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Article

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Technical efficiency decomposed – The case of Ugandan referral hospitals

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Abstract:

Aim: In an audit report provided to the Ugandan Parliament by the Office of the Audit General, Uganda, technical efficiency in Ugandan referral hospitals was measured and analysed. The audit report pointed out that there was a relatively low level of technical inefficiency, at least in comparison with other African countries. The purpose of this study is to look further into the issue of why there is inefficiency.

Design / Research methods: We use a Data Envelopment Analysis framework and decompose long-run technical efficiency into short-term technical efficiency, scale efficiency and congestion.

Conclusions / findings: Our results reveal that the source of the long-run inefficiency varies over the years. For 2012, more than 50% of the observed inefficiency relates to scale factors. However, in 2013 and 2014 the major contributor to the long-run inefficiency was input congestion.

Originality / value of the article: Even though there are a substantial amount of research on efficiency in African hospitals, no other study have investigated existence of congestion. In that respect our research contributes to the existing research.

Implications of the research: We recommend that inefficient hospitals should use efficient hospitals as benchmarks for improving their own efficiency. Further, since a large part of the technical inefficiency relates to congestion we recommend further investigation to identify factors in the production, or organisation that could be related to congestion.

Key words: technical efficiency, scale efficiency, congestion, Uganda, hospitals

JEL: D2, H4, I2.

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1. Introduction

In sub-Saharan Africa, poor health among the population is generally a reality, and Uganda is no exception here. One cause could be that the health care systems are inadequate to meet the needs of the ever-growing population. This suspicion has raised concerns among policy makers and planners about whether health services are being delivered efficiently by hospitals. This study is a development of the work presented in the Uganda Office of the Audit General (2016). In that study long run technical efficiency was investigated and the result was that, compared to other studies targeting African hospitals, the inefficiency was relatively low. However, in secondary analysis performed there were indications that not only internal factors contributed to the inefficiency. The report reported for example bed occupancy rates above 100 per cent which indicates congestion. The development in this paper consists of analysing factors that are not directly related to the overuse of inputs, but relates to different parts of the production. This includes the concept of scale efficiency as well as congestion.

The outline of the study is as follows. Section 2 will give a brief overview of the health care sector in Uganda. In section 3 we will make a comprehensive survey of previous studies targeting technical efficiency in hospital services production in African countries. The main finding is that, even if there are similarities between the country-specific studies in terms of how production is defined, there is a large variation in technical efficiency. This suggests that countries can learn from each other. Further, we have not found any study that explicitly studies the influence of congestion on long run technical efficiency. In section 4 we present the model, definitions and data used for this study. In this section we also discuss the inputs and outputs selected for our study, and we introduce the concept of input congestion. The inputs and outputs have been chosen after considering previous studies and in discussion with the stakeholders. In section 5 our results are presented. Overall, we find relatively small amount of inefficiency, especially when compared to other African countries. Our results also reveal that the source of long-run inefficiency varies between years. For 2012 more than 50% of the observed inefficiency related

to scale factors. However, in 2013 and 2014 the major contributor to long-run inefficiency relates to congestion.

2. The health sector in Uganda – a short description

In Uganda, hospital services are provided under a four-tier health care system (primary, secondary, tertiary and quaternary care), with regional referral hospitals (RRHs) being major contributors to essential clinical care because of their provision of specialist clinical services. This study covers thirteen out of the fourteen RRHs in Uganda.

The state has a duty to guarantee the right to health care to all its citizens. In addition, a number of international treaties oblige the Government of Uganda to commit sufficient resources and establish a comprehensive health care framework that meets the health needs of its citizens.¹ In order to deliver the health services required, the Government of Uganda has endeavoured to put in place a regulatory framework in line with the 1995 Constitution of the Republic of Uganda (as amended). The regulatory framework spells out the responsibilities of hospitals at different levels, including RRHs, to provide for the health care needs of the population. Over the past three financial years (2011/12, 2012/13 and 2013/14), there has been an 18% increment in the funding of RRHs, which has risen from UGX 53.86 billion to UGX 63.56 billion (Ministry of Finance, Planning and Economic Development 2011, 2013). Despite the increase in the funding of RRHs over the years there has been a declining quality of health services in the country. This decline in quality is mainly attributed to the lack of drugs and other stocks, the shortage of health workers, delays in accessing health care services in every RRH, mismanagement of hospital infrastructures, and the overcrowding of hospital facilities. This has raised concerns as to whether these hospitals are operating efficiently with the resources available to them. There is a need for the efficient

¹ We refer here to international treaties such as the International Covenant on Economic, Social and Cultural Rights (ICESCR), the Universal Declaration of Human Rights (UDHR) and the Convention on the Rights of the Child, and a number of other non-binding declarations such as the Alma Ata Declaration, the Millennium Declaration and the Abuja Declaration, among others.

provision of clinical and non-clinical services to produce a healthy population as an input for economic development. The inefficiency in the RRHs is an issue that needs to be addressed if Uganda is to reap significant savings from all the activities carried out by RRHs and to meet its Millennium Development Goals related to health.

Uganda has fourteen autonomous RRHs that are responsible for delivering a complementary, integrated, and continuous package of health care to achieve a common national goal. RRHs offer specialised services such as psychiatry, Ear, Nose and Throat (ENT) services, radiology, pathology, ophthalmology, and higher level surgical and medical services, including teaching and research. This is in addition to the services offered at general hospitals. RRHs are required to provide this more specialised care for a population of 2,000,000 people, to have a bed capacity of 500, to employ an average of 349 members of staff and to maintain all the relevant health equipment prescribed by the Ministry of Health. The Ugandan hospital policy provides that RRHs are part of the system for delivering health services in Uganda. RRHs derive their vision and mission from the vision of the health sector, which is: “A healthy and productive population that contributes to social-economic growth and national development” (Ministry of Health 2010: 38). The stated mission for the sector is: “To provide the highest possible level of health services to all people in Uganda through delivery of promotive, preventive, curative, palliative and rehabilitative health services at all levels.” (Ministry of Health 2010: 38). The organisational structure of RRHs includes a Management Board as the highest authority; this provides oversight for the activities of the hospital. The executive function is headed by the Hospital Director. The Government of Uganda’s budget allocation to the thirteen (out of the existing fourteen) RRHs under review for the financial years 2011/12 to 2013/14 amounted to an average of UGX 59 billion, while the money spent amounted to an average of UGX 57.8 billion.

3. Previous studies of hospital efficiency in African countries

Data Envelopment Analysis (DEA) has been widely used across the world to analyse the efficiency in general but also of hospitals.² O'Neill et al. (2008) present a survey of efficiency studies on hospitals that spans the time period 1994 to 2004. One of their general findings is that the majority of studies used an input-oriented DEA model. Furthermore, they show that about half of the studies used a long run perspective, i.e. a constant return to scale (CRS) model. The other half used either a short run, i.e. a variable return to scale (VRS) model, or both a VRS and a CRS model. When it comes to quality measures, O'Neill et al. (2008) identify only six studies that included a quality measure such as risk-adjusted in-hospital mortality. The majority of studies have been conducted in the USA and in Europe, however recently several studies on technical efficiency have been conducted in African countries. Studies in countries like Algeria, Angola, Botswana, Burkina Faso, Ghana, Kenya, Namibia, South Africa, Uganda and Zambia have all used DEA to evaluate hospital efficiency. However, none of the studies investigate existence of congestion. We therefore use previous research to determine model and to get a reference for the computed long run efficiency scores. Table 1 summarises the findings of the previous studies in African countries. The presentation is divided into two parts according to the number of studies in each country. First, countries with more than one study are reported, and, thereafter, countries with only one study.

² See e.g. Emrouznejad, Yang (2018) for a recent survey of the use of DEA.

Table 1. Studies of technical efficiency in hospitals on the African continent

Author	Country	Units	Data year	No. of inputs	No. of outputs	Method	No. of efficient units	Average technical inefficiency
Multiple country studies								
Marschall & Flessa (2009)	Burkina Faso	20	2004	4	4	DEA	14	29%
Marschall & Flessa (2011)	Burkina Faso	25	2005	4	4	DEA (two stage)	11	13.8% (CRS)
Ramanathan et al. (2003)	Botswana	13	1997	5	14	DEA (SFA per output)	12	1%
Tlotlego et al. (2010)	Botswana	21	2006 – 2008	2	2	DEA	3 (CRS) 8 (VRS)	53% - 38%
Akazili et al. (2008a)	Ghana	89	2004	4	5	DEA	30	28%
Akazili et al. (2008b)	Ghana	113	2003/2004	4	5	DEA (two stage)	25	Not reported
Osei et al. (2005)	Ghana (hospitals)	17	2000	4	4	DEA	9	18.5%
	(health centres)	17	2000	2	4	DEA	15	9%
Kirigia et al. (2001)	South Africa	115	1996	2	8	DEA	47	26%
Zere et al. (2001)	South Africa	86	1992/93 – 1996/97	2	2	DEA	11 (total)	35% - 47%
Kibambe & Koch (2007)	South Africa (Gauteng)	14	2004	3	4	DEA	Uses each output separately and several models	30.7% - 1.1%
Linden (2013)	South Africa	52	2007 – 2009	3	4	DEA	7 for all years	10.6%; 9.5%; 9.4%
Masiye (2007)	Zambia	30	2006	6	4	DEA	12	33%
Masiye et al. (2006)	Zambia	40		3	1	DEA	5	38%

Table 1. Continuation

Author	Country	Units	Data year	No. of inputs	No. of outputs	Method	No. of efficient units	Average technical inefficiency
Single country studies								
Djema & Djerdjouri (2012)	Algeria	174	2008	4	5	DEA (two stage)	60	25%;19% ; 23%
Kirigia et al. (2008)	Angola	28	2000 – 2002	3	2	DEA, Malmquist index	11,12,10 (yearly)	33.8%; 34.2%; 32.5%
San Sebastian & Lemma (2010)	Ethiopia	60	2000	2	8	DEA	15 (CRS), 31 (VRS)	43%; 5%
Kirigia et al. (2002)	Kenya	54	1998	11	8	DEA	40	16%
Zere et al. (2006)	Namibia	30	1997/98 – 2000/01	3	2	DEA	3-5	37.3-25.7%
Ichoku et al. (2011)	Nigeria	200	2009	11	4	DEA	48 (CRS), 87 (VRS)	48%; 28%
Kirigia et al. (2007)	Seychelles	17	2001 – 2004	2	9	DEA and Malmquist	5-7 (yearly)	7% (average over years)
Renner et al. (2005)	Sierra Leone	37	2000	2	6	DEA	15	37%
Mujasi et al. (2016)	Uganda	14	2013/14	2	2	DEA	4 (CRS), 9 (VRS)	20% 9%
Yawe (2010)	Uganda	25	1999 – 2003	4	4	DEA (super efficient)	NA	Allows efficiency scores above 100%

Marschall and Flessa (2009, 2011) study technical efficiency in health centres and in primary care in Burkina Faso. Both studies use the same specification of inputs and outputs. The inputs are: personnel costs in 2005 [US\$], building area [m²], depreciation of CSPS equipment in 2005 [US\$] and vaccination costs in 2005 [US\$]. As outputs, general numbers of consultations and nursing care, numbers of

deliveries, numbers of immunisations, special services such as number of consultations for family planning, and numbers of prenatal and postnatal consultations, are used. For the health centres an average inefficiency of 29% is reported and for primary care the average inefficiency is 13.8%.

Ramanathan et al. (2003) and Tlotlego et al. (2010) study efficiency in Botswana. A novelty with Ramanathan et al. (2003) is that the study, besides using DEA, uses a stochastic frontier approach while, however, analysing each of the fourteen selected outputs separately. An obvious problem with this study is dimensionality. The authors use fourteen outputs and five inputs and only have access to thirteen observations. The specification in Tlotlego et al. (2010) is different. In this study there are two inputs and two outputs, and 21 units for the analysis. The inputs in this study are the number of clinical staff and the number of hospital beds. The outputs are the number of outpatient visits and the number of inpatient days. The average inefficiency ranges from 53 per cent to 38 per cent, depending on scale assumptions.

There have been three studies on technical efficiency in Ghana. Osei et al. (2005) use DEA to investigate technical efficiency in Ghana in the year 2000. Their data cover seventeen hospitals and seventeen health centres. The inputs used in the analysis are: number of medical officers; number of technical officers; number of support or subordinate staff; and number of hospital beds. The outputs are the number treatments relating to maternity and child care, the number of babies delivered and the number of patients discharged (not including deaths). The average inefficiency for Ghana in this study is 18.5%. Akazili et al. (2008a, 2008b) also use DEA, but in contrast to other studies Akazili et al. (2008b) also cover allocative and long run efficiency. The inefficiency in Akazili et al. (2008a) is 28%; inefficiency is not reported in Akazili et al. (2008b).

Health care in South Africa has been studied by Kirigia et al. (2001), Zere et al. (2001), Kibambe and Koch (2007) and Linden (2013). Kirigia et al. (2001) study technical efficiency in the Kwazulu-Natal province, where the inefficiency was below ten percent. Numbers of nurses and of general staff (administrative and subordinate staff) are used as inputs, and numbers of antenatal care visits, deliveries/births, child health care visits, dental care visits, family planning visits,

psychiatric visits, sexually transmitted disease related care visits, and tuberculosis related care visits are used as outputs. In Zere et al. (2001) level I, II and III hospitals in three different provinces in South Africa are in focus. The authors compute measures of CRS, VRS, technical efficiency and scale efficiency. The result was an average technical inefficiency between 32 and 26 per cent if CRS technology is assumed and between 18 and 17.2 per cent if VRS technology is assumed. The study uses two inputs (recurrent expenditure and beds) and two outputs (outpatient visits and inpatient days). Kibambe and Koch (2007) use data for 2004 and the DEA framework, and apply a number of different specifications, among other things taking each output separately. The inefficiency scores are in the range of 1.1% to 30.7%. The inputs in this study are the numbers of physicians (doctors and specialists), nurses, and active beds. The outputs are: total admissions, inpatient visits, outpatient days and total surgeries. Linden (2013) find an average inefficiency of 10.6 percent. The study uses numbers of medical doctors, specialists, active beds, staffed beds, and non-nursing medical and dental staff, cost of drugs, and capital charges as inputs, and numbers of out-patient department attendances, births, surgeries, emergency room visits, admissions and acute discharges as outputs. Masiye et al. (2006) and Masiye (2007) conduct studies of the Zambian hospital sector. In Masiye et al. (2006) roughly 23 per cent of the hospitals are reported to be inefficient. Furthermore, the sample was divided into private and public hospitals. The average technical inefficiency was 30 per cent for the private and 44 per cent for the public hospitals. The inputs used are number of clinical officers, number of nurses and number of other staff. As outputs, outreach services, number of visits and immunisations are used. Masiye (2007) uses a slightly different specification and expands the number of both inputs and outputs. The inputs in the study are non-labour expenditure, number of medical doctors, sum cost for nurses, laboratory technicians, radiographers and pharmacists and finally, administrative and other staff. As outputs the author uses number of ambulatory care visits, inpatient days, maternal and child health, and the sum of the number of lab tests, X-rays and theatre operations. The average inefficiency in the study was 33%.

There are also countries where single studies have been performed. Djema and Djerdjouri (2012) investigate efficiency in Algeria, applying the DEA method. In

their study hospitals are divided into three groups according to size, and the analysis is performed on each group. Average technical inefficiency for the small, medium and large hospitals is reported to be 25%, 19% and 23% respectively. The study uses four inputs: numbers of paramedical staff, medical staff, administrative staff and beds. The outputs used are the number of admissions, days of hospitalisation, average duration of the stay and finally, hospital mortality.

In Kirigia et al. (2008), DEA and the DEA-based Malmquist index are used to study hospital production in Angola. The technical inefficiency for the three years was 34, 34 and 32 per cent respectively. Using the Malmquist index the study concludes that the productivity increase was 4.5 per cent for the period, and was due to improvements in efficiency rather than innovation. The study uses the sum of the numbers of doctors and nurses, the amounts spent on drugs and maintenance, and the number of beds as inputs. The outputs used are the numbers of outpatient visits and inpatient admissions.

San Sebastian and Lemma (2010) study technical efficiency in Ethiopia. The results reveal that 15 out of the 60 hospitals were efficient and that the average inefficiency was 43%. The study uses a model consisting of two inputs and eight outputs. The two inputs are: number of health extension workers and number of voluntary health workers (traditional birth attendants and community health workers). The outputs for the model are the number of health education sessions; the number of completed (three) antenatal care visits; the number of babies delivered; the number of people that repeatedly visited the family planning service; the number of cases of diarrhoea treated in children under five; the number of visits carried out by community health workers; the number of totally new patients attending hospital; and finally, the number of malaria cases treated.

Kirigia et al. (2002) and Kirigia et al. (2004) investigate the situation in Kenya. Kirigia et al. (2002) concludes that 56 per cent of the public health centres and 26 per cent of the public hospitals were technically inefficient. The study uses the number of medical officers/pharmacists/dentists, clinic officers, nurses (including enrolled, registered, and community nurses), administrative staff, technicians/technologists, other staff, subordinate staff, pharmaceuticals, non-pharmaceutical supplies, maintenance of equipment, vehicles, and buildings, and

food and rations as inputs. The used outputs are; outpatient Department casualty visits, special clinic visits, MCH/FP visits, dental care visits, general medical admissions, paediatric admissions, maternity admissions, and amenity ward admissions. In a follow up, Kirigia et al. (2004), a slightly specification is used for the public health centres. In the study the authors find that around 56 per cent were technical efficient. Inputs are defined as: clinical officers + nurses, physiotherapist + occupational therapist + public health officer + dental technologist, laboratory technician+ laboratory technologist, administrative staff, nonwage expenditures and number of beds. As outputs the author uses: diarrhoeal + malaria + sexually transmitted infection + urinary tract infections + intestinal worms + respiratory disease visits, antenatal + family planning visits, immunization and finally, other general outpatient visits

Zere et al. (2006) study hospital efficiency in Namibia. In Namibia 30 hospitals were studied, and between three and five were technically efficient between the years 1997 and 2001. The average technical inefficiency was more than 25 per cent. In the study, recurrent expenditure and numbers of beds and nursing staff are inputs, and numbers of outpatient visits and inpatient days are outputs.

Kirigia et al. (2007) investigate both technical efficiency and productivity development in seventeen primary health centres in the Seychelles between 2001 and 2004. The inputs used in the model are the total numbers of hours worked by doctors and nurses. The study uses nine outputs (numbers of patients dressed, domiciliary cases treated, school health sessions, MCH visits, antenatal visits, postnatal visits, immunisations, pap smear visits, and family planning clinic visits). The inefficiency reported was an average over the years of 7 per cent.

Ichoku et al. (2011) study hospital efficiency in 200 Nigerian hospitals in 2009. The method used is DEA. The study uses eleven inputs and four outputs. Depending on the scale assumption, the average inefficiency ranges from 48% (CRS) to 28% (VRS).

Renner et al. (2005) investigate technical efficiency in Sierra Leone. The data cover 37 hospitals in one district. The results reveal an average inefficiency of 37%. Out of the 37 hospitals, 22 were considered to be efficient. The model used has two inputs and six outputs. The inputs are the numbers of technical staff (community

health nurses, vaccinators and maternal and child health aides) and subordinate staff (including traditional birth attendants, porters and watchmen). As for the outputs, these are the numbers of antenatal plus postnatal visits, babies delivered, nutritional/child growth monitoring visits, family planning visits, children under the age of five years immunised plus pregnant women immunised with tetanus toxoid (TT), and health education sessions conducted through home visits, public meetings, school lectures and the outpatient department.

Yawe (2010) uses a super efficiency DEA model to analyse hospitals in Uganda between 1999 and 2003. In the study 25 out of 38 district referral hospitals are analysed, using four input and four output variables, as can be seen in Table A1 in Appendix A. The reasons for using a super efficiency DEA model were that the standard DEA model failed to rank the set of efficient hospitals. Using a super efficiency model, the hospitals can be ranked into four groups: strongly super efficient, super efficient, efficient and inefficient. The study estimates five different models and all of them have a feasible solution under constant returns to scale technology. The conclusion is that not adjusting one of the output variables (admissions) would understate the efficiency scores. Furthermore, the results are sensitive for lumping human resources into one variable: this reduces the efficiency score and reduces the number of hospitals on the production possibilities frontier. The focus of the study is on methodology rather than the result. Finally, Mujasi et al. (2016) investigate referral hospitals in Uganda. The authors found a long run efficiency (CRS) of almost 80% and a short run technical efficiency (VRS) of more than 91%. The model consisted of two inputs, beds and medical staff and two outputs; outpatient visits and inpatient admissions.

In summary, the previous research on hospital and health centre performance reveals varying, but overall high, levels of inefficiency. There are a variety of inputs and outputs used, but numbers of staff and beds are used as inputs in the majority of studies. Also, the previous studies generally use inpatient and outpatient measures as outputs. All, with the exception of one study, use the DEA approach to assess efficiency.

4. The data, the definitions and the model

The dataset includes 13 RRHs for the three (3) fiscal years 2011/2012, 2012/2013 and 2013/2014. It was sourced from the Health Management Information System (DHIS-2) which is produced by the Ministry of Health. The Health Management Information System data was used because its reliability makes it the recommended data source for the health sector. The study also obtained data from the RRHs. For each hospital, the dataset included the numbers of health workers, beds, diagnostic equipment, diagnostic tests, outpatient attendances, admissions, deliveries, mortality, stillbirths, live births, immunisation data, antenatal visits, Standard Units of Output (see below), drug expenditure and other operating costs. The input and output variables were chosen following discussions with the Ministry of Health and RRHs and in the light of the hospital production process and the variables commonly used in previous similar research studies on the efficiency of hospitals, as explained above.³

The input variables

Health workers: These were chosen because they are directly involved in the provision of health services to patients. Furthermore, for RRHs the wage bill constitutes about two thirds of the total operating costs. The health worker category includes medical professionals (medical officers, specialists and consultants), nursing staff, midwifery staff, dental professionals, and allied health professionals.

Beds: This is commonly chosen in hospital studies as a proxy for capital investment and hospital size.⁴

Drug expenditure: This represents the treatment given to both inpatients and outpatients. It constitutes the actual expenditure on essential medicines and health supplies. Drug expenditure can also act as a proxy for the alternative of admitting patients.

³ Several specifications have been tested. The results concerning sensitivity analysis is presented in Appendix B, Table B1.

⁴ O'Neill et al. (2008)

Output variables

We use the Standard Unit of Output (SUO) proposed by the Ministry of Health in their Annual Health Sector Performance reports, and convert all the outputs of the RRH into outpatient equivalents. The SUO enables a uniform and fair comparison of outputs across hospitals that have varying capacities, and is based on an earlier work of cost comparisons. The SUO is defined as = [(Inpatients x 15) + (Outpatients x 1) + (Deliveries x 5) + (Immunisations x 0.2) + (ANC/MCH/FP x 0.5)].⁵ Furthermore, the SUO captures the different types of patient care services provided by the RRHs, such as outpatient services, inpatient services, maternity services, and prevention and rehabilitation services.

Table 2. Summary statistics for inputs and outputs per financial year

2011/12	Output	Inputs			Quality indicator
	<u>SUO</u>	<u>Health Workers</u>	<u>Beds</u>	<u>Drugs (UGX mil)</u>	<u>Mortality</u>
Mean	412,385	172	278	851	241
SD	127,873	43	95	317	135
Minimum	188,681	97	120	329	90
Maximum	609,384	251	429	1356	578
2012/13					
Mean	503,599	172	319	1057	249
SD	176,885	43	92	276	257
Minimum	225,951	97	150	556	56
Maximum	858,116	251	447	1591	962
2013/14					
Mean	524,750	186	321	895	209
SD	158,569	58	88	226	212
Minimum	206,090	69	170	379	62
Maximum	885,840	310	447	1254	893

Source: OAG Analysis of data from RRHs

⁵ ANC = 1st and 4th Antenatal Care visits; MCH = Maternal and Child Health contacts; FP = Family Planning visits.

Mortality is used as a rough measure of the quality of the health care provided by the RRHs. It is assumed that the higher the mortality a hospital reports, the lower the quality of its services. This same parameter was, as discussed earlier, used in previous studies as a quality measure. Since the objective is to minimise mortality, this variable is transformed by taking its inverse. The descriptive statistics are presented in Table 2.

The quantity of each input and output generally varies amongst the RRHs and from one year to another. The only exceptions are the numbers of health workers and beds, which remain fairly constant on a year-on-year basis. The aforementioned variation meant that the efficiency analysis had to be carried out for each year separately in order to obtain unbiased results.

The model

In the study we use the DEA framework that first was used by Farrell (1957) and was later extended for use with multiple inputs and outputs by Charnes et al. (1978). From previous research, the dominant model used when measuring technical efficiency is a model that sets the objective as minimising input for a given output level, i.e. an input-based model. First, the concept of technical efficiency needs to be defined. Let $k, k = 1, \dots, K$ represent the K different hospitals, $x_n, n = 1, \dots, N$ represent the N different inputs and $y_m, m = 1, \dots, M$ represent the M different outputs. The production technology, or input requirement set, is defined as $T = \{(x; y) \mid x \text{ can produce } y\}$. Input-based technical efficiency can then be defined as: If $(x, y) \in T$ but $(\lambda x, y) \notin T$ for $0 < \lambda < 1$ (that is, if the inputs are reduced it will not be possible to produce the observed level of outputs). Technical inefficiency, on the other hand, is a situation where $(\lambda x, y) \in T$ for $\lambda \in (0, 1)$ (that is, it is possible to reduce the inputs and still be able to produce the observed output levels). In micro economic theory, long-run technical efficiency requires that the efficiency is evaluated against constant return to scale (CRS) technology, here denoted $TE(CRS)$. In the short run, however, it is possible to allow for different types of scales of operation. Therefore, technical efficiency is also evaluated against

a variable return to scale (VRS) frontier [$TE(VRS)$]. How much of the long run technical efficiency that is explained by the scale of operation is computed and referred to as scale efficiency.

The focus of this study is congestion, and we will follow the framework suggested in Färe and Svensson (1980) and applied in, for example, Grosskopf et al. (2001), Ferriet et al. (2006), Clement et al. (2008), Valdmanis et al. (2008), Simões and Marques (2011).⁶ Input congestion refers to a situation where an increase in one or more inputs will cause a reduction in the output produced. To define congestion, the concept of disposability is required. A technology is congestion-free if it is free to dispose of inputs that are not used. This is referred to as the strong disposability of inputs. However, if this is not the case, we refer to the weak disposability of inputs. Technical efficiency for hospital ‘o’ (λ_o) is computed as follows:

$$\begin{aligned}
 [1] \quad & \text{Max } \lambda_o \\
 & \text{s.t.} \\
 [2a] \quad & \sum_{n=1}^N z_n x_{n,k} \geq \lambda_o x_{n,o} \\
 [2b] \quad & \sum_{n=1}^N z_n x_{n,k} = \lambda_o x_{n,o} \\
 [3] \quad & \sum_{m=1}^M z_m y_{m,k} \leq y_{m,o} \\
 [4a] \quad & z_k \geq 0 \\
 [4b] \quad & \sum_{k=1}^K z_k = 1, z_k \geq 0
 \end{aligned}$$

Using the objective function [1], restrictions [2a], [3] and [4a] will measure technical efficiency imposing constant returns to scale and strong disposability of inputs [$TE(S, CRS)$], or long-run technical efficiency. By replacing restriction [4a] by [4b] the model will measure technical efficiency imposing variable returns to scale and strong disposability of inputs [$TE(S, VRS)$]. Finally, by replacing restriction

⁶ There are a number of ways to assess congestion, and there has been a recent debate concerning the differences between the different approaches. In general, all the approaches have advantages and disadvantages, and the choice of approach for measuring congestion depends on the question put forward. See e.g. Haghighi et al. (2014) or Khodabakhshi et al. (2014) for reviews of the different approaches.

[2a] with [2b] we get the corresponding results under the assumption of weak disposability, $TE(W,CRS)$ and $TE(W,VRS)$. Given these models, the long-run technical efficiency can be decomposed into three components: pure technical efficiency, scale efficiency and congestion efficiency:

$$[5] \quad TE(S,CRS) = \underbrace{TE(W,VRS)}_{\text{pure technical efficiency}} \cdot \underbrace{\frac{TE(W,CRS)}{TE(W,VRS)}}_{\text{scale efficiency}} \cdot \underbrace{\frac{TE(S,CRS)}{TE(W,CRS)}}_{\text{congestion}}$$

5. Results

Table 3 presents the results of the analysis. The first row indicates the year for the analysis. In column 2 the level of long run technical inefficiency is presented. Technical inefficiency is computed as one minus the efficiency score. For example; if the computed efficiency score equals 0.8, this means that the hospital could produce the same amount of output using 80% of the observed input. This equals a potential reduction of inputs of 20%, i.e. 1-0.8. In the following columns we present computations of how much of the observed inefficiency is attributed to each of pure technical efficiency, scale efficiency and congestion. These are expressed as percentage points of the long run inefficiency. For example, in 2014 Mbarara had a long run inefficiency of 23 per cent. This means that Mbarara in 2013/14 could have reduced its use of inputs by 23% if it had mimicked the operation of one of the efficient hospitals. To illustrate what this means, note that Mbarara had a total cost of approximately UGX 4,528 million. A reduction of 23 per cent means a saving equal to approximately UGX 1,041 million. Further, 20.7 percentage points of the long run inefficiency related to pure technical efficiency, 1.1 percentage points to not producing on an optimal scale and 1.1 percentage points to congestion.

Table 3. Long run technical inefficiency (per cent) and the share of the observed inefficiency attributed to each of pure technical inefficiency, scale inefficiency and congestion for Ugandan referral hospitals in 2012, 2013 and 2014

	2012				2013				2014			
	Long run Technical In- efficiency (Per cent)	Pure Technical In- efficiency (Percentage points)	Scale In- efficiency (Percentage points)	Congestion (Percentage points)	Long run Technical In- efficiency (Per cent)	Pure Technical In- efficiency (Percentage points)	Scale In- efficiency (Percentage points)	Congestion (Percentage points)	Long run Technical Inefficiency (Per cent)	Pure Technical In- efficiency (Percentage points)	Scale In- efficiency (Percentage points)	Congestion (Percentage points)
Arua	16.0	0.0	1.1	14.9	35.0	22.3	7.17	5.53	29.0	0.0	4.6	24.4
Fort Portal	8.0	0.0	1.0	7.0	24.0	13.2	9.79	1.02	11.0	8.9	1.1	1.0
Gulu	4.0	0.0	1.0	3.0	34.0	0.0	3.64	30.36	23.0	20.7	0.0	2.3
Hoima	0.0	0.0	0.0	0.0	7.0	0.0	7.00	0.00	1.0	0.0	1.0	0.0
Junja	5.0	0.0	1.0	4.0	35.0	25.6	4.85	4.58	25.0	0.0	8.8	16.2
Kabale	40.0	5.7	22.5	11.8	26.0	0.0	10.94	15.06	10.0	0.0	1.0	9.0
Lira	11.0	0.0	1.1	9.9	27.0	0.0	12.04	14.96	8.0	0.0	1.0	7.0
Masaka	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	1.0	0.0	1.0	0.0
Mbale	14.0	0.0	14.0	0.0	1.0	0.0	1.00	0.00	0.0	0.0	0.0	0.0
Mbarara	0.0	0.0	0.0	0.0	20.0	0.0	3.30	16.70	23.0	20.7	1.1	1.1
Moroto	16.0	0.0	16.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0
Mubende	0.0	0.0	0.0	0.0	13.0	0.0	13.00	0.00	0.0	0.0	0.0	0.0
Soroti	0.0	0.0	0.0	0.0	22.0	0.0	7.61	14.39	2.0	0.0	1.0	1.0
Average	8.8	0.4	4.4	3.9	18.77	4.70	6.18	7.89	10.2	3.9	1.6	4.8

Source: Authors' own elaboration

Table 3 reveals an average yearly long run inefficiency of between 9 and 19 per cent, with 2012/13 being the year with the highest amount of inefficiency. These results are in line with, or below, other studies of hospital efficiency in African countries. In columns three to five the sources of the observed inefficiency are expressed as percentage points of long run inefficiency. Pure technical inefficiency refers to the excess use of inputs. For the years 2013/14, an average 3.9 percentage points of the 10.2 per cent long run inefficiency relates to the excess use of inputs, 1.6 percentage points are related to not producing at an optimal scale, and, finally, 4.8 percentage points can be referred to as congestion. Looking at the individual hospitals, Gulu, Mbarara and Jinja show the highest amount of long run inefficiency, but the sources of inefficiency differ considerably. While the majority of the long run technical inefficiency in Gulu and Mbarara relates to input use (pure technical inefficiency), the situation in Jinja is different. In fact, none of the observed long run technical inefficiency is related to input use in Jinja. Instead, 8.8 percentage points relate to operating outside the optimal scale, and as much as 16.2 percentage points relate to congestion. In Kabale and Lira the major part of the observed long run technical inefficiency also relates to congestion rather than the scale of input use.

6. Conclusion and concluding remarks

The aim of this study is to investigate efficiency in Ugandan referral hospitals by decomposing long run technical efficiency into three components: Pure technical efficiency, scale efficiency and congestion. The long run results showed a potential for improving efficiency in the RRHs by saving on the inputs currently used to produce the outputs. The inefficiency ranges from 0% to 40%, with an average inefficiency score of 12.6% across the three years. Another finding is that the saving potential of each RRH may not be uniform across the hospitals. This implies that the policy to make referral hospitals more efficient should target those hospitals that have the potential to save costs. Cutting resources from hospitals that are already

efficient might, in fact, create a situation where inefficiency is induced because of an inappropriate efficiency improvement policy. The policy recommendation is that committees should be instituted in the inefficient RRHs to re-examine their operational procedures with a view to identifying inefficiencies in their utilisation of resources. This could be done by encouraging inefficient hospitals to interact with efficient RRHs, especially the consistently efficient RRHs, to compare their usage of inputs and organisation. A third finding is that inefficiency for some hospitals can be related to existence of congestion. This is not surprising since the Office of the Audit General (2015) indicate existence of congestion. For example, the study reports bed occupancy rates exceeding 100 per cent. It is beyond the scope of this study to further investigate the causes to the observed inefficiency relating to congestion. However, based on our results we feel confident to recommend that resources are spent to further investigate what in the production organisation that might be the cause for the identified congestion.

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Appendix A

Table A1. Summary of previous research in Africa with respect to number of hospitals, inputs and outputs and scale assumptions

Author	Number of hospitals	Inputs and outputs	Returns to scale
Akazili et al. (2008) ^a	89	<i>Inputs:</i> numbers of clinical staff and non-clinical staff, expenditure on drugs and other consumables and numbers of beds and cots. <i>Outputs:</i> outpatient visits, and numbers of antenatal care visits, deliveries, children immunised, and family planning visits.	CRS VRS
Akazili et al. (2008b)	113	<i>Inputs:</i> numbers of staff and beds/cots, costs of supplies and recurrent expenditure. <i>Outputs:</i> number of outpatients, antenatal care, deliveries, children immunised, and family planning updates.	CRS
Djema & Djerdjouri (2012)	174	<i>Inputs:</i> numbers of paramedical, medical and administrative staff, and number of beds. <i>Outputs:</i> number of admissions, days of hospitalisation, average duration of the stay rate of rotation and hospital mortality.	VRS
Ichoku et al. (2011)	200	<i>Inputs:</i> numbers of beds in the facility, patients, pharmacists employed by the facility, registered and auxiliary nurses employed, and other paramedical staff employed; and annual expenditure on drugs, power including running of generators, and equipment including maintenance. Dummy variables: urban or rural location, facility is in Enugu or Anambra state, government or private <i>Outputs:</i> numbers of outpatients treated in facility in the last year, inpatient admissions, laboratory tests conducted and X-rays attended	CRS VRS
Kibambe & Koch (2007)	14	<i>Inputs:</i> numbers of physicians (doctors and specialists), nurses, and active beds. <i>Outputs:</i> total admissions, inpatient visits, outpatient days and total surgeries.	CRS VRS
Kirigia et al. (2001)	115	<i>Inputs:</i> numbers of nurses and of general staff (administrative and subordinate staff). <i>Outputs:</i> numbers of antenatal care visits, deliveries/births, child health care visits, dental care visits, family planning visits, psychiatric visits, sexually transmitted disease related care visits, and tuberculosis related care visits.	CRS VRS

Table A1. Continuation

Author	Number of hospitals	Inputs and outputs	Returns to scale
Kirigia et al. (2002)	54	<p><i>Inputs:</i> Medical officers/pharmacists/dentists, clinic officers, nurses (including enrolled, registered, and community nurses), administrative staff, technicians/technologists, other staff, subordinate staff, pharmaceuticals, non-pharmaceutical supplies, maintenance of equipment, vehicles, and buildings, and food and rations</p> <p><i>Outputs:</i> Outpatient Department casualty visits, special clinic visits, MCH/FP visits, dental care visits, general medical admissions, paediatric admissions, maternity admissions, and amenity ward admissions</p>	CRS, VRS
Kirigia et al. (2007)	17 primary health care	<p><i>Inputs:</i> total number of doctor hours and total number of nurse hours.</p> <p><i>Outputs:</i> numbers of patients dressed, domiciliary cases treated, school health sessions, maternal and child health (MCH) visits, antenatal visits, postnatal visits, immunisations, pap smear visits, family planning clinic visits.</p>	CRS VRS
Kirigia et al. (2008)	28 public municipal hospitals	<p><i>Inputs:</i> Sum of doctors and nurses, the amounts spent on drugs and maintenance, and the number of beds</p> <p><i>Outputs:</i> Numbers of outpatients visits and number of inpatient admissions</p>	CRS, VRS
Linden (2013)	138	<p><i>Inputs:</i> numbers of FTE RN, medical doctors, specialists, active beds, staffed beds, and non-nursing medical and dental staff, costs of drugs, capital charge.</p> <p><i>Outputs:</i> numbers of OPD attendances, births, surgeries, emergency room visits, admissions, and acute discharges</p>	CRS, VRS
Masiye (2007)	32	<p><i>Inputs:</i> non-labour expenditure, medical doctors, sum of nurses cost, laboratory technicians, radiographers and pharmacists, administrative and other staff</p> <p><i>Outputs:</i> number of ambulatory care visits, inpatient days, MCH, sum of number of lab tests, X-rays and theatre operations</p>	CRS VRS
Masiye et al. (2006)	40 health centres	<p><i>Inputs:</i> clinical officers, number of nurses, other staff,</p> <p><i>Outputs:</i> outreach services, number of visits, immunisations</p>	CRS, VRS

Table A1. Continuation

Author	Number of hospitals	Inputs and outputs	Returns to scale
Marschall & Flessa (2009)	20, Health centres	<i>Inputs:</i> Personnel costs in 2005 [US\$], CSPS building area [m ²], depreciation of CSPS equipment in 2005 [US\$], and vaccination costs in 2005 [US\$]. <i>Outputs:</i> General consultation and nursing care, deliveries, immunisations, special services e.g. family planning, and prenatal and postnatal consultations.	CRS
Marschall & Flessa (2011)	25, Primary care	<i>Inputs:</i> Personnel costs in 2005 [US\$], CSPS building area [m ²], depreciation of CSPS equipment in 2005 [US\$] and vaccination costs in 2005 [US\$]. <i>Outputs:</i> General consultation and nursing care, deliveries, immunisations, special services, e.g. family planning, and prenatal and postnatal consultations.	CRS VRS
Mujasi et al. (2016)	14 referral hospitals	<i>Inputs:</i> Beds and medical staff <i>Outputs:</i> Outpatient visits and inpatient admissions.	CRS VRS
Osei et al. (2005)	17 hospitals and 17 health centres	<i>Inputs:</i> number of medical officers, number of technical officers (including medical assistants, nurses and paramedical staff), number of support or subordinate staff (including orderlies, ward assistants, cleaners, drivers, gardeners, watchmen, etc.), and number of hospital beds. <i>Outputs:</i> number of maternal and child care (i.e. antenatal care, postnatal care, family planning, tetanus toxoid, child immunisation and growth monitoring), number of babies delivered, and number of patients discharged (not including deaths)	CRS VRS
Ramanathan et al. (2003)	13	<i>Inputs:</i> numbers of health posts, beds, doctors, nurses and health staff. <i>Outputs:</i> numbers of outpatients from eleven different ailment groups, all outpatients, inpatients discharged alive, new births discharged alive and patient days.	CRS

Table A1. Continuation

Author	Number of hospitals	Inputs and outputs	Returns to scale
Renner et al. (2005)	37 health units	<p><i>Inputs:</i> numbers of technical staff (vaccinators, community health nurses, emergency and humanitarian officers, maternal and child health aides) and subordinate staff (traditional birth attendant, porter, watchman), costs of materials and supplies, capital inputs</p> <p><i>Outputs:</i> numbers of antenatal and postnatal care visits, babies delivered, nutrition/growth monitoring visits, family planning visits, under 5's and pregnant women immunised, health education sessions</p>	CRS VRS
San Sebastian & Lemma (2010)	60	<p><i>Inputs:</i> number of health extension workers and number of voluntary health workers (traditional birth attendants and community health workers).</p> <p><i>Outputs:</i> number of health education sessions given by HEWs; number of completed (three) antenatal care visits; number of babies delivered; number of people repeatedly visiting the family planning service; number of cases of diarrhoea treated in children under five; number of visits carried out by community health workers; number of totally new patients attending hospital; number of malaria cases treated.</p>	CRS VRS
Tlotlego et al. (2010)	21 (3 year)	<p><i>Inputs:</i> numbers of clinical staff (physicians, nursing and midwifery personnel, dentistry personnel, and other technical health service providers) and hospital beds.</p> <p><i>Outputs:</i> numbers of outpatient department visits and inpatient days.</p>	CRS VRS
Zere et al. (2001)		<p><i>Inputs:</i> recurrent expenditure, beds</p> <p><i>Outputs:</i> outpatient visits, inpatient days</p>	CRS VRS
Zere et al. (2006)	30	<p><i>Inputs:</i> recurrent expenditure, numbers of beds and nursing staff</p> <p><i>Outputs:</i> numbers of outpatient visits and inpatient days</p>	CRS
Yawe (2010)	25	<p><i>Inputs:</i> numbers of doctors, nurses, other staff, and beds</p> <p><i>Outputs:</i> numbers of total annual admissions, annual outpatient department attendances, surgical operations, deliveries in the hospital</p>	Super efficiency model

Appendix B: Results of Sensitivity Analysis

Sensitivity analysis was carried out using four models. The input and output variables of each model are:

Table B1. Different models in the sensitivity analysis

Model	Inputs	Outputs
Preferred Model	Beds Health Workers Drugs	Standard Unit of Output Mortality
Model 1	Beds Health Workers Drugs	Adjusted Standard Unit of Output*
Model 2	Beds Health Workers Drugs	Standard Unit of Output Average Length of Stay
Model 3	Beds Health Workers Drugs	Standard Unit of Output
Model 4	Beds All Staff Drugs	Standard Unit of Output Mortality

a) Model 1

This model uses the same variables as the preferred model but applies floor admissions as a quality measure rather than mortality. This is because the Hospital Directors considered floor admissions to be an indicator of the quality of health care. The average efficiency scores change slightly from the preferred model because most of the hospitals report few or no floor admissions. Of interest are Masaka and Mbale RRHs, which report the highest number of floor admissions in 2011/12 (Masaka) and in 2012/13 (Mbale), resulting in a drop in their average efficiency scores from 100% to 91% and 96% respectively.

b) Model 2

This model uses the same variables as the preferred model but applies average length of stay as a quality measure rather than mortality. The average scores generally remain the same for all the RRHs, with only marginal changes from

the preferred model results of 1%-3% for three RRHs. This model does not, therefore, offer unique information.

c) Model 3

This model uses the same variables as the preferred model but excludes mortality, therefore leaving quality measures out of the model. There are slight changes in the average efficiency scores of four RRHs, but a considerable change for Soroti RRH which goes from 95% to 100% efficiency. However, this model has not been chosen because Carey and Burgess (1999) and Ferrier and Trivitt (2013) argue that disregarding quality results in omitted variable bias.

d) Model 4

This model uses the same variables as the preferred model but replaces health workers with total number of staff, therefore incorporating administrative and support staff in the model. This changes the average efficiency score of five RRHs. However, this model has not been chosen because the administrative and support staff are not directly involved in delivering the health service to patients.

The sensitivity analysis conducted to ascertain the reaction of the model to changes in the mix of inputs and outputs did not show much change in the score and rankings of the RRHs. This further emphasises the comprehensiveness of the input and output variables used and the credibility of the preferred model.

Analiza (rozkład) wydajności technicznej – przykład ugandyjskich szpitali

Streszczenie

Cel: W audytoryjnym raporcie przekazanym do Parlamentu Ugandyjskiego przez Główne Biuro Audytu (ang.: *Office of the Audit General*) w Ugandzie zawarto wyniki pomiaru i analizy wydajności technicznej w ugandyjskich szpitalach, w których pacjenci są przyjmowani ze skierowaniem. Raport audytoryjny wskazał na względnie niski poziom niewydajności technicznej, przynajmniej w porównaniu do innych krajów afrykańskich. Celem niniejszego artykułu jest głębsze zbadanie kwestii dotyczących przyczyn występowania niewydajności.

Metodyka badań: Autorzy wykorzystali analizę obwiedni danych (ang.: *Data Envelopment Analysis*) i dokonali rozkładu długoterminowej wydajności technicznej w krótkoterminową wydajność techniczną, wydajność skalową i kongestię.

Wnioski: Wyniki badań wykazały, że źródła długoterminowej niewydajności różnią się na przestrzeni lat. W 2012 roku ponad 50% obserwowanej niewydajności odnosi się do czynników skalowych. Jednak w 2013 i 2014 roku głównym powodem długoterminowej niewydajności była kongestia na wejściu.

Wartość artykułu: Mimo że problemowi wydajności w afrykańskich szpitalach poświęcono znaczącą liczbę badań, żadne z nich nie koncentrowało się na występowaniu kongestii. Z tego względu niniejsze badanie przyczynia się do poszerzenia wiedzy wynikającej z dotychczasowych badań.

Implikacje: Zgodnie z rekomendacjami autorów, niewydajne szpitale powinny wykorzystywać wydajne szpitale jako wzorce i punkty odniesienia dla poprawy własnej wydajności. Co więcej, ponieważ spora część niewydajności technicznej odnosi się do kongestii, należy nadal prowadzić badania w celu identyfikacji czynników dotyczących produkcji lub organizacji, które mogą być związane z kongestią.

Słowa kluczowe: wydajność techniczna, wydajność skalowa, kongestia, Uganda, szpitale

JEL: D2, H4, I2