Benchmarking Supply Chains for Better Performance

Ananth Iyer, Gemma Berenguer, Prashant Yadav, and Amanda Glassman

Abstract

Donors play a significant role in funding medicines and other commodities in global health. Of the approximately US $28.2 billion spent by donors in 2010, approximately 40% went towards medicines, vaccines and other health commodities, mainly in sub-Saharan Africa. The efficiency of this spend is therefore of great concern, given the large variability in supply chain costs.

In this paper, we develop quantitative estimates of the feasible opportunity for efficiency improvement in country level reproductive health supply chains in sub-Saharan Africa. We used Data Envelopment Analysis (DEA) to identify peer groups of countries in the region (whose inputs and outputs are similar) that could share best practice to deliver efficiency improvements. Our first analysis suggested an opportunity to improve contraceptive prevalence rate (CPR) by on average 61% and timeliness by 32% for the set of initially classified as inefficient countries, which corresponds to 84% of the countries studied. We then identified country specific environmental variables that could affect outcomes, and estimated their impact on managerial efficiency. This analysis suggested that the observed output CPR values should be adjusted on average by a factor of 5.18 and the observed timeliness should be adjusted by an average factor of 0.86 – suggesting that environmental factors have a significant impact on health outcomes. Our adjusted outputs continue to suggest an opportunity to improve CPR by 56% and timeliness by 26% for the set of inefficient countries, which now corresponds to 75% of the countries.

Thus, despite the impact of environmental variables, there continues to be an opportunity to improve both health outcomes and supply chain performance through process improvement and benchmarking. Finally, we document a significant relationship between donor funding fragmentation and efficiency and suggest steps to mitigate that effect. Our analysis suggests a set of concrete steps to improve supply chains for global health products along with an estimate of their impact.

CGD is grateful for contributions from its funders in support of this work.

Ananth Iyer, Gemma Berenguer, Prashant Yadav., and Amanda Glassman. 2015. "Benchmarking Supply Chains for Better Performance." CGD Policy Paper 57. Washington DC: Center for Global Development.
http://www.cgdev.org/publication/benchmarking-supply-chains-better-performance

Center for Global Development
2055 L Street
Fifth Floor
Washington DC 20036
202-416-4000
www.cgdev.org

Center for Global Development
Independent research and practical ideas for global prosperity

CGD Policy Paper 057
March 2015

Contents

Introduction

Donors play a significant role in funding medicines and other commodities in global health. Of the approximately US $28.2 billion spent on global health by donors in 2010[i], approximately 40% went towards medicines, vaccines and other health commodities. In Sub-Saharan Africa, where the resource constraints are the severest and the disease burden the highest; approximately US $8.1 billion was spent on health programs in 2010. Funding from donors comes with requirements of accountability to ensure that donors can, in turn, assure their funding sources of both deployment and results as promised, and of efficiency of usage and delivery, thus ensuring minimal resource wastage. In such an environment, imagine that one country's supply chain costs are 45% of product cost, while another claims its costs are only 15%. Is it time to berate the former and praise the latter, or should one consider the contexts within which such claims are made? How much do attributes like roads, air links, landlocked status, communications, workforce, warehouses or governance matter for supply chain efficiency? And how should we adjust for differing country attributes when determining performance goals for the supply chain?

Our goal is to develop quantitative estimates of the feasible extent of efficiency improvement in country level reproductive health supply chains in Sub-Saharan Africa. We use a tool, termed Data Envelopment Analysis (DEA), to identify peer groups of countries in the region (whose inputs and outputs are close) that can share best practices to deliver efficiency improvements. We also identify country specific environmental variables that impact outcomes and estimate their impact on managerial efficiency. Finally we document a significant relationship between donor funding fragmentation and efficiency and suggest steps to mitigate that effect. Our analysis thus suggests a concrete set of steps to improve global health supply chains along with an estimate of their impact. Our next steps are focused on implementing processes to improve performance.

Improvement using Benchmarking Tools

Benchmarking is a commonly used approach to identify process improvements in industry, both public and private. Data Envelopment Analysis (DEA) is a benchmarking tool that has a long tradition for measuring system wide productivity when many different inputs and outputs are involved. It best reflects relative productivity i.e., productivity performance relative to others in the dataset rather than some theoretical maximum. It also reflects the concept of global improvement in which some performance indicators might be worse off in order to achieve this overall improvement. This is due to the fact that DEA employs a composite of weighted outputs and weighted inputs indicators that replicate the level of complexity required to achieve improvement in practice.

DEA has been used in the literature as a benchmarking technique in different context areas. Past work in the private sector include studies in the automotive industry (Iyer et al. 2013), in assessing primary schools (Mancebo and Molinero 2000) and in the banking industry (Liu and Tone 2008). DEA related techniques have been used to measure health care delivery efficiency and benchmark and evaluate hospitals (Gravelle et al. 2003) and nursing homes (Bjorkgreen et al. 2001). In global health care, a study using DEA to assess the efficiency of hospitals in Zambia demonstrated that costs could be lowered by up to 36% without compromising output (Masiye 2007). Yadav et al. (2012) summarize opportunities to improve in health supply chains despite its differences from private sector supply chains. Following this direction, we believe that there is an opportunity to use techniques from business supply chains to generate efficiencies in low- and middle-income countries' health care supply chains, namely benchmarking performance across countries and commodity supply chains.

While benchmarking supply chains might be a useful exercise, it often generates concern that supply chains in countries with poor physical or technological infrastructure would get penalized for factors beyond their control. First, the level of improvement that should be expected for a supply chain based in a specific region should reflect the characteristics of that region in terms of per capita GDP, healthcare structure, logistics infrastructure to name a few characteristics. Second, observed performance should reflect relevant performance measures that include both supply chain focused and outcome focused measures. For example, improving a supply chain's overall shipping efficiency may require coordination between different transportation modes and suggest more expensive deliveries for a specific transportation mode such as an increased use of less-than-truckload shipments. This might increase transport cost but also increase availability, thus improving health outcomes.

DEA: A quick primer

The basic concept of DEA was described by Farrell (1957) and Charnes, Cooper and Rhodes (CCR) (1978). The idea in CCR (1978) was to use techniques of linear programming to permit individual firms or decision making units (DMUs) to choose weights for inputs and outputs that would maximize their productivity while recording its impact on other DMUs. Once such an analysis is done across DMUs, the results generate an efficient frontier of performance. This frontier suggests different combinations of inputs and outputs that can enable performance on the frontier i.e., generating the maximum possible level of productivity. In effect, a line joining the set of inputs and outputs between pairs of DMUs generates possible "virtual" units that can simulate the expected output performance for a given input level. Any unit that does not lie on this frontier would be considered inefficient relative to others. Along with such a measure of inefficiency comes an identification of a reference set – i.e., others close to this inefficient DMU that are on the frontier. This identification of peer supply chains enables smaller sets of supply chains, with close sets of inputs and outputs, to share best practices and thus improve performance.

To illustrate this idea, consider Figure 1 below which shows five different supply chains, each with an input parameter (such as cost or man-hours) and an output parameter (such as number of products manufactured or customers served). Spending a lot on manufacturing products should mean more units produced. On the other hand, spending less on the manufacturing process should imply fewer products produced. Of course, supply chains that spend a lot of money to produce very little amount of product will fall below the efficient frontier.

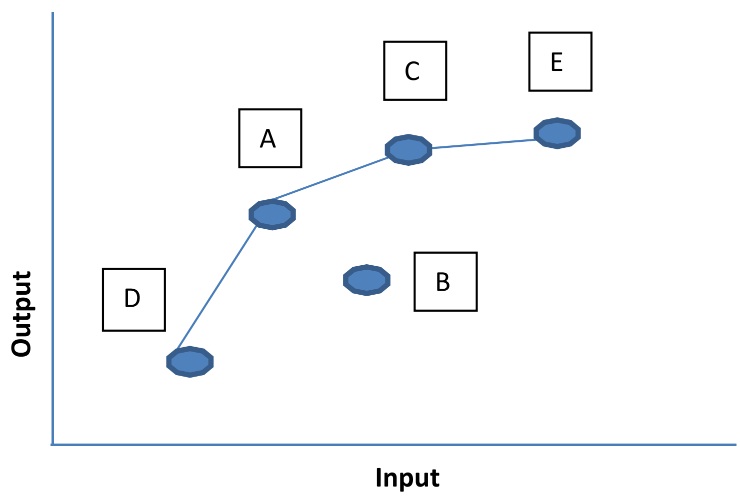


Figure 1 illustrates the concept behind Data Envelopment Analysis (DEA)

From the DEA plot above, we can observe that supply chain B is not on the efficient frontier. Given this supply chain's input level, supply chains A and C are the closest in the graph and so its reference set. Thus, deploying supply chain B the way A and C are operating, could result in an improvement in the output and thus higher productivity. In other words, the analysis suggests both a measure of relative productivity and a set of "peer"

DMUs that can be used as benchmarks to share best practices and thus deliver performance improvement.

Improving Supply Chain Performance

DEA analysis enables supply chains to be paired to identify performance improvement opportunities. But the Lean Supply Chain philosophy suggests the need to target an improvement rate that results in steady improvements over time. This approach to continuous improvement is called "kaizen" and provides a steady stream of improvements. There are many examples where a 5% cost reduction per year is the norm (see examples from the automobile industry). But such a steady improvement also requires continual sharing of best practices in an effort to deliver improvements.

Note that these cost reductions are effectively a 5% budget increase on an annual basis – something that can immediately be deployed to deliver best healthcare outcomes. We suggest that such kaizen thinking can be fostered in healthcare supply chains – thus encouraging identification of improvements and celebrating them as successes rather than as instances that are demonized as past poor practices.

We suggest a benchmarking approach that (a) generates relative productivity measures across countries in Sub-Saharan Africa that include both health outcomes and supply chain performance measures, (b) adjusts for in country parameters and identifies their importance thus suggesting ways to improve supply chains by improving these values, and (c) pairs countries up with others that offer better performance so that learning can be enables in small groups. We suggest that these country groups might be effective venues for supply chain performance improvement.

Our Dataset

We illustrate our approach by focusing on supply chains for Reproductive Health commodities. International donor assistance is the major funding stream for Reproductive Health programs in developing countries, especially in Sub-Saharan Africa. In 2012 the donor assistance for Family Planning and Reproductive Health was US $1.3 billion. For the supply chain for reproductive health commodities we explore how funding, attributes of supply chains and program performance are associated. The latter measures are proxies for the "productivity" of the supply chain and the program itself.

One metric of success in family planning is measured as Contraceptive Prevalence Rate (CPR) for modern methods[ii] – a measure that is obtained from the World Contraceptive Use 2012 data set[iii]. These are model-based estimates based on all available CPR data including Demographic and Health Surveys (DHS), Fertility and Family Surveys (FFS), Reproductive Health Surveys (RHS), Multiple Indicator Cluster Surveys (MICS), and other international survey programs and national surveys. This measure varies across countries in Sub-Saharan Africa as seen in Figure 2. The CPR values range from 3.6% for Chad to 63.5% in South Africa. We have selected CPR among a mix of measurements of fertility control because there is a reasonably complete current data set across countries and it directly captures the usage and availability of the delivered products.

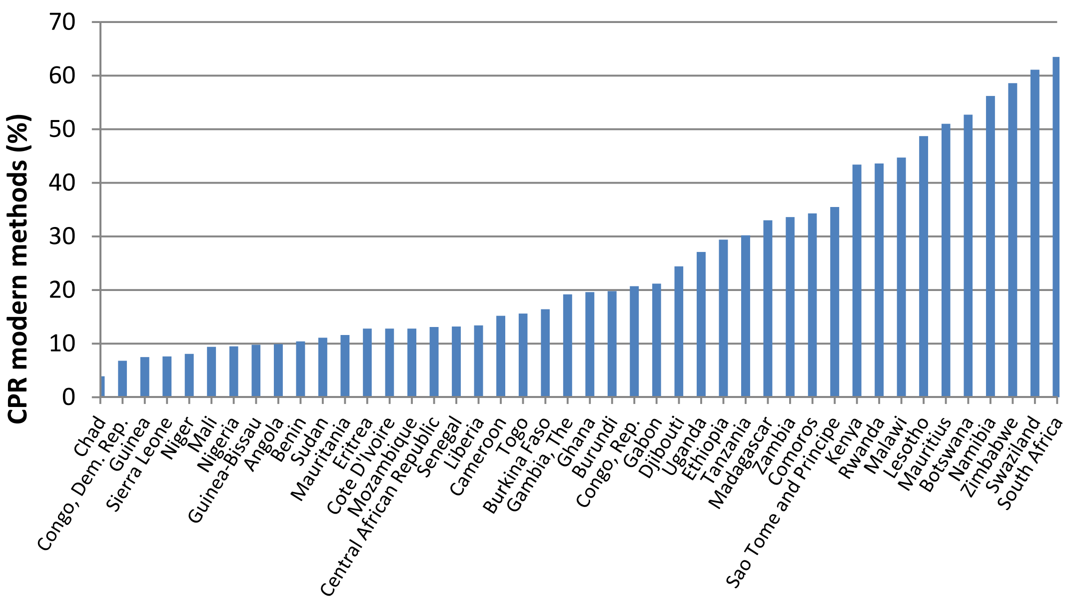


Figure 2 shows the Contraceptive Prevalence Rate (CPR) for countries in our dataset

Similarly, data from the Reproductive Health Interchange (RHI) database reconciled with data from the USAID Global Supply Chain data set[iv] allows us to obtain accurate timeliness values (in number of days) of the orders of reproductive health products delivered in 2012, assigning large values of timeliness to the countries with low average order lead times[v] and lower values to those countries with large order lead times. The output measure of timeliness is a standard measure in supply chain management, where a higher value reflects lower lead time. Lead time is known to impact required working capital, inventory levels and order variability in supply chains because long lead times imply that supply chains need to forecast demands for longer periods of time increasing the risk of stock outs. A focus on increasing timeliness will enable better matching of reproductive health product inventories with demand, thus improving outcomes. This measure, that reflects the performance of the supply chain, substantially varies by country – with values ranging from 0.5 for the Congo Democratic Republic to 74 for Comoros (Figure 3).

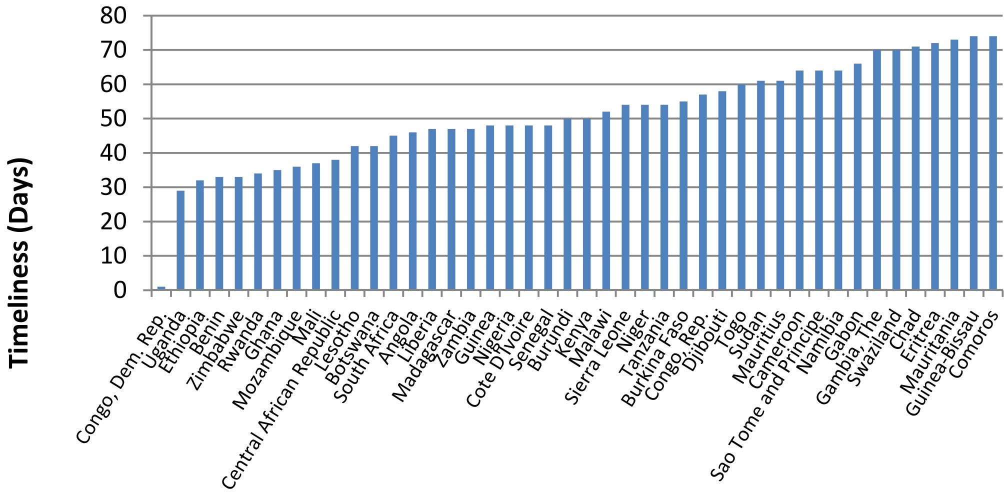


Figure 3 shows the timeliness of shipments across countries

Another perspective brings these variables together with funding to explore how funding relates to timeliness and program performance (CPR). For example, a ratio of the observed output variables (timeliness and CPR) divided by the funding level (landed costs per capita[vi]) can generate an estimate of productivity. The two graphs below show the rankings of the countries under this measure, where Figure 4 plots the range of CPR per unit of landed costs per capita and Figure 5 similarly uses timeliness per unit of landed costs per capita. Notice the large range of values for the productivity measures as well as the different locations of some of the countries. While the Congo Democratic Republic shows up at the low end for most of the metrics, some countries switch positions dramatically. For example, South Africa appears at the high end for CPR (Figure 2), the lower 50% for timeliness (Figure 3), low for productivity with respect to timeliness (Figure 5) and the upper end for CPR productivity (Figure 4). Sierra Leone appears to have low CPR, middle of the road for timeliness but the upper 50% for timeliness productivity.

Yet simple associations are not able to account for differing contextual factors. For example, how should the differing infrastructure in Sierra Leone versus in South Africa be reflected in the analysis and how should the conditions in the Congo Democratic Republic be included in figuring out their productivity? What factors should be incorporated in adjusting the observed performance?

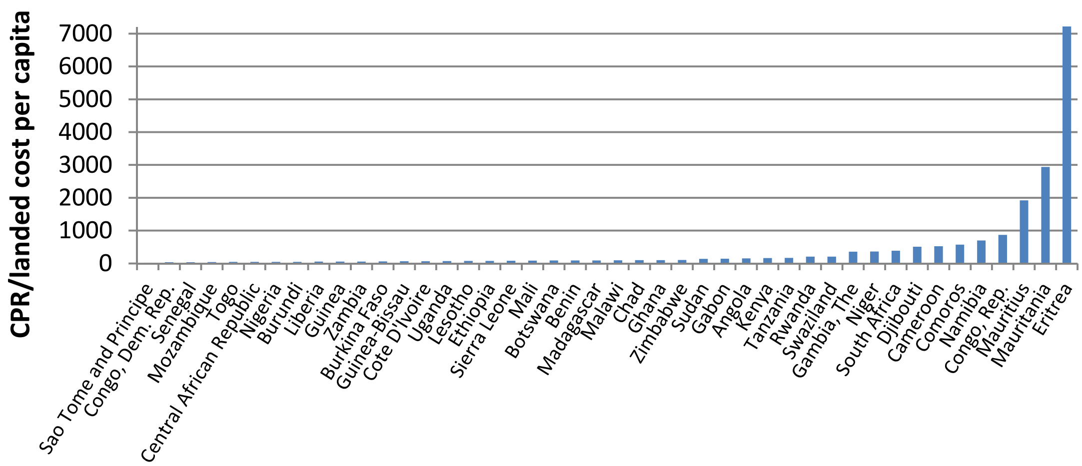


Figure 4 shows the CPR per unit/landed cost per capita (in US$) for countries in our dataset

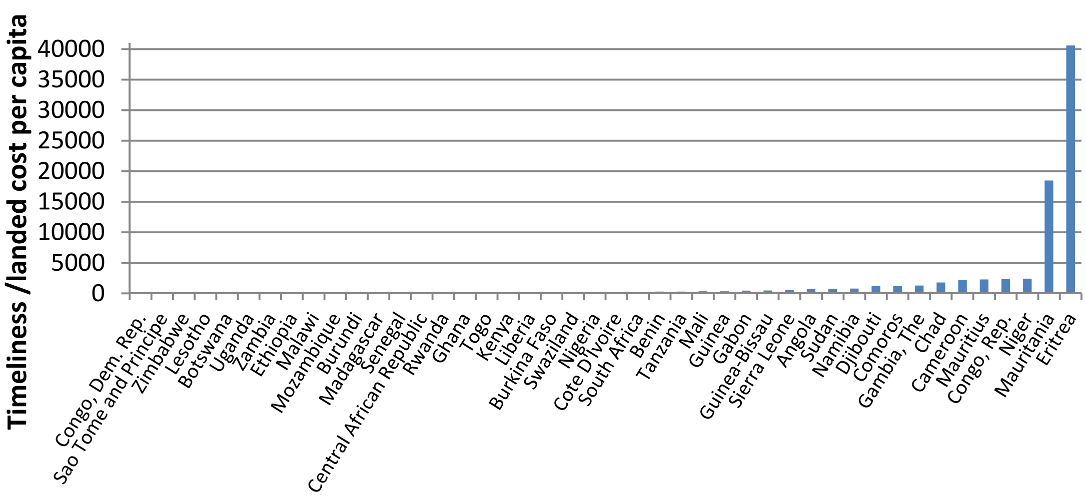


Figure 5 shows the timeliness per unit/landed cost per capita (in US$) for countries in our dataset

Weighting Inputs and Outputs across the country set

At this point, we have illustrated the differing measures of outcomes and their link to the input landed costs per capita. But from a productivity measurement perspective, how should these two separate productivity measures be combined to create an overall measure? How can this measure be considered as a relative measure, whose expected optimal performance is generated relative to the data across Sub-Saharan countries?

We first consider countries in Sub-Saharan Africa as a collective because of their similarity in terms of geographic location, their historic health challenges, their shared contexts for funding and performance comparisons, the possible benchmarking across these countries, etc. But within this country set, we expect to see significantly differing performance because of the differing approaches to the organization of health care, levels of communication regarding fertility, financing of health care needs, infrastructure capabilities, etc.

The approach we use, Data Envelopment Analysis (DEA), treats the set of countries as members of a common population that use inputs (funding) to generate outputs (timeliness, CPR). The model tries to find the possible outputs that can be generated with the same input level provided to a country and the "slack" in performance observed. Because the approach suggests combinations of currently observed performance across countries, in addition to estimating productivity, the model also provides a reference set of countries that can be used to benchmark possible ways to improve productivity. The results of this approach are shown in Figure 6 and they suggest that there are seven countries that are on the frontier with a productivity level of 100%. Other than an outlier with very low productivity, the rest have productivity levels ranging from around 21% to 100%.

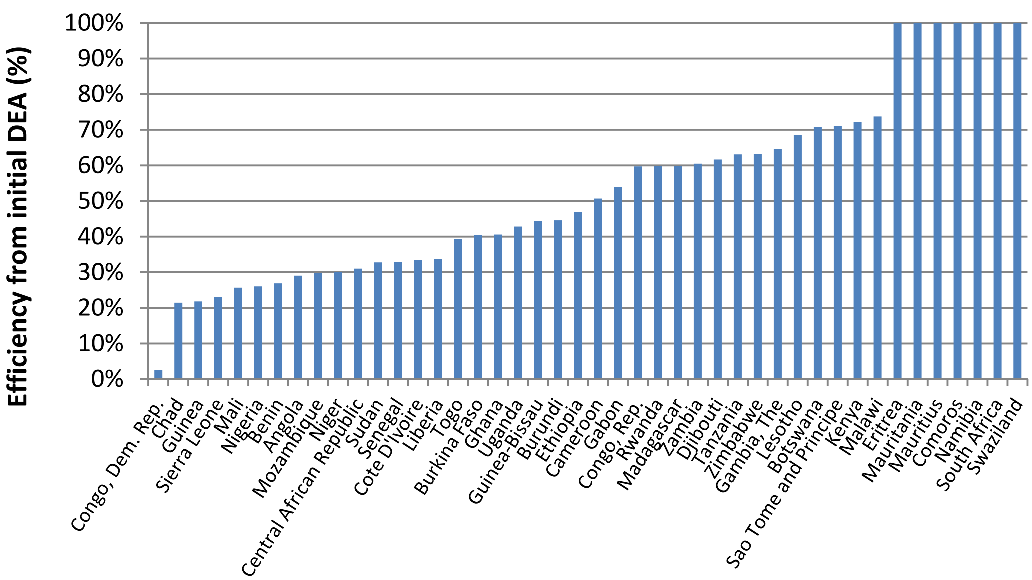


Figure 6 shows the efficiency obtained from DEA without adjusting for environmental factors

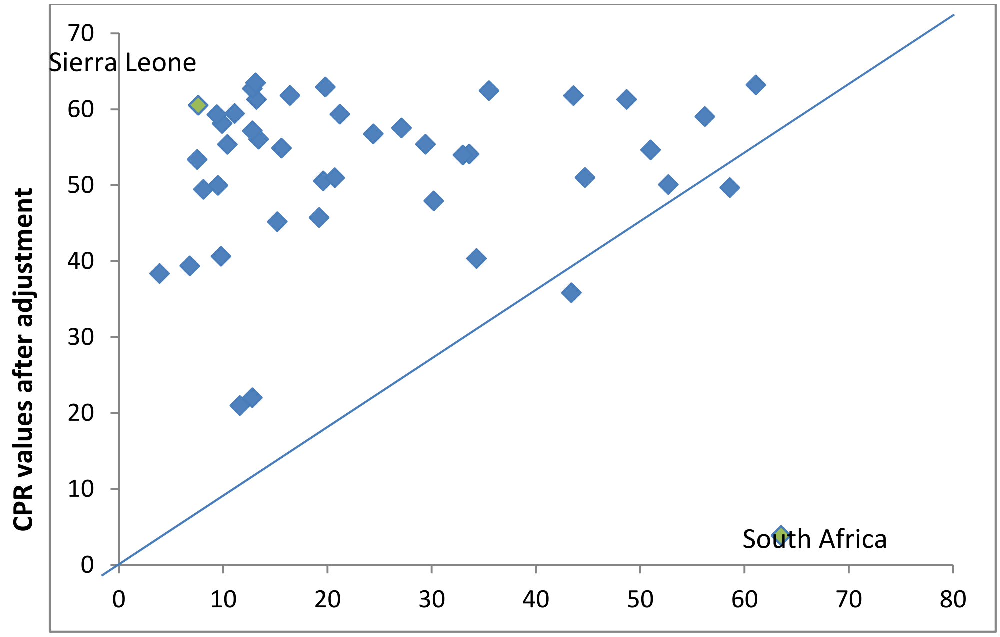
But notice that this analysis has been done without adjusting for differences between the environmental variables in each of the countries. As a result, some of the countries with high observed performance, like South Africa, show up as efficient. Countries with low performance, like Niger or Sierra Leone, show up as inefficient. Since there are several environmental factors outside the control of the supply chain that can impact the output values, is it fair to compare countries without adjusting for these endowed factors? We suggest that a "fair" benchmarking would need to adjust for such differences in countries[vii]. After much experimentation, the environmental variables we choose are:

1) GDP per capita - gross domestic product divided by midyear population
2) Female literacy rate - % female adults (ages 15 and above) who can read and write
3) Landlock - dummy variable for landlocked countries
4) Public health expenditure - % of public health expenditure from total health expenditure
5) LPI - Logistics Performance Index
6) Merchandise - % of sum of merchandise exports and imports divided by the GDP

In addition, the possible variance variables related to random shocks (such as omitted variables or statistical noise) that impact our output variables are:

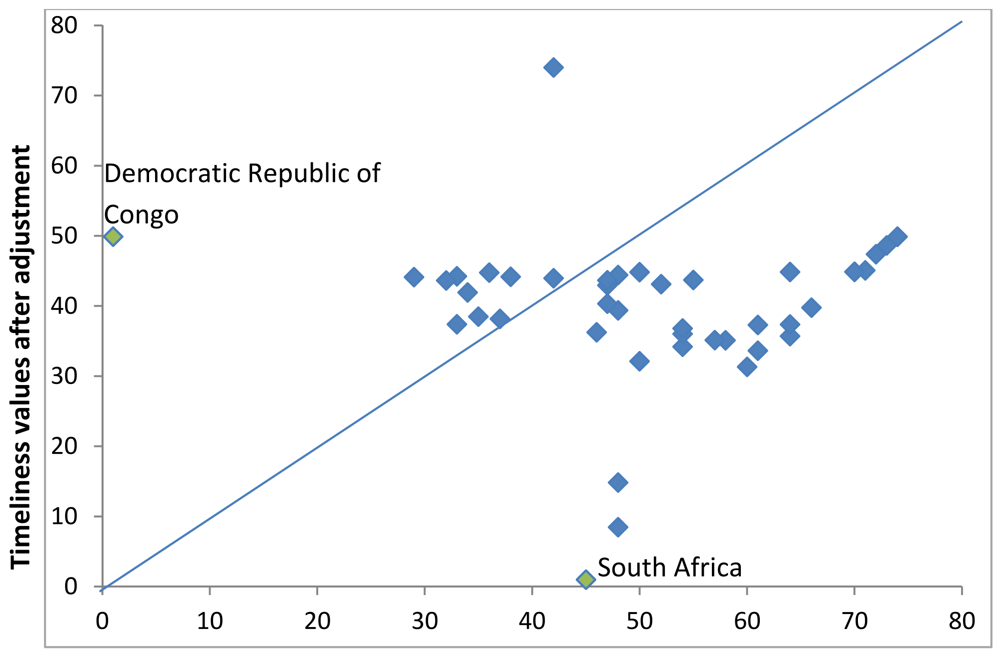
1) Population - total number of persons inhabiting a country
2) Density - midyear population divided by land area in square kilometers

The goal of the next step is to identify the significance of these variables, and to use the implied multipliers to adjust the output variables[viii]. The impact of these adjustments will be to provide a normed set of values of outputs that adjusts for the extent of shortfall of performance that can be attributed to the level of these environmental variables and random shocks. Once these outputs are adjusted, the new values for performance are shown as a scatter plot against the original values for CPR in Figure 7. Note that the values of CPR for South Africa were decreased from 63.5 to 3.9 to account for the environmental variables and random shocks, while those for Sierra Leone were increased from 7.6 to 60.6. Similarly, Figure 8 shows the values for timeliness before and after adjustment.



Original CPR values

Figure 7 provides a scatter plot of CPR values by country – the original values on the X-axis and the adjusted values on the Y-axis. There is one point for each country.



Original Timeliness values

Figure 8 provides a scatter plot of the original timeliness values against the values after adjustment. Each point represents the values for one country.

Notice that given its better infrastructure, education and communication, we would expect South Africa's performance to be superior. The adjustment for South Africa thus decreases its CPR and timeliness to account for the level of its environment. Similar adjustments thus "level" the playing field for all country measurements. Thus, for Sierra Leone, the CPR values are increased to account for its endowed variables, and for Democratic Republic of Congo its timeliness is increased to account for its environmental variables. This allows each country's supply chain management of donated reproductive health goods to be evaluated by the same rules and it is a crucial component of a fair benchmarking system. But it also points to the importance in making changes to these environmental variables, something that may be a country or donor responsibility, but cannot be changed by the supply chain manager.

We thus repeat our DEA analysis to generate a new set of productivity measurements as shown in Figure 9. These new measurements adjust each country's output variables based on the impact of environmental variables and random shocks. The results are shown below.

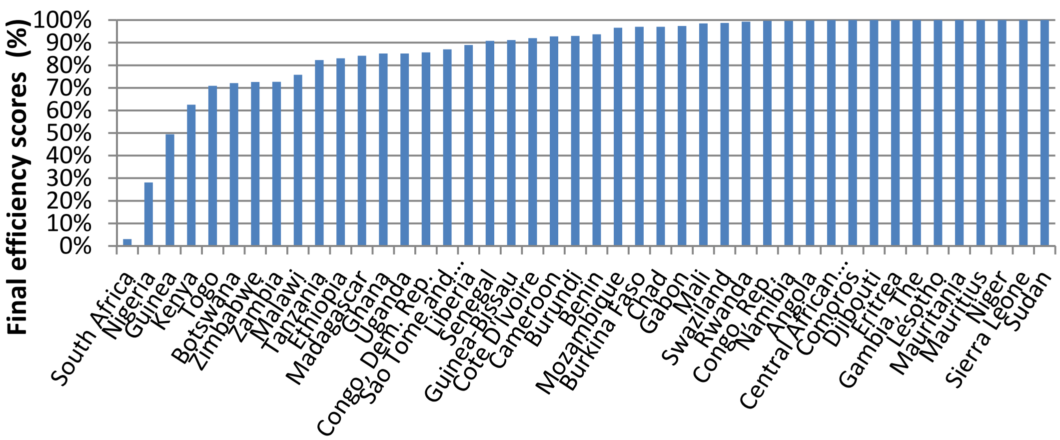


Figure 9 provides the final efficiency scores for each country after adjusting for environmental effects

Notice that we have 11 countries that are efficient; where some of these countries have changed after being adjusted (Table 1 provides the details). Comoros, Eritrea, Mauritania and Mauritius continue to be efficient countries despite the readjustments of their output values (CPR and timeliness). This efficiency level remains mainly due to these countries having input values (landed costs per capita) smaller than the average country in the pool. Moreover, there are seven seemingly unexpected countries lying on the efficient frontier: Central African Republic, Djibouti, Lesotho, Niger, Sierra Leone, Sudan and the Gambia. For these seven countries, the readjustments in their outputs have been due to them having one or multiple environmental variables at a clear disadvantage compared to the rest of countries, so the readjustments try to eliminate the negative effects of the environmental variables. The details on the particular effects of each environmental variable to both types of output are provided in Table 2. This "fair" classification of efficiency may shed a better light into the role of supply chain managers in these countries.

	Original outputs		Environmental values						Adjusted outputs		Input
Countries	CPR (%)	Timeliness (Days)	GDP per capita (US $)	Female literacy rate (%)	Landlock (0 if not 1 if yes)	Public health exp. (%)	LPI (from 1 to 5)	Merchandise trade (%)	CPR (%)	Timeliness (Days)	Landed cost per capita
Central African Rep.	13.1	38	489	56	1	51.9	2.57	25	63.5	44.17	0.2735
Comoros	26	74	810	75	0	57.2	2.14	33	40.36	49.89	0.0599
Djibouti	24.4	58	1467	30	0	68.1	1.8	50	56.78	35.11	0.0477
Eritrea	8	72	482	68	0	48.8	2.11	50	22.04	47.39	0.0017
Lesotho	47	56	1104	90	1	74.1	2.24	153	61.3	74	0.6569
Mauritania	9	73	1151	58	0	60.6	2.4	129	21	48.64	0.0039
Mauritius	51	61	8755	89	0	40.3	2.82	69	54.67	33.63	0.0265
Niger	18	54	374	29	1	55.1	2.69	61	49.48	36.02	0.0222
Sierra Leone	7.6	54	374	42	0	18	2.08	91	60.55	34.20	0.0918
Sudan	11.1	61	1435	71	0	28.4	2.1	28	59.46	37.30	0.0796
The Gambia	19.2	70	506	50	0	54	2.46	38	45.75	44.89	0.0537
Countries mean	25.10	51	1873	65	0.341	47.2	2.46	66	51.34	39.72	0.2458

Table 1: Summary of values of variables from the 11 efficient countries and the mean of the pool of all countries. Note that the larger the values of CPR and Timeliness, the better in terms of output value.

	GDP per capita (US $)	Female literacy rate (%)	Landlock (0 if not 1 if yes)	Public health exp. (%)	LPI (from 1 to 5)	Merchandise trade (%)
CPR	↑	↑***	↓	↑***	↑***	↓***
Timeliness	↑	↓	↓***	↑**	↑***	↓*

Table 2: Summary of how environmental variables affect the output variables for our data set. The sign ↑ indicates that larger values of that environmental variable positively affect output and sign ↓ indicates that lower values of the variable negatively affect that output variable. The asterisks *, **, * indicate statistical significance of 10%, 5%, and 1% or better, respectively.**

Impact of funding concentration

Across countries in Sub-Saharan Africa, the funding strategies of donors vary – from cases where they are part of a pool, to cases where there is a single large donor accounting for the bulk of the overall funding. The presence of a variety of donors may also result in the use of a variety of different performance metrics. It is thus important to examine the link between the observed efficiency and the extent of donor funding concentration for countries. We measure the donor funding concentration as the sum of squares of the funding provided by each donor. The donor funding metric ranges from 0 to 100%. The results show that there is a 68% correlation between funding concentration and country level efficiency. This suggests that donors pressure on measurement metrics, and the potentially uncoordinated directions that country managers are pulled, may impact the efficiency of the management of the supply chains. Figure 10 depicts a scatter plot of this relationship. Additionally, this impact can also be observed if we divide the set of countries between efficient (100%) and inefficient (<100%) countries. For the set of efficient countries the funding concentration has mean of 0.96 and deviation of 0.08, while for the set of inefficient countries these values are mean of 0.59 and standard deviation of 0.22.

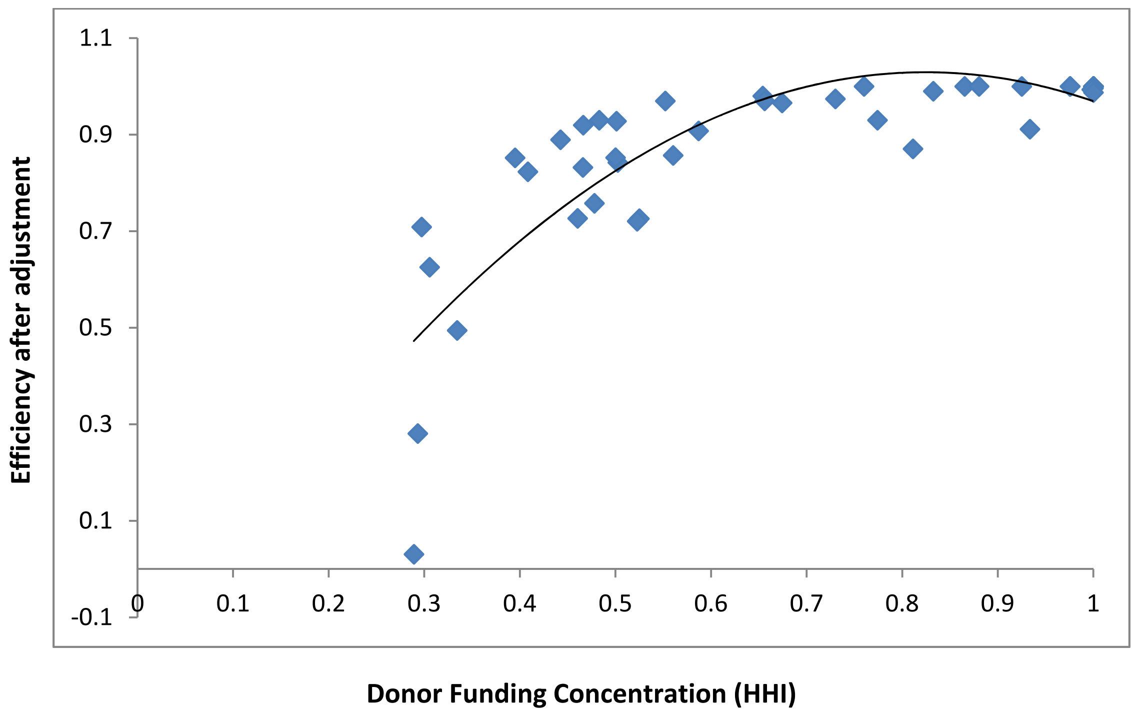


Figure 10 shows a plot of the donor funding concentration in the X-axis and the efficiency after adjusting for environmental variables in the Y-axis. Each country is a point in the graph. The fitted line shows that efficiency increases with HHI.

A Path to Improve performance

To illustrate how the data provided in the analysis can provide a path to improvement, we focus on one country – Botswana – and how it can use the results from our analysis to improve performance. Note that Botswana was initially inefficient (Figure 6) and remained inefficient after accounting for environmental factors and random shocks (Figure 9). This shows that Botswana's reproductive health products supply chain performance is managerial inefficient compared to its peer countries. In particular, our analysis shows that Botswana has an estimated efficiency of 72.1% with a reference set of efficient countries that are Lesotho, with an 84.9% weight, and the remaining 15.1% weight assigned to Sudan. Figure 11 shows how Botswana's performance is lower than should be expected based on the results obtained for Lesotho and Sudan. The figure also provides the projected position of Botswana alongside the efficient frontier, which is the optimal position for Botswana if it improved its CPR and timeliness values to get to the efficient frontier.

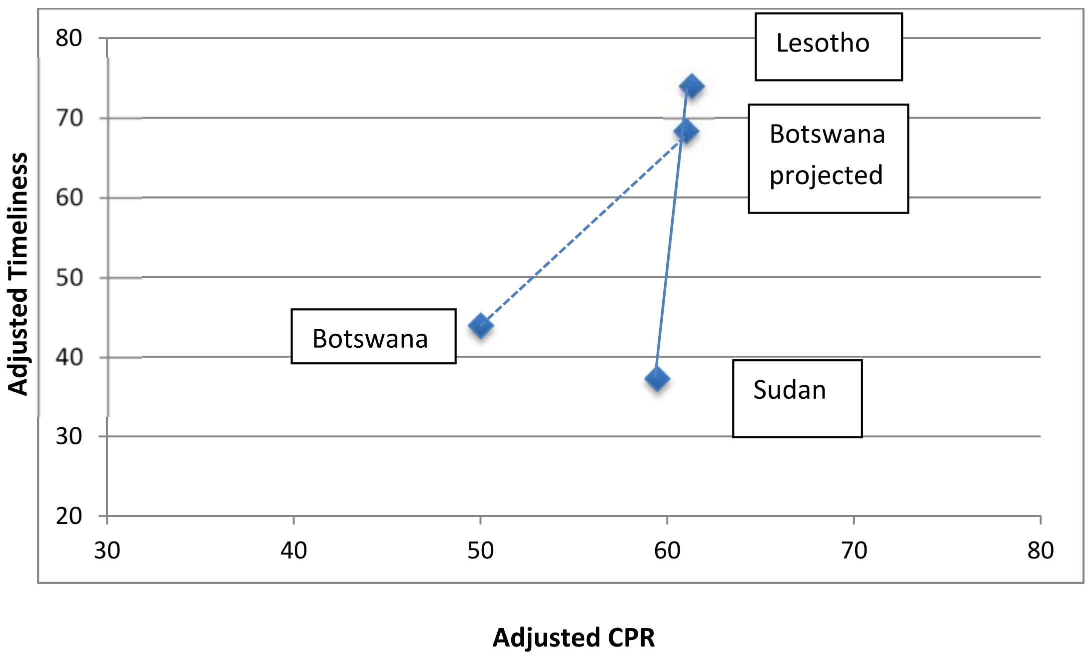


Figure 11 provides Botswana's position relative to the frontier and its reference set of countries

If we examine Lesotho and Botswana, we see that both are landlocked countries in southern Africa with a similar population of 2.1 million people and 2 million people, respectively. Both countries have high rates of HIV/AIDS in the world. Based on national income, Botswana is considered a middle-income country (GNI per capita US $7480 in 2011), while Lesotho is classified as a lower middle income country (GNI per capita US $1220 in 2011). Our analysis suggests that a learning group involving Lesotho and Botswana may help Botswana identify specific ideas for improvement. A quick summary of specific attributes of supply chains in Lesotho and Botswana are listed below in Table 3.

Managerial attribute	Lesotho	Botswana
Funding Concentration	Yes (HHI=0.76)	Yes (HHI=0.52)
Donor coordination alignment	A well-defined role for an entity (DPCF)	No clearly defined role
Integration with nonpublic health facilities	CHAL facilities integrated with common SOPs	Nonpublic facilities not integrated
Procurement approach	All commodities supplied by NDSO	Centralized but erratic availability
LMIS systems	In place and functioning well	In place but new DHMT system has impacted robust information flows
Social marketing	Yes (87% of 2012 reproductive health orders in RHI)	Yes (25% of 2012 reproductive health orders in RHI)

Table 3: Summary of differences in reproductive health supply chain practices in Lesotho and Botswana (Berenguer et al. 2014)

Our recommendation is to start a process where countries that are not on the efficient frontier work with their close peer countries on the frontier to exchange best practices and thus improve performance. It may be the case that the learning could be a two way process – because even countries on the frontier can improve their performance by changing the level of their environmental variables. Our results suggest that donor funding fragmentation impacts managerial efficiency – this result holds even after robustness checks, suggesting a possible causal relationship. Thus, concrete steps to compensate for funding fragmentation, which include joint planning or common and consistent data warehouses, may deliver improved efficiency. Our approach can be used to conduct similar analysis for assessing supply chain efficiency for other product categories, such as medicines, diagnostics and preventive products for HIV/AIDS, Malaria and Tuberculosis and other diseases, with existing public datasets as a means to drive improvement and thus better health outcomes.

Summary

We suggest that a combination of a focus on efficiency measurement and on identifying peer supply chains that can learn and improve may create a culture of performance improvement – thus improving productivity. Our first analysis of the data using DEA suggested an opportunity to improve contraceptive prevalence rate (CPR) by on average 61% and timeliness by 32% for the set of initially classified as inefficient countries, which corresponds to 84% of the countries studied. A study of the impact of country specific environmental variables suggested that the observed output CPR values should be adjusted on average by a factor of 5.18 and the observed timeliness should be adjusted by an average factor of 0.86 – suggesting that environmental factors have a significant impact on health outcomes. Finally, a third stage DEA analysis using the adjusted outputs continue to suggest an opportunity to improve CPR by 56% and timeliness by 26% for the set of inefficient countries, which now corresponds to 75% of the countries. In summary, while environmental variables have a large impact, there continues to be an opportunity to improve both health outcomes and supply chain performance through process improvement and benchmarking. We believe that a discussion of the data, the results and associated relationships, and the magnitudes of the impacts can permit a dialog of the various drivers of efficiency and how best to impact results. Our recommendations are in the form of a process for continued improvement across a range of choices in supply chains and health empowerment – we hope to start soon on a prototype to demonstrate this projected improvement. To finish we would like to note that more systematic data collection for outcome measures (e.g., CPR, fertility rate, etc.), costs, and logistics measures (e.g., lead times) are key to improve the accuracy of any benchmarking study.

---

[i] Institute for Health Metrics and Evaluation, 2013

[ii] CPR for modern methods is defined as the proportion of women of reproductive age (from age 15-49 age) who are married or in a union and who are currently using (or whose partner is using) a modern contraceptive method.

[iii] available at url http://www.un.org/esa/population/publications/WCU2012/MainFrame.html.

[iv] see Amendment 3, fourth link to spreadsheet of url https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=2478efc9936c75d19abbf7241e3e1d27&_cview=0

[v] Lead time is defined as the difference in number of days between order received time and order shipped time.

[vi] Landed cost per capita has been calculated by adding all landed cost per order for a country during the timespan studied (year 2012) and dividing it for the population of that country. Landed cost per order is provided in the RHI dataset and it is defined as a composite of product unit price, shipping, insurance, any related testing, fees, etc., in US dollars.

References

Berenguer, Gemma, Ananth, Iyer and Prashant, Yadav, Disentangling the efficiency drivers in country-level global health programs: An empirical study, Working paper, Purdue University, 2014.

Bjorkgren, Magnus A and Hakkinen, Unto and Linna, Miika, Measuring efficiency of long-term care units in Finland, Health Care Management Science, Vol 3, pages 193-200, 2001

Charnes, Abraham, William W Cooper, Edwardo Rhodes. 1978. Measuring the efficiency of decision making units. European Journal of Operational Research 2(6) 429{444.

Farrell, Michael J. 1957. The measurement of productive efficiency. Journal of the Royal Statistical Society. Series A (General) 120(3) 253{290.

Gravelle, Hugh and Jacobs, Rowena and Jones, Andrew M and Street, Andrew, Comparing the efficiency of national health systems: a sensitivity analysis of the WHO approach, Applied health economics and health policy, Vol. 2, pages 141-148, 2003

Iyer, Ananth and Saranga, Haritha and Seshadri, Sridhar, Effect of Quality Management Systems and Total Quality Management on Productivity Before and After: Empirical Evidence from the Indian Auto Component Industry, Production and Operations Management, Vol 22, pages 283-301, 2013

Liu, Junming and Tone, Kaoru, A multistage method to measure efficiency and its application to Japanese banking industry, Socio-Economic Planning Sciences, Vol 42, pages 75-91, 2008

Mancebon, Maria Jesus and Molinero, C Mar and others, Performance in primary schools, Journal of the Operational Research Society, Vol. 51, pages 843-854, 2000

Masiye, Felix, Investigating health system performance: An application of data envelopment analysis to Zambian hospitals. BMC Health Services Research Vol. 7, pages 1-11, 2007.

P. Yadav, O. Stapleton, and L. N. Van Wassenhove. Learning from Coca-Cola Comparing Medicine and Consumer Product Supply Chains in the Developing World, Stanford Social Innovation Review. Nov 2012

[viii] The environmental variables that have resulted to be more significant are female literacy rate, public health expenditure, and the Logistics Performance Index (LPI).