have used such output specification (www.deazone.com).

**Model presentation**

On his point 2, reviewer 2 advises that the model be presented differently. I have agreed with some of his views in this and have made an effort to re-write. I have also motivated my choice of assumption of VRS, input-based and free-disposability. These assumptions are in my view the most widely adopted. I have provided my reasons for adopting them. The choice between input based and output based model would not add any material difference to the analysis.

In response to Reviewer 2, I have attempted to describe the DEA methodology a bit. This is always going to be difficult to accomplish in any greater detail in a short article.

However, beyond that, I have not agreed with reviewer 2 that the model is not well spelt out. Anybody who is familiar with the DEA literature understands that this is the standard presentation. In the model, we make the case that DEA is minimizing some coefficient representing input contraction, subject to a set of constraints which define the technology. I am yet to read a paper in which this presentation (LP algorithm) has been found unnecessary.

Further, Reviewer 2 asks about the choice of VRS. Well, I have handled both VRS and CRS in this paper. I have motivated this decision by stating that we first wanted to demonstrate technical efficiency that is free of scale effects. The main argument is that hospital scale is affected by geographical factors and the option of changing scale is a long term phenomenon. This is the reason why I have complemented the analysis by running a full model on scale efficiency on scale efficiency analysis to show policy makers which hospitals might benefit from decreasing or increasing scale of operations.

Finally, there are several DEA variants with different analytical attributes (perhaps the best presentation of the most recent applied DEA research from all the world can be found at www.deazone.com). The model presented in this paper is a radial VRS in which gross technical efficiency is estimated. A consequence of this is that an over-estimation of efficiency may occur. There are non-radial DEA models which take account of slacks. However, when input prices are unavailable this distinction is unimportant. A radial model which assumes equi-proportionate reduction in inputs is employed. Any slacks are treated as having zero shadow prices, implying that they are unimportant from a strict economic perspective. Directional distance functions have been used to measure industry level efficiency.

**Number of beds as input**

Reviewer 4 suggested that using beds and number of admissions as inputs. Some studies have done in the literature but others have instead used bed days. I have not considered this option for practical reasons. In Zambia, there are problems using number of beds because hospitals sometimes do have patients on the floor or improved beds, while at other times they have empty beds.

**Technical content in methods**
Two reviewers (1 and 2) discussed that the technical methodological content be taken to an appendix. This has been contradicted by at least reviewer 3. I think that this paper aims to satisfy both the general policy making community and the academic economists. It is important to keep the brief description of the methodology providing it is explained in plain language. This is what I have attempted to do in this revised version.

Further, in the methodology section, an attempt has been made to explain using plain language the meaning of the key terms used in this paper: technical efficiency, scale efficiency and congestion efficiency. For instance, the following paragraph has been added:

Scale efficiency has to do with a production unit operating at its optimal operating size given its output. An intuitive interpretation of scale efficiency is that, given its output level or external demand, there is a hypothetical scale of operations that makes the hospital most productive or efficient. When a firm becomes too big or too small, scale changes can lower costs and efficiency. Scale efficiency is health care industry is a consequence of market and institutional constraints which ensures that production units do not operate at optimal size.

**Allocative efficiency discussion**

Reviewer 2 raised an issue regarding the discussion of allocative efficiency in the introductory section of chapter 3. Although my intention was to give a brush of the concept of efficiency, I have deleted this piece from the text in case it is confusing to some other readers. The sub-section 3.1 has also been re-written in the light of this alteration.

**Results section**

**Methodological issues in results**

As suggested by reviewers 1 and 4, the section on methods previously in 5.1 has been re-written and moved up to the methods section.

Reviewer 4 pointed out some mis-representation about two frontiers on page 15. This text has been removed.

**Geometric mean**

Two reviewers (Zere and Blas) raised an issue about the use of geometric mean alongside the arithmetic mean. Although in the literature some authors have used both, I have removed the use of geometric mean from the manuscript altogether.

**Scale efficiency and official beds**

I have included data on bed capacity for each hospital.

**Intensity variables**

In addressing reviewer3 comments, I discuss that Lumezi seems to be sized like 18 others. The DEA program chooses the selection of reference units by associating similarly size units.

**Jacknife analysis**

Reviewer 4 advised that the use of a sensitivity analysis by a method known as Jacknife analysis. I take note of this for future work. Right now the small sample size undermines the use of this method.

**Determinants of technical efficiency**
Reviewers 1 and 2 suggested that a test for the determinants of efficiency be performed. Typically, a regression model is run with efficiency score as the dependent variable and a set of explanatory variables which include; ownership, location, managerial attributes, and other variables. I did this analysis and have added the text below to explain the findings.

The effects of ownership and location on efficiency
Reviewer 2 and 3 would have liked more discussion of the factors associated with efficiency. Indeed this is important and has been done. Reviewer 2 was not for the use of hotelling statistic to distinguish between the efficient and inefficient. He proposed the non-parametric chi-square and a regression model. I have performed the analysis.

Another consideration for future work might include using hospital characteristics and contextual factors such as ownership status, epidemiological profile, poverty levels, location and other variables. A test for the effects of ownership, geographical location and bed capacity in a tobit model did not turn out to be informative, indicating that geographical location, ownership and bed capacity do not explain sufficiently the variation in efficiency scores in this sample. None of these variables was significant though they had plausible signs. For instance, the coefficient of ownership defined as 1 for government and zero otherwise was negative but not significant. Collectively, mission and private hospitals together had an averaged efficiency score of 73.2% while Government-owned hospitals combined for an average of 62.3%. However, individually some government facilities performed better mission facilities. It is plausible that hospital internal characteristics and other external factors could explain more variation. Regrettably, there is no unified theoretical guidance in the literature about determinants of efficiency. This issue remains a challenge for future work.

Study limitations
As suggested by Reviewer 2, a sub-section detailing the study limitations and recommendations for future research has been added at the end of the discussion section.

Acknowledgements
A section on acknowledgements has been added as requested by reviewer 2.