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Technical efficiency of human resources for health in Africa

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Abstract

There is growing peer and donor pressure on African countries to utilize available resources more efficiently in a bid to support the ongoing efforts to expand coverage of health interventions with a view to achieving the health-related Millennium Development Goals. The purpose of this study was to estimate the technical and scale efficiency of national health systems (NHS) in utilizing human resources for health in African continent. The study applied the Data Envelopment Analysis (DEA) approach to estimate the technical efficiency and scale efficiency among the 53 countries of the African Continent.

Out of the 38 low-income African countries, 12 countries national health systems manifested a constant returns to scale technical efficiency (CRSTE) score of 100%; 15 countries had a variable returns to scale technical efficiency (VRSTE) score of 100%; and 12 countries had a SE score of one. The average VRSTE score was 95% and the mean scale efficiency (SE) score was 59%; meaning that while on average the degree of inefficiency was only 5% and the magnitude of scale inefficiency was 41%.

Of the 15 middle-income countries, 5 countries, 9 countries and 5 countries had CRSTE, VRSTE and SE scores of 100%. Ten countries, six countries and 10 countries had CRSTE, VRSTE and SE scores of less than 100%; and thus, they were deemed inefficient. The average VRSTE (i.e. pure efficiency) score was 97.6%. The average SE score was 49.9%.

There is large unmet need for health and health-related services among countries of the African Continent. Thus, it would not be advisable for health policy-makers address NHS inefficiencies through reduction in excess human resources for health. Instead, it would be more prudent for them to leverage health promotion approaches and universal access prepaid (tax-based, insurance-based or mixtures) health financing systems to create demand for underutilized health services/interventions with a view to increasing ultimate health outcomes to efficient target levels.

Keywords: Africa, Technical efficiency, Scale efficiency, Health systems, Human resources for health

1. Introduction

The African continent has 53 countries and a population of 914 million. The continent population suffers a heavy burden of communicable and non-communicable diseases. In the year 2002, there were over 10.7 million deaths in the continent (World Health Organization 2004). About 66% of those deaths resulted from HIV/AIDS, lower respiratory tract infection, malaria, diarrheal diseases, maternal and perinatal conditions, cardiovascular disease, ischemic heart disease, childhood diseases (especially measles) and road traffic accidents.

The heavy disease burden can be attributed to multiple challenges, including: 47% of the population in the Region have no access to health services and more than 70% of the people have no access to essential drugs (World Health Organization 2000a); about 59% of pregnant women deliver babies without the assistance of skilled health personnel (World Health Organization 2005a); 64% of the population in the Region lack sustainable access to improved sanitation facilities and 42% lack sustainable access to an improved water source (United Nations Development Programme 2004); out-of-pocket expenditures constitute 51% to 90% of the private health expenditure in 14 countries and 91% to 100% in 24 countries (World Health Organization 2005a); 38.2% of people in sub-Saharan Africa live below the international income poverty lines of US$1 per day (United Nations Development Programme 2004); low investment in health development (World Health Organization 2005a); poor governance (Transparency International 2006); human resources for health crisis (World Health Organization 2006a); weak national health research systems (Kirigia and Wambebe 2006); and poorly performing national health systems (NHS) (World Health Organization 2000a).

A NHS performs the functions of stewardship (oversight), health financing (revenue collection, pooling of resources and sharing of financial risk, purchasing of health services), creating resources/inputs (including human resources for health) for producing health, and providing health services with a view to improving responsiveness to people's non-medical expectations, ensuring fair financial contribution to health systems and ultimately improving health (the three being goals of health system) (Murray and Frenk 2000). The World Health Report 2000 ranked the 191 Member States on the basis of their overall health system goal performance and majority of the African continent countries NHS performed poorly (World Health Organization 2000a).

Our concern with measurement of efficiency emanates from the fact that efficiency improvement is a key strategy for coping with the human resource crisis (World Health Organization 2006a) and mobilizing more domestic resources for the massive expansion in the coverage of health interventions envisaged in the Millennium Development Goals (MDGs) (United Nations 2000). Thus, while African countries are striving to develop strategies for increasing motivation and retention of human resources for health (World Health Organization 2006a), and mobilize more domestic and external resources (World Health Organization 2001), it is important to ensure that all the available health-related sectors resources are optimally used to produce health outcomes.

The objectives of the study reported in this article were to: (i) estimate the technical and scale efficiency of national health systems (NHS) in utilizing human resources for health in African continent to produce various ultimate health outputs (or outcomes); (ii) identify the magnitudes of inefficiencies in the use of human resources for health in individual countries; (iii) identify the best performer NHS whose practice could be emulated by others; (iv) highlight the implications for policy to health sector policy-makers.

2. Methods

2.1 Data Envelopment Analysis (DEA) Conceptual Framework

World Health Organization (2000a) defines NHS as comprising of all the organizations, institutions and resources that are devoted to producing health actions (personal health care, public health services or inter-sectoral initiatives), whose primary purpose is to improve health. *Figure 1* shows that each country's NHS employs multiple inputs (e.g. physicians, nurses, midwives, dentists, pharmacists, public, environmental and community health workers, pharmaceuticals, beds, medical equipment, buildings) to ultimately produce multiple health outputs (or outcomes) such as improvements in life expectancies and survival probabilities.

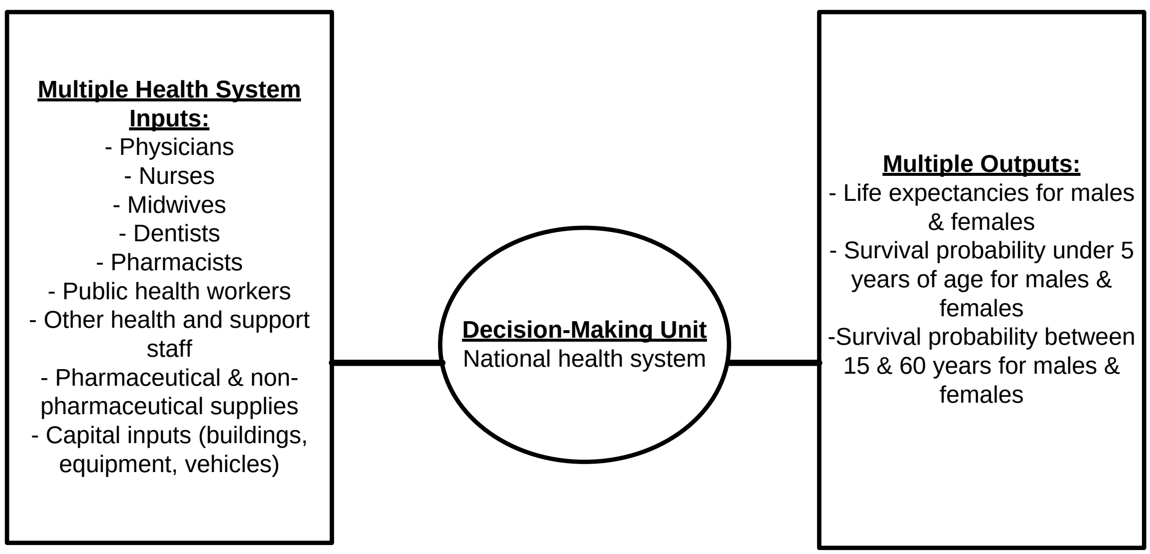

Figure 1: National health system production process

When confronted with such a multiple input-multiple outcome situation, the DEA (a non-parametric linear programming approach) defines efficiency as the ratio of weighted sum of health outputs of a NHS to its weighted sum of health inputs. For example, assuming there are '*n*' Decision Making Units (DMUs) (i.e. countries national health systems), each producing '*s*' different health outputs using 'r' different health inputs, the technical efficiency (TE) of 'k^{th}' country's NHS is measured as (Emrouznejad and Podinovski 2004):

$$TE_k = \frac{\sum_{i=1}^{s} u_i y_{ik}}{\sum_{j=1}^{r} v_j x_{jk}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1).$$

Where:

TE = relative efficiency of the DMU;

s = number of outputs/outcomes produced by the DMU;

r = number of inputs employed by the DMU;

y_i = the i[th] output/outcomes produced by the DMU;

x_j = the j[th] input employed by the DMU;

u_i = s x 1 vector of output/outcome weights;

v_j = r x 1 vector of input weights; and

i=1,…,s and j=1,…,r.

Charnes, Cooper & Rhodes (CCR) (1978) argues that equation 1 can be rewritten in fractional programming form and then transformed into a linear programming (CCR) problem:

$$Max\ TE_k = \sum_{i=1}^{s} u_i y_{ik} \ ....(2)$$

$$subject\ to:$$

$$\sum_{j=1}^{r} v_j x_{jk} = 1$$

$$\sum_{i=1}^{s} u_i y_{im} - \sum_{j=1}^{r} vx \leq 0, m = 1,...,n$$

$$u_i, v_j \geq 0.$$

The *u* and *v* are small but positive quantities. The first constraint guarantees that it is possible to move from a linear programming to a fractional programming as well as from a fractional programming to a linear programming problem.

Equation 2 is constructed under the assumption of constant returns to scale (CRS), and it is only appropriate when all DMUs are running at an optimal scale. Coelli (1996) highlighted that the use of CRS specification when some of the DMUs are not running at optimal scale will result in measures of technical efficiency which are mixed up with scale efficiency. Banker, Charnes and Cooper (BCR) (1984) introduced a variable that captures returns to scale in the CCR model to allow estimation of technical efficiency that is free from the scale efficiency effects. That innovation led to the following BCR model:

$$Max\ TE_k = \sum_{i=1}^{s} u_i y_{ik} - c_k ....(3)$$

$$subject\ to:$$

$$\sum_{j=1}^{r} v_j x_{jk} = 1$$

$$\sum_{i=1}^{s} u_i y_{im} - \sum_{j=1}^{r} vx - c_k < 0, m = 1,..., N.$$

The parameter c_k is unconstrained in sign. It indicates the various possibilities of returns to scale. $c_k > 0$ means increasing returns to scale (IRS); $c_k = 0$ implies constant returns to scale (CRS); and $c_k < 0$ implies decreasing returns to scale (DRS).

Returns to scale refer to how much health outputs or outcomes expand when in the long-run situation all health inputs are increased together, that is, when a country's national health system (NHS) production process is expanded exactly to scale. There are three possibilities (Pindyck and Rubinfeld 1995). Firstly, if doubling of all health system inputs lead to more than doubling of health outputs then the NHS is manifesting IRS. IRS may partly be attributed to indivisibilities of NHS inputs such as fixed health facility (e.g. hospitals, health centres) buildings. A NHS manifesting IRS should expand both outputs and inputs in order to become efficient.

Secondly, outputs or outcomes may double when all inputs are doubled. That is a case of CRS. With CRS, the size of the NHS's operation does not affect the productivity of its inputs. The average and marginal productivity of the NHS's inputs remains constant whether the health system is small or large. Thus, any country's health system exhibiting CRS can be said to be operating at its most productive scale size.

Lastly, health outputs or outcomes may less than double when all inputs in a health system double. This case of DRS is likely to apply to any NHS with large-scale operations. Eventually, difficulties of management associated with the complexities of organizing and running a large-scale operation may lead to decreased productivity of both labour and capital (Pindyck and Rubinfeld 1995). Thus, DRS is likely to be associated with the problems of coordinating and supervising health activities and maintaining amicable line of communication between health systems managers and unmotivated health workers. Or it may result due to challenges related to broad determinants (potable water and hygienic sanitation, food, shelter, income, education, environmental cleanliness, cultural values) of health. In order to operate at the most productive scale size, a NHS manifesting DRS should scale down both outputs and inputs, to become efficient.

Equations 2 (CCR) and 3 (BCR) were estimated using the DEAP version 2.1 Banker, Charnes and Cooper (1984). The former yields constant returns to scale technical efficiency (CRSTE) and the latter produces variable returns to scale technical efficiency (VRSTE) scores (i.e. pure technical efficiency scores). Scale efficiency (SE) is obtained by dividing the CRSTE by VRSTE scores.

Let's assume that under VRSTE we found an average pure technical efficiency score for a specific country's NHS of 75%. It would imply that the health system could have produced, on average, the same amount of outcomes with approximately 25% fewer resources than they actually employed.

Suppose the average scale efficiency (SE) score was 80%; that would imply that the actual scale of production has diverged from the most productive size by about 20%. If VRSTE was greater than SE, then inefficiency would be attributed mainly to inappropriate scale operation, meaning that the NHS have difficulty in finding an appropriate optimal combination between various inputs to produce the desired output.

2.1.1 Illustration of the DEA analysis

Let's postulate that a hypothetical continent called *Afroland* has 10 countries, i.e. Aburi, Kainyu, Kanana, Karimi, Kimathi, Koome, Mukiri, Muturi, Mwendwa, and Nkirote. Each country has a NHS that produces two outcomes, i.e. under age 5 probability of surviving per 1000 (*U5probsurviving*) and adult aged 15-60 probability of survival (*1560probsurviving*) using a single input of health workers (*healthworker*). Table 1 contains data on outcomes and the input for the 10 countries.

The efficiency of each country's NHS in producing the two health outcomes were estimated by dividing each of their outcomes by their input to determine which country's NHS have the highest ratios. The results are contained in the last two columns of Table 1. The higher the ratio of an outcome to input the more efficient a national health system is in producing that outcome. In this example, Kainyu and Karimi NHS had the highest number of *U5probsurviving/healthworker* and *1560probsurviving/healthworker*. Thus, they are more technically efficient than the other eight countries NHS.

By plotting *U5probsurviving/healthworker* against *1560probsurviving/healthworker* for the ten countries national health systems we derive the efficiency or production possibilities frontier (which is a fundamental concept of DEA) depicted in Figure 2.

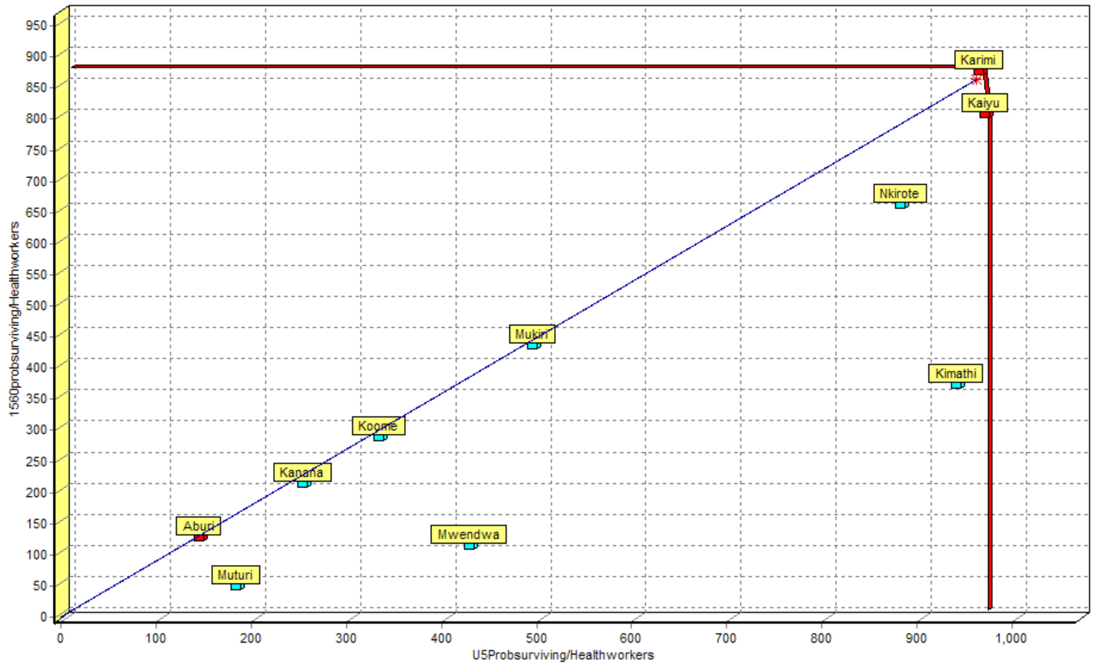

Figure 2: Production possibilities or efficiency frontier graph

The straight lines from Karimi to the *Y* axis (labelled *1560probsurviving/healthworker*) and from Karimi to the *X* axis (labelled *U5probsurviving/healthworker*) represent the efficiency frontier. The efficient frontier, derived from the most efficient countries health systems (i.e. Karimi and Kainyu in our example) in the hypothetical dataset, represents a benchmark of technically best performance that can be achieved from available health input and technology endowment. Consequently, it is used as a threshold against which to measure the performance of all other countries NHS.

The efficiency frontier 'envelops' the inefficient countries NHS within it and clearly shows the relative efficiency of each country's NHS. The NHS for countries like Karimi and Kainyu, which are located on the frontier, is considered 100% technically efficient. Any NHS like Aburi, Muturi, Kanana, Mwendwa, Koome, Mukiri, Nkirote and Kimathi that is below the efficiency frontier is relatively inefficient and is allotted a technical efficiency score of less than 100%.

Aburi NHS, for example, could become efficient if it increased its outputs, in the same proportions, while holding its input level constant, i.e. assuming an output-orientated model. Alternatively, it could become efficient by reducing its input while keeping its outputs the same, i.e. assuming an input-orientated model. Its technical efficiency is equal to the distance from the origin (0) to Aburi divided by the distance from the origin (0) to Karimi, i.e. the point of intersection on the efficiency frontier. This gives Aburi a technical efficiency score of 14.3%; which means that its NHS can potentially increase its outcomes by 85.7% using the current input endowment. Similarly, Kimathi NHS is 96.78% as efficient as Karimi and Kainyu (i.e. the best practise NHS), Nkirote is 90.77%, Mukiri is 50.78%, Mwendwa is 43.78%, Koome is 34.02%, Kanana is 25.58%, and Muturi is 18.34%. These scores, which are contaminated with scale inefficiencies, were estimated assuming CRS.

Frequently NHS production processes are not linear (partly due to indivisibilities, unmotivated labour force, broad determinants of health), and thus it may be appropriate to assume variable returns to scale (VRS). Thus, when we estimated the DEA model assuming VRS, the efficiency scores for various countries were as follows: Karimi = 100%, Koome = 100%, Kanana = 100%, Kainyu = 100%, Mukiri = 100%, Aburi = 99.42%, Kimathi = 96.78%, Nkirote = 90.77%, Muturi = 89.75% and Mwendwa = 86.56%. This implies that if Aburi, Kimathi, Nkirote, Muturi and Mwendwa health systems were to operate efficiently, they are capable of producing their current outcome levels with 0.58%, 3.22%, 9.23%, 10.25% and 13.44% less inputs than they are currently utilizing. Whereas, in the CRS model only Karimi and Kainyu had a 100% efficiency score, in the VRS model five countries health systems (Karimi, Koome, Kanana, Kainyu and Mukiri) achieved a pure technical efficiency score of 100%.

The effect of each country's NHS scale or size on its technical efficiency was assessed in three steps: (i) the model was estimated assuming CRS; (ii) the model was run assuming VRS; and (iii) scale efficiency was obtained by dividing each country's CRS technical efficiency score by its VRS technical efficiency score. For example, Aburi CRS score was 14.3% and VRS score was 99.42%; which led to scale efficiency score of 14.38% (14.3/99.42). Karimi, Kainyu, Kimathi and Nkirote had scale efficiency score of 100%, implying they had an optimal size. Mukiri scored 50.78%, Mwendwa scored 50.58%, Koome scored 34.02%, Kanana scored 25.58%, and Muturi scored 20.43%. Those six countries national health systems (i.e. including Aburi) were scale inefficient since they were not operating at their most productive size for their observed input mix.

2.1.2 Output orientation

All countries in the African continent have unmet need for health promotion, disease prevention, treatment and care. Thus, even though the national health systems managers have control over inputs (especially health workers), there is pressure on all countries national health systems to serve more people with unmet health needs and attain higher health outcomes with their current input endowments. Partly this peer pressure is due to the need to attain the internationally agreed health goals such as the health-related MDGs (United Nations 2000) and the national health development goals. There is evidence that majority of the countries in the African continent are not on track to achieving the health MDGs by 2015 (World Health Organization 2004; The World Bank 2006). Therefore, due to the abovementioned reasons, the output-orientated DEA model was used for the country national health systems efficiency analysis.

2.1.3 Strengths and weaknesses of DEA

We chose to employ DEA in this study due to a number of its strengths, namely: easily handles multiple inputs and outputs without averaging; being a non-parametric technique it does not require a priori functional form; allows inputs and outputs to be measured in any unit; DMUs (NHS) are directly compared against peer best performers; not only identifies the inefficient DMUs but also the magnitudes of inefficiencies among individual inputs; provides information on the output increases and input decreases necessary to make inefficient NHS efficient; technically easy for policy-makers and advisors to grasp; and availability of user-friendly DEA software's for estimating efficiency (Charnes, Cooper and Rhodes 1978; Coelli 1996).

Even though we chose to use DEA, we were fully cognizant of its weaknesses, namely: does not take account of measurement errors because it is an extreme point technique (Charnes, Cooper and Rhodes 1978); does not compare a NHS performance to a theoretical maximum; attributes all poor health outcomes to inefficient use of input (Coelli 1996), where as, it would be due to dearth of broad determinants of health, e.g. security, food, shelter, education, income, water, sanitation, environmental pollution, natural and manmade disasters (World Health Organization 2008).

2.1.4 Variables

The unit of analysis in this study was a country NHS, i.e. the DMU. The country health system DEA model had a total of 13 variables, including six ultimate outputs (or outcomes) and seven inputs. The six outputs for each individual country NHS were: (i) life expectancy at birth (in years) for males; (ii) life expectancy at birth (in years) for females; (iii) probability of surviving (per 1000) under age 5 years males; (iv) probability of surviving (per 1000) under age 5 years females; (v) probability of surviving (per 1000) between ages 15 and 60 years for males; (vi) probability of surviving (per 1000) between ages 15 and 60 years for females.

The seven inputs were: (i) number of physicians; (ii) number of nurses and midwives; (iii) number of dentists; (iv) number of pharmacists; (v) number of public, environmental and community health workers; (vi) number of laboratory technicians and other health workers; and (vii) number of health management and support workers. The choice of output and input variables was guided by past studies (Evans *et al* 2001; Hollingsworth and Wildman 2003) and availability of data in the World Health Report 2006 (World Health Organization 2006a).

2.1.5 Data

The data used in this paper was obtained from the Annex Tables 1, 2 and 4 of the World Health Report 2006 (World Health Organization 2006a). The report contained data for all the 53 countries in the African continent. Those countries were categorized using the World Bank classification of countries as low income and middle income (subdivided into lower middle and upper middle) based on their gross national income (GNI) per capita (The World Bank 2006). The groups are: low income, $825 or less; lower middle income, $826 - $3,255; and upper middle income, $3,256 - $10,065. Out of the 53 countries, 38 were low-income countries and the remaining 15 middle-income countries. Since DEA is applied where there are many fairly similar units each of which has multiple inputs and multiple outputs (Charnes 1994), the analysis was done for the low- and middle-income groups of countries separately.

3. Results and Discussion

3.1 African continent

The African continent has a total of approximately 232,729 physicians; 1,038,170 nurses and midwives; 41,004 dentists; 65,108 pharmacists; 218,624 public, environmental and community health workers; 207,935 laboratory technicians and other health workers; 258,605 health management and support workers (World Health Organization 2006a). When these human resources for health were combined with the other complementary inputs, they produced an average life expectancy at birth of 50 years for Males; average life expectancy at birth of 53 years for females; average probability of survival for males under age 5 years of 857 per 1000; average probability of survival for females under age 5 years of 869 per 1000; average probability of survival for males between ages 15 and 60 years of 535 per 1000; and average probability of survival for females between ages 15 and 60 years of 600 per 1000.

3.2 Low income countries

Table 2 presents the descriptive statistics (sum, median, mean, standard deviation, minimum, maximum) for the 38 low income countries that host 77% of the population in Africa. The low income countries combined have 36% of the physicians; 52% nurses and midwives; 21% dentists; 39% pharmacists; 85% public, environmental and community health workers; 52% laboratory technicians and other health workers; and 50% of the health management and support workers in the continent.

Table 3 presents the output orientated efficiency summary scores for the 38 low-income African countries national health systems. Twelve countries manifested a CRSTE score of one; 15 countries had a VRSTE score of one; and 12 countries had a SE score of one. This means that those countries NHS were 100% relatively efficient compared their groups of peer countries. The remaining countries had CRSTE, VRSTE and SE scores of less than one, implying that they were utilizing their human resources for health inefficiently. However, it is interesting to note that all the inefficient countries had VRSTE (pure efficiency) scores of above 80%. The average VRSTE score was 95% and the mean SE score was 59%; meaning that while on average the degree of inefficiency was only 5% and the magnitude of scale inefficiency was 41%. An average VRSTE score of 95% implies that the inefficient countries could potentially produce 5% more ultimate health outputs with their current levels of human resource endowments. Out of the 38 low-income countries, 12 countries NHS manifested CRS, and 26 countries NHS experienced DRS.

Table 4 provides a summary of output slacks (short-falls) for low-income countries NHS. If the inefficient low income countries could utilize their human resources for health more efficiently, they are capable of increasing the males life expectancy at birth an average of 4.9 years; females life expectancy at birth by an average of 6.1 years; probability of survival for males under age 5 years by an average of 5 per 1000; probability of survival for females under age 5 years by an average of 1 per 1000; probability of survival for males between ages 15 and 60 years by an average of 94.4 per 1000; probability of survival for females between ages 15 and 60 years by an average of 96.9 per 1000.

An alternative strategy for alleviating inefficiencies among countries with excess inputs would be to reduce them, while holding output constant. Table 5 provides a summary of the input slacks for low-income countries. The inefficient low income countries have a total input slack of 31,507 physicians; 194,168 nurses and midwives; 4,769 dentists; 12,776 pharmacists; 40,099 public, environmental and community health workers; 78,299 laboratory technicians and other health workers; 78,542 health management and support workers.

3.3 Middle income countries

Descriptive statistics for the 15 middle-income countries (hosting 23% of the population in Africa) are presented in Table 6. This group of countries have 64% of the physicians; 48% nurses and midwives; 79% dentists; 61% pharmacists; 15% public, environmental and community health workers; 48% laboratory technicians and other health workers; 50% health management and support workers in the African Continent. Even though the middle-income countries host only 23% of the African continent population, they own more than half of the population of health workers in the continent.

Table 7 summarizes output orientated DEA efficiency scores summary for the 15 middle-income countries NHS. Five countries, 9 countries and 5 countries had CRSTE, VRSTE and SE scores of 100%. This means that those countries were relatively technically efficient in relation to their peers. The six countries that had VRSTE of less than 100% were deemed relatively inefficient; their VRSTE score was over 80%. The mean CRSTE score was 44.8% (with much of the inefficiency being attributed to scale inefficiencies) with a standard deviation (STD) of 42.9%. The average VRSTE (i.e. pure efficiency) score was 97.6% with a STD of 3.5%; which means that the variation in pure technical efficiency was quite limited across the countries. Among the middle-income countries, Swaziland had the lowest pure technical efficiency score of 90%. The average SE score was only 49.9% with a STD of 43.2%. This implies that majority of the CRS technical inefficiencies were explained by inefficient sizes of the health production units in the countries concerned.

An average VRSTE score of 97.6% implies the inefficient middle-income countries health systems could potentially produce their current levels of health outcomes with 2.4% less of their current human resource endowments. The excess human resources could potentially be traded to other African countries with a deficit.

Five middle-income countries were found to be manifesting CRS and the remaining 10 countries DRS. CRS implies that a percentage increase in the numbers of human resources for health in a country would elicit an equivalent increase in output levels. From an efficiency standpoint, countries experiencing CRS should continue with the status quo. On the other hand, DRS imply that an increase in the human resource endowment in the countries experiencing DRS would yield a less than proportionate increase in output. Once again, all other factors held constant, inefficiencies in such countries can be reduced through pursuit of strategies geared at either increasing effective demand or reducing inputs.

Table 8 gives a summary of output slacks for middle-income countries in Africa. The inefficient middle income countries could alleviate their inefficiencies through an increase (while holding inputs constant) in the males life expectancy at birth by an average of 6 years; females life expectancy at birth by an average of 8 years; probability of survival for males under age 5 years by an average of 4 per 1000; probability of survival for males between ages 15 and 60 years by an average of 211 per 1000; and probability of survival for females between ages 15 and 60 years by an average of 233 per 1000.

Table 9 summarizes the input slacks for middle-income countries. The inefficient middle income countries have a total input slack of 73,029 physicians; 349,042 nurses and midwives; 15,621 dentists; 19,829 pharmacists; 26,167 public, environmental and community health workers; 67,830 laboratory technicians and other health workers; and 42,122 health management and support workers.

3.4 Implications for policy

Given the very large unmet need for promotive, preventive, curative and rehabilitative care in the Continent, it would not be wise for the low and middle income countries to contemplate addressing inefficiencies through reductions in numbers of human resources for health. Instead, it would be more prudent to increase national health systems ultimate outputs (outcomes) through simultaneous leverage of a number of strategies.

Firstly, use health promotion approaches (e.g. advocacy; health education; communication for behaviour change; information, education and communication; social marketing; social mobilization; investment in policies, actions and infrastructure to address broad determinants of health; building capacity for policy development, leadership, health promotion practice, knowledge transfer and research, and health literacy; regulate and legislate to ensure high level of protection from harm; partner and build alliances with public, private, nongovernmental organizations and civil society to create sustainable actions) to create demand for proven health services and interventions (World Health Organization 2006b).

Secondly, design national health financing system in a manner that assures people in need access to health services and protects households from financial catastrophe and impoverishment through drastic reduction in direct out-of-pocket payments. Overtime the aim of African governments should be to develop prepayment mechanisms, such as social health insurance, tax-based financing of health services, or a mixture of prepayment mechanisms (Carrin and James 2005; World Health Organization 2005b; World Health Organization 2010). A reduction of financial barriers to access through prepaid systems might create demand for under-utilised proven health services and interventions, and ultimately help to increase ultimate health outputs (or outcomes).

Thirdly, support human resources for health performance through development and use of the three groups of levers proposed in the World Health Report 2006 (World Health Organization 2006a):

(a) job-specific levers: development of clear job descriptions, professional norms and codes of conduct, proper matching of skills to tasks, and supervision that is supportive, educational, consistent and helps to solve specific problems;

(b) create basic support systems: ensure appropriate remuneration, adequate information (e.g. medical records, facility level reports, financial accounts, health workforce inventories and payrolls, population-based survey data and scientific literature) and communication, improve infrastructure (decent buildings and functional equipment) and supplies (e.g. clean water, adequate lighting, heating, drugs and other supplies);

(c) create an enabling environment: promote lifelong learning (intermittent training courses, continuous professional development, web-based training and access to scientific literature), establish effective team management, and combine responsibility with accountability.

In case for some other reason, the inefficient countries decide to alleviate inefficiencies through input reduction, Tables 5 and 9 provides a summary of input targets that low and middle income countries should aim at.

3.5 Areas for further research

There is need for more research in the African Continent on the following aspects:

(a) Estimate technical and allocative efficiency of national health systems with the full range of inputs and outputs.

(b) Employ DEA-type Malmquist productivity index (Zere, Addison and McIntyre 2000) to analyze total factor productivity, efficiency change, and technological progress in the national health systems of countries of the African continent over a number of years.

(c) Undertake further more detailed investigations among the best performing NHS with a view to identifying and documenting practices and lessons that could be copied or emulated by inefficient national health systems to improve their performance.

(d) Conduct health facility level efficiency analysis to guide the health decision-makers on ameliorative actions to take at micro level to address inefficiencies in individual hospitals (Kirigia, Lambo and Sambo 2001; Jacobs 2001; White, Fache and Ozcan 1996; Kirigia, Emrouznejad and Sambo 2002; Chang 1998; Wan et al 2002; Masiye et al 2002; Osei et al 2005), health centres (Kirigia, Sambo and Scheel 2001; Guiffrida and Gravelle 2001; Zavras et al 2002; Kirigia et al 2004; Renner et al 2005), dispensaries, community-based public health programmes.

3.6 Limitation of the study

The three main weakness of our study were:

(a) We used only one category of input, that is human resources for health, due to dearth of data on other health systems inputs such as medicines, non-pharmaceutical supplies, utilities (water, electricity, gas, telephone), capital inputs (buildings, equipment, beds, vehicles), operating and maintenance expenses, and community inputs.

(b) According to the World Health Report 2006 (World Health Organization 2006a), there are four dimensions of health workforce performance, namely: availability (distribution and attendance of existing workers); competence (technical knowledge, skills and behaviours'); responsiveness (treating people decently, regardless of whether or not their health improves or who they are); and productivity (producing maximum effective health services and health outcomes possible given the existing stock of health workers). Our study addresses only the latter dimension.

(c) Apart from health systems there are many other factors that impact on health status of populations, e.g. education, employment, food, income, shelter, water, sanitation, and security (World Health Organization 2008). Our study did not include those factors.

4. Conclusion

This study has estimated the technical and scale efficiency of African Continent national health systems in utilizing human resources for health to produce various ultimate health outputs (or outcomes); identified the magnitudes of shortfalls in ultimate health outputs and excess human resources for health in individual countries; identified the best performers whose practise could be emulated by others; and highlighted the implications for policy to health sector policy-makers.

Out of the 38 low-income African countries, 12 countries national health systems manifested a CRSTE score of 100%; 15 countries had a VRSTE score of 100%; and 12 countries had a SE score of one. The average VRSTE score was 95% and the mean SE score was 59%; meaning that while on average the degree of inefficiency was only 5%, the magnitude of scale inefficiency was 41%.

Of the 15 middle-income countries, 5 countries, 9 countries and 5 countries had CRSTE, VRSTE and SE scores of 100%. Ten countries, six countries and 10 countries had CRSTE, VRSTE and SE scores of less than 100%; and thus, they were deemed inefficient. The average VRSTE (i.e. pure efficiency) score was 97.6%. The average SE score was 49.9%.

There is large unmet need for health and health-related services among countries of the African Continent. Thus, it would not be advisable for health policy-makers address NHS inefficiencies through reduction in excess human resources for health. Instead, it would be more prudent for them to leverage health promotion approaches and universal access prepaid (tax-based, insurance-based or mixtures) health financing systems to create demand for under utilized health services/interventions with a view to increasing ultimate health outputs to efficient target levels. This is in line with the recent decision of the Ministers of Health of the African Union to institutionalize equity and efficiency monitoring within their national health information management systems.

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Table 1: Illustration of DEA analysis using a hypothetical example of ten countries national health systems

Country	U5probsurviving (A)	1560probsurviving (B)	Healthworkers (C)	U5probsurviving/ healthworker D=(A/C)	1560probsurviving/ healthworker E=(B/C)
Aburi	960	862	7	137	123
Muturi	884	222	5	177	44
Nkirote	875	658	1	875	658
Kainyu	964	802	1	964	802
Koome	981	853	3	327	284
Kanana	985	836	4	246	209
Karimi	958	871	1	958	871
Kimathi	933	368	1	933	368
Mwendwa	844	218	2	422	109
Mukiri	975	862	2	488	431

Table 2: Descriptive statistics (sum, median, mean, standard deviation, minimum, maximum) for low income countries in Africa

Variables	Sum	Median	Mean	STD	Minimum	Maximum
Outputs						
Life expectancy at birth (in years) for males		46	47	47	37	62
Life expectancy at birth (in years) for females		48	50	50	34	67
Probability of surviving (per 1000) under age 5 years for males		842	829	829	704	924
Probability of surviving (per 1000) under age 5 years for females		849	924	844	731	936
Probability of surviving (per 1000) between ages 15 and 60 years for males		507	502	502	143	746
Probability of surviving (per 1000) between ages 15 and 60 years for females		570	567	567	151	818
Inputs						
Number of physicians	84,539	554	2,225	2,225	81	34,923
Number of nurses and midwives	535,642	5,241	14,096	14,096	308	210,306
Number of dentists	8,691	51	229	229	0	2,482
Number of pharmacists	25,201	155	663	663	0	6,344
Number of public, environmental and community health workers	184,868	507	4,865	4,865	0	115,761
Number of laboratory technicians and other health workers	107,700	755	2,834	2,834	0	31,242
Number of health management and support workers	130,280	671	3,428	3,428	0	35,374

Table 3: Output oriented efficiency summary scores for low income countries

Country (DMUs)	*CRSTE*	*VRSTE*	*SCALE*	*Returns*
Angola	1.00	1.00	1.00	CRS
Benin	0.98	1.00	0.98	DRS
Burkina Faso	0.26	0.87	0.30	DRS
Burundi	0.65	0.90	0.73	DRS
Cameroon	0.12	0.98	0.12	DRS
CAR	0.86	0.96	0.90	DRS
Chad	0.63	0.90	0.70	DRS
Comoros	1.00	1.00	1.00	CRS
Congo	0.91	1.00	0.91	DRS
Cote D'Ivoire	0.12	0.90	0.14	DRS
DRC	1.00	1.00	1.00	CRS
Eritrea	1.00	1.00	1.00	CRS
Ethiopia	1.00	1.00	1.00	CRS
Gambia	0.76	0.95	0.81	DRS
Ghana	1.00	1.00	1.00	CRS
Guinea	0.31	0.91	0.34	DRS
Guinea Bissau	1.00	1.00	1.00	CRS
Kenya	0.05	0.95	0.05	DRS
Lesotho	1.00	1.00	1.00	CRS
Liberia	0.82	0.87	0.94	DRS
Madagascar	0.16	0.94	0.17	DRS
Malawi	1.00	1.00	1.00	CRS
Mali	0.17	0.85	0.20	DRS
Mauritania	0.43	0.95	0.46	DRS
Mozambique	0.17	0.92	0.19	DRS
Niger	0.63	0.86	0.74	DRS
Nigeria	0.03	1.00	0.03	DRS
Rwanda	0.40	0.87	0.46	DRS
STP	1.00	1.00	1.00	CRS
Senegal	0.31	0.93	0.33	DRS
Sierra Leone	1.00	1.00	1.00	CRS
Somali	1.00	1.00	1.00	CRS
Sudan	0.02	0.98	0.02	DRS
Togo	0.51	0.94	0.54	DRS
Uganda	0.06	0.93	0.06	DRS
Tanzania	0.16	0.94	0.17	DRS
Zambia	0.07	0.88	0.08	DRS
Zimbabwe	0.10	0.94	0.11	DRS
Median	***0.63***	***0.95***	***0.71***	
Mean	***0.57***	***0.95***	***0.59***	
STDEV	***0.39***	***0.05***	***0.39***	
Minimum	***0.02***	***0.85***	***0.02***	
Maximum	***1.00***	***1.00***	***1.00***	

Note: crste = technical efficiency from CRS DEA; vrste = technical efficiency from VRS DEA; scale =

scale efficiency, i.e. crste/vrste.

Table 4: Summary of output slacks for low income countries

Country	Life expectancy at birth (in years) for males	Life expectancy at birth (in years) for females	Probability of surviving (per 1000) under age 5 years for males	Probability of surviving (per 1000) under age 5 years for females	Probability of surviving (per 1000) between ages 15 and 60 years for males	Probability of surviving (per 1000) between ages 15 and 60 years for females
Angola	0.0	0.0	0.0	0.0	0.0	0.0
Benin	0.0	0.0	0.0	0.0	0.0	0.0
Burkina Faso	8.2	12.0	0.0	9.7	141.5	142.5
Burundi	5.3	3.6	2.5	0.0	72.5	0.0
Cameroon	3.3	6.1	4.9	0.0	63.1	127.0
CAR	9.4	10.8	12.3	0.0	239.8	262.3
Chad	3.0	3.5	17.3	0.0	3.9	0.0
Comoros	0.0	0.0	0.0	0.0	0.0	0.0
Congo	0.0	1.1	0.0	2.1	0.0	3.9
Cote D'Ivoire	16.2	14.5	58.4	0.0	282.5	259.5
DRC	0.0	0.0	0.0	0.0	0.0	0.0
Eritrea	0.0	0.0	0.0	0.0	0.0	0.0
Ethiopia	0.0	0.0	0.0	0.0	0.0	0.0
Gambia	3.8	4.6	2.8	0.0	52.2	38.5
Ghana	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	4.8	6.5	0.0	1.0	46.4	68.9
Guinea Bissau	0.0	0.0	0.0	0.0	0.0	0.0
Kenya	8.4	14.4	8.0	0.0	196.0	294.3
Lesotho	0.0	0.0	0.0	0.0	0.0	0.0
Liberia	7.3	5.2	24.4	0.0	86.5	29.0
Madagascar	3.7	4.5	0.0	0.3	44.5	44.5
Malawi	0.0	0.0	0.0	0.0	0.0	0.0
Mali	10.0	11.5	14.0	0.0	143.3	125.5
Mauritania	3.8	3.5	8.1	0.0	32.1	20.5
Mozambique	13.9	16.8	0.0	7.6	338.6	325.4
Niger	3.7	7.3	0.0	15.7	10.0	30.4
Nigeria	0.0	0.0	0.0	0.0	0.0	0.0
Rwanda	8.7	9.7	5.2	0.0	133.6	104.9
STP	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	3.9	5.7	0.0	2.3	55.4	52.1
Sierra Leone	0.0	0.0	0.0	0.0	0.0	0.0
Somali	0.0	0.0	0.0	0.0	0.0	0.0
Sudan	4.8	5.7	2.3	0.0	122.7	106.8
Togo	3.6	3.6	10.9	0.0	38.8	26.0
Uganda	10.2	12.0	0.9	0.0	233.8	220.6
Tanzania	12.2	15.1	6.0	0.0	270.1	313.4
Zambia	16.7	21.7	7.2	0.0	387.2	428.7
Zimbabwe	22.6	30.8	4.0	0.0	593.7	657.2
Median	***3.7***	***4.0***	***0.0***	***0.0***	***41.7***	***27.5***
Mean	***4.9***	***6.1***	***5.0***	***1.0***	***94.4***	***96.9***

STDEV	***5.7***	***7.2***	***10.6***	***3.2***	***136.0***	***149.1***
Minimum	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
Maximum	***22.6***	***30.8***	***58.4***	***15.7***	***593.7***	***657.2***

Table 5: Summary of input slacks for low income countries

Country	Doctors	Nurses+ Midwives	Dentists	Pharmacists	Public, environmental and community health workers	Laboratory technicians and other health workers	Health Management+ Support workers
Angola	-	-	-	-	-	-	-
Benin	-	-	-	-	-	-	-
Burkina Faso	674	6,662	29	302	1,279	1,327	53
Burundi	70	-	-	13	466	1,049	1,718
Cameroon	1,587	17,726	32	245	-	-	-
CAR	159	-	2	-	51	114	-
Chad	256	1,922	-	-	245	213	1,284
Comoros	-	-	-	-	-	-	-
Congo	532	23	-	20	62	1,099	438
Cote D'Ivoire	1,966	9,592	310	974	97	1,265	1,835
DRC	-	-	-	-	-	-	-
Eritrea	-	-	-	-	-	-	-
Ethiopia	-	-	-	-	-	-	-
Gambia	41	1,293	14	7	943	30	119
Ghana	-	-	-	-	-	-	-
Guinea	872	4,233	31	489	170	213	239
Guinea Bissau	-	-	-	-	-	-	-
Kenya	4,391	36,525	1,311	3,053	6,438	12,538	1,525
Lesotho	-	-	-	-	-	-	-
Liberia	19	494	-	-	3	471	304
Madagascar	5,086	5,073	381	134	457	630	5,764
Malawi	-	-	-	-	-	-	-
Mali	938	6,523	55	310	1,468	569	380
Mauritania	198	1,305	35	40	371	82	784
Mozambique	399	5,595	130	577	506	2,502	9,245
Niger	225	-	3	-	81	91	327
Nigeria	-	-	-	-	-	-	-
Rwanda	224	1,879	-	196	12,025	345	916
STP	-	-	-	-	-	-	-
Senegal	479	2,699	68	44	647	698	292

Sierra Leone	-	-	-	-	-	-	-
Somali	-	-	-	-	-	-	-
Sudan	7,437	30,908	1,053	3,517	8,636	11,710	35,102
Togo	33	83	-	42	683	675	684
Uganda	2,094	18,737	334	647	984	5,247	6,227
Tanzania	707	12,704	238	324	1,773	31,170	417
Zambia	1,149	21,422	462	998	969	4,673	10,581
Zimbabwe	1,971	8,769	281	842	1,745	1,588	309
Total	***31,507***	***194,168***	***4,769***	***12,776***	***40,099***	***78,299***	***78,542***
Median	***179***	***289***	***-***	***10***	***89***	***163***	***266***
Mean	***829***	***5,110***	***126***	***336***	***1,055***	***2,061***	***2,067***
STD	***1,592***	***8,902***	***283***	***761***	***2,509***	***5,625***	***6,046***
Minimum	-	-	-	-	-	-	-
Maximum	7,437	36,525	1,311	3,517	12,025	31,170	35,102

Table 6: Descriptive statistics for the middle income countries

Variables	*Sum*	*Median*	*Mean*	*STDEV*	*Minimum*	*Maximum*
Life expectancy at birth (in years) for males		66	58.2	12.3	36	70
Life expectancy at birth (in years) for females		70	62.1	13.9	39	78
Probability of surviving (per 1000) under age 5 years for males		953	925.6	59.8	787	986
Probability of surviving (per 1000) under age 5 years for females		961	934.1	54.6	805	987
Probability of surviving (per 1000) between ages 15 and 60 years for males		761	617.1	238.1	177	847
Probability of surviving (per 1000) between ages 15 and 60 years for females		842	685.8	247.8	230	917
Number of physicians	148,190	715	9,879	14,535	121	38485
Number of nurses and midwives	502,528	6,828	33,502	57,004	271	184459
Number of dentists	32,313	113	2,154	3,506	10	9917
Number of pharmacists	39,907	333	2,660	3,853	18	12521
Number of public, environmental and community health workers	33,756	474	2,250	3,693	0	11,689
Number of laboratory technicians and other health workers	100,235	458	6,682	12,269	0	42,494
Number of health management and support workers	128,325	829	8,555	16,457	0	60,882

Table 7: Output orientated DEA efficiency scores summary for middle income countries

Country	*Crste*	*vrste*	*scale*	*Returns*
Algeria	0.015	1	0.015	drs
Botswana	0.396	0.917	0.432	drs
Cape Verde	1	1	1	Crs
Djibouti	1	1	1	Crs
Egypt	0.007	0.979	0.008	drs
Equatorial Guinea	1	1	1	Crs
Gabon	0.614	0.939	0.654	Drs
Libyan Arab Jamahiriya	1	1	1	Crs
Mauritius	0.239	1	0.239	drs
Morocco	0.076	1	0.076	Drs
Namibia	0.224	0.955	0.235	Drs
Seychelles	1	1	1	Crs
South Africa	0.005	0.95	0.005	drs
Swaziland	0.707	0.9	0.785	Drs
Tunisia	0.033	1	0.033	drs
Median	***0.396***	***1***	***0.432***	
Mean	***0.488***	***0.976***	***0.499***	
STDEV	***0.429***	***0.035***	***0.432***	
Minimum	***0.005***	***0.9***	***0.005***	
Maximum	***1***	***1***	***1***	

Note: crste = technical efficiency from CRS DEA;
vrste = technical efficiency from VRS DEA;
scale = scale efficiency = crste/vrste

Table 8: Summary of output slacks for middle income countries

Country	Life expectancy at birth (in years) for males	Life expectancy at birth (in years) for females	Probability of surviving (per 1000) under age 5 years for males	Probability of surviving (per 1000) under age 5 years for females	Probability of surviving (per 1000) between ages 15 and 60 years for males	Probability of surviving (per 1000) between ages 15 and 60 years for females
Algeria	0.0	0.0	0.0	0.0	0.0	0.0
Botswana	23.4	29.6	12.9	0.0	550.0	628.3
Cape Verde	0.0	0.0	0.0	0.0	0.0	0.0
Djibouti	0.0	0.0	0.0	0.0	0.0	0.0
Egypt	0.2	5.9	0.0	1.0	0.0	51.5
Equatorial Guinea	0.0	0.0	0.0	0.0	0.0	0.0
Gabon	8.4	12.8	21.8	0.0	148.6	199.6
Libya	0.0	0.0	0.0	0.0	0.0	0.0
Mauritius	0.0	0.0	0.0	0.0	0.0	0.0
Morocco	0.0	0.0	0.0	0.0	0.0	0.0
Namibia	12.6	20.4	12.6	0.0	294.9	382.2
Seychelles	0.0	0.0	0.0	0.0	0.0	0.0
South Africa	17.5	26.4	9.5	0.0	417.6	494.0
Swaziland	23.0	25.1	9.5	0.0	537.4	533.8
Tunisia	0.0	0.0	0.0	0.0	0.0	0.0
Median	***0***	***0***	***0***	***0***	***0***	***0***
Mean	***6***	***8***	***4***	***0***	***130***	***153***
STDEV	***9***	***12***	***7***	***0***	***211***	***233***
Minimum	***0***	***0***	***0***	***0***	***0***	***0***
Maximum	***23***	***30***	***22***	***1***	***550***	***628***

Table 9: Summary of input slacks for middle income countries

Country	Doctors	Nurses+ Midwives	Dentists	Pharmacists	Public, Environmental and community health workers	Laboratory Technicians and other health workers	Health Management+ Support workers
Algeria	0	0	0	0	0	0	0
Botswana	520	4,270	0	284	97	165	779
Cape Verde	0	0	0	0	0	0	0
Djibouti	0	0	0	0	0	0	0
Egypt	37,087	142,624	9,701	6,820	9,470	23,630	5,167
Equatorial Guinea	0	0	0	0	0	0	0
Gabon	237	6,416	0	8	74	174	119
Libya	0	0	0	0	0	0	0
Mauritius	0	0	0	0	0	0	0
Morocco	0	0	0	0	0	0	0
Namibia	477	5,511	19	227	163	984	7,782
Seychelles	0	0	0	0	0	0	0
South Africa	34,708	183,825	5,901	12,460	11,612	42,400	28,005
Swaziland	0	6,396	0	30	4,751	477	270
Tunisia	0	0	0	0	0	0	0
Sum	**73,029**	**349,042**	**15,621**	**19,829**	**26,167**	**67,830**	**42,122**
Median	***0***	***0***	***0***	***0***	***0***	***0***	***0***
Mean	***4,869***	***23,269***	***1,041***	***1,322***	***1,744***	***4,522***	***2,808***
STDEV	***12,607***	***57,409***	***2,837***	***3,542***	***3,794***	***12,103***	***7,338***
Minimum	0	0	0	0	0	0	0
Maximum	***37,087***	***183,825***	***9,701***	***12,460***	***11,612***	***42,400***	***28,005***