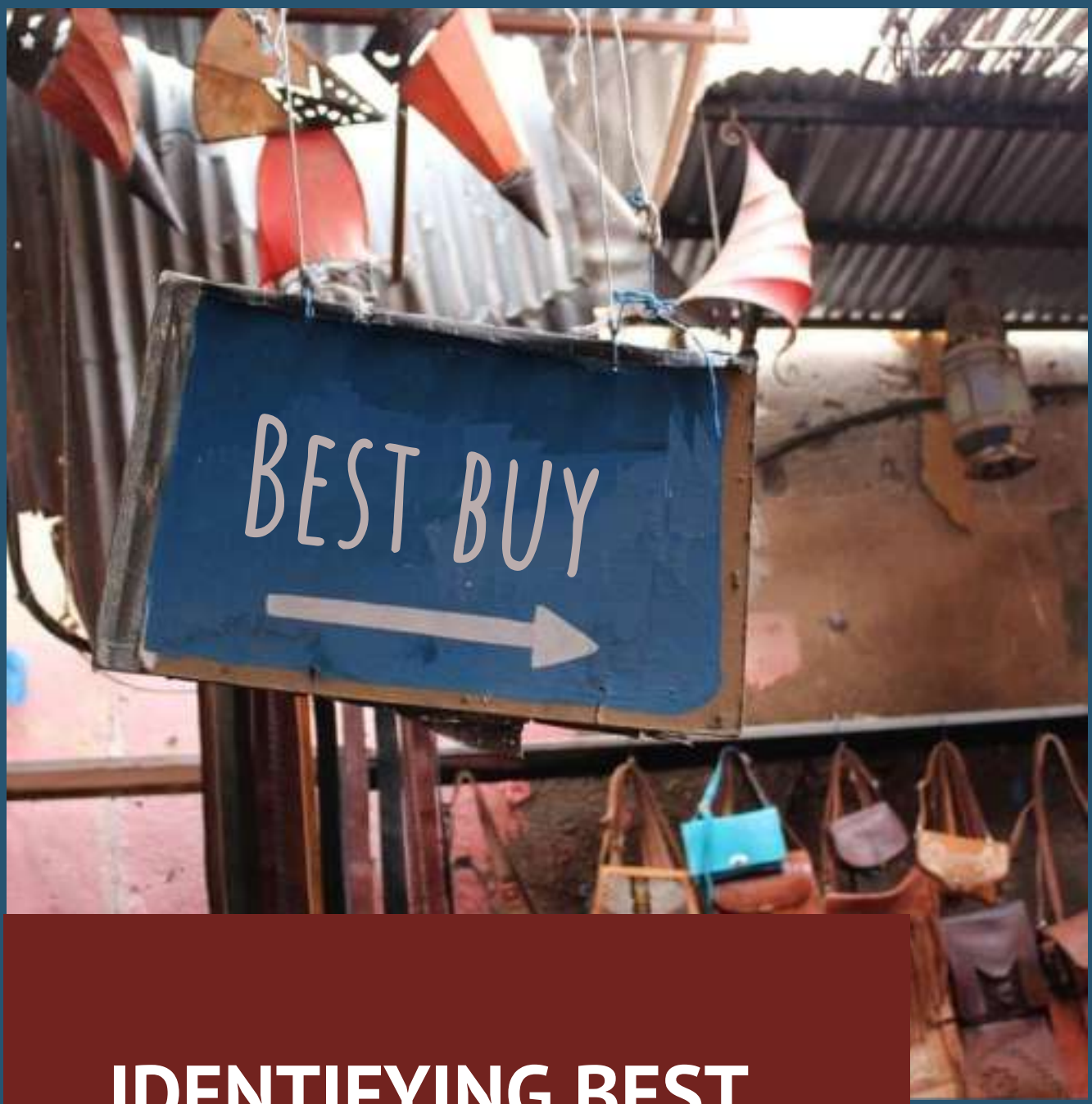

IDENTIFYING BEST BUYS FOR AFRICA

COMPARING COSTS AND BENEFITS • 2021

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This work has been produced as a part of the project Prioritizing best buys for development across the African continent

This project is undertaken with the financial support of the Bill & Melinda Gates Foundation. The opinions and interpretations in this publication are those of the authors and do not necessarily reflect those of the Bill & Melinda Gates Foundation.

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PART 1

BENEFIT AND COSTS OF INTERVENTIONS USING CURRENT TECHNOLOGIES

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Summary for Policy Makers

No nation can tackle all problems at once. Resources are limited, including money, time, manpower and attention. Hence, it might make sense to **first focus** where the used resources can achieve the highest impacts on welfare.

This report gives African nations a first glimpse of where extra money can be best spent first. It is a **fast-track analysis** of some of the best policies across the continent, analyzed in time for the Grand Challenges Summit in Addis Ababa 27-30 October.

What are "best policies"?

This publication aims to identify some of the best policies for Africa. Some of these policies can readily be implemented or scaled up with existing technology. These policies are outlined in this section of the report.

Other policies are good candidates for investment in R&D to develop new technologies that can make deployment much more feasible. These policies are described in the second section of this report, starting on page 146.

For both sets of policies, this report uses **social cost-benefit analysis** to find the best policies. For any policy, we estimate the **total costs**. Much of this will be monetary costs — for vaccinations, it might include vaccines, extra health care staff and overhead. It will also include social and environmental costs, such as transport costs and time spent, that could otherwise have been used for wage work. All costs are converted into monetary terms through well-established, economic procedures.

Similarly, we estimate **total benefits**. These can be economic, social and environmental. For vaccines, they will mostly consist of the benefits from avoided premature death. For other policies for example within education the benefits consist of increased productivity, for trade facilitation the benefits are primarily increased economic activity. Again, all benefits are converted into monetary terms.

If this analysis has included all major costs and benefits of the policy and translated them well into monetary terms, we can now show the **effectiveness of that policy using the benefit-cost ratio**: That for each dollar spent, it will produce, say, 10 dollars of social welfare.

While the report uses US$ for costs and benefits, the analysis can effortlessly be used for any other currency. If a policy spends $1 to

Background

A new initiative implemented by the African Academy of Sciences (AAS) and the African Union Development Agency (AUDA) and supported by the Bill & Melinda Gates Foundation seeks to answer these questions:

- Looking at the scientific priorities set by the SDGs, African Union Agenda 2063, and national development plans, which will give African countries the greatest return on investment?
- How do we get these priorities in front of African and global decision-makers, and use them to guide and inform investment decisions by African governments and global funders?

The AAS is convening African science leaders to determine which 10-15 pressing health and development priorities can be answered by science and innovation. They will then determine which of those priorities can be addressed with existing interventions that are ready to scale, and which require further scientific research. For those priorities where promising interventions exist, work will focus on aligning African governments and global funders to support their introduction and drive impact. For those areas where further research is needed, efforts will focus on funding researchers and innovators to develop and test new solutions.

produce $10 of social welfare, the policy spends one shilling (or naira, rand or franc) to produce 10 shillings (or nairas, rands or francs) of social welfare.

This analysis makes it possible to **compare and rank policies**: some policies produce $5 of social welfare for every dollar spent, some policies produce $50 of social welfare. Indeed, some will be ineffective and produce less than a dollar of social welfare for every dollar spent. All other things equal, the policies producing high returns should be funded before the ones with low return.

All policies are **additional**: the report looks at the added benefit of the next dollar spent. The analysis does *not* look at past spending, but help policy makers **today**, making a decision on spending across a number of different policies.

Finding the best policies that can be immediately implemented or scaled up

The report takes the starting point in the African Union's goals and priority areas of **Agenda 2063**, national development plans and the UN's SDG targets. From existing work on the efficiency of development policies, 30 areas were selected for their promise of high efficiency and/or high salience. For each area, prominent economists were interviewed to ensure the analyzed policies are the most relevant ones for Africa.

The project is a fast-track product, done over 3 months. It delivers back-of-the-envelope calculations that are relatively rough, but enough to provide a reasonable ranking in terms of relative value for money.

Best, good, fair and poor policies

The policies have been placed in one of four traffic light signal categories. The best policies all yield more than 15 times their costs in social, economic and environmental benefits (BCR over 15). Good policies generate benefits worth 5 to 15 times more than the expenses (BCR 5-15). Fair policies return the same up to the five-fold amount invested (BCR 1 to 5), and for poor policies the costs exceed the benefits (BCR lower than 1).

CATEGORIZED POLICIES:

Family Planning
Women's Empowerment Collectives
R&D for agricultural yield increase
Vaccination against rotavirus
Preschool education
Tobacco control
Trade Facilitation in the ACFTA
Expanded malaria interventions
Breastfeeding promotion
Reduced child malnutrition
Improved cookstoves
Soil fertility management from cell phone
Voluntary medical male circumcision for HIV
Delayed pregnancy among school-girls
Expansion of Marine Protected Areas
Rural improved access to clean water
Community Health Workers (CHWs) for tuberculosis control
Improved child cancer treatment
Urban improved access to clean water
Resilience to drought
SME training
Solar energy for unreliable urban grids
CHWs for hypertension control:
Graduation from ultra-poverty
Community-Led Total Sanitation
High Speed Train Network
Off-Grid Rural Electrification

Best policies that can be immediately scaled up (expected BCR higher than 15)

Family planning: (BCR of 94).

Family planning is beneficial to individuals, families, and societies alike, and investing in the expansion of family planning and reproductive health services has been recognized as an essential step to achieving many of the Sustainable Development Goals. It is estimated that 45 million women in Sub-Saharan Africa with an unmet need for family planning.

The total direct and indirect costs associated with expanding contraceptive coverage to 100% is $27 per woman per year. In addition to the costs of providing family planning services, this number also includes all costs to the women from out-of-pocket expenses to costs related to the loss of time from seeking care, and management of contraceptive-related side effects.

The most immediate effect is the prevention of unwanted pregnancies and allowing women to space their children. This leads to the aversion of 230,000 maternal deaths and other negative health outcomes, conservatively estimated at 2 times the cost.[1]

Better spacing of children will lead to higher levels of female education, increases in female labor force participation and earnings. Better spacing also means fewer children in each cohort, thus higher population percentage in the workforce. This leads to a demographic dividend, which increases economic growth in the coming decades. Essentially, reductions in fertility and population growth rates would result in sustained increases in GDP per capita over several decades. Discounting these future benefits at 5% reveals a present-day value of the demographic dividend at 86 times the cost of scaling up family planning services.

In addition to this dividend, a reduced fertility rate leads to major costs savings from reduced health, education, and other societal expenditures from increased populations. These savings further outweigh the family planning cost by 4 to 7 times.

Summing it up, benefits are worth a staggering $573 billion per year for Sub-Saharan Africa can be achieved through scaling up family planning services.

Women empowerment collectives: (BCR of 58).

Voluntary groups of 15-25 women, also known as Self Help Groups (SHGs), who meet every week to save, start small business activities, and grant loans to one another. They have been used in a wide range of contexts, adapted for refugees, caregivers of orphans and vulnerable children, people living with HIV/AIDs, adolescents, as well as layered with maternal, neonatal, child, and sexual and reproductive health support.

The evidence base for the impact of these collectives is nascent but highly promising. Only one study estimates BCRs, while several rigorous evaluations have estimated cost-effectiveness.

A 2013 cost-benefit analysis of Self Help Groups in Ethiopia found that the intervention yielded benefits between $58 and $173 for every dollar spent.

Self Help Groups and Women's Empowerment Collectives are numerous and widespread but have received little visibility or investment. The intervention is already widespread and may be replicated at scale. However, the model is also founded in peer support, solidarity, and trust, and therefore there is a risk that these groups will fail if they are expanded rapidly or with

[1] Order of magnitude adjustment of the number presented in the authors' brief to make it more comparable with the other BCRs in this report: 5% discount rate and only valuing averted infant child deaths resulting in a living newborn, as opposed to the result of an averted pregnancy (averted newborn deaths estimated as 90% of the total averted DALYs).

external financial incentives to achieve scale. Rather, a programmatic approach should focus on mapping and investing in the very large ecosystem of Self Help Groups that exist already, and facilitating investments in the systems that can support them to thrive.

Agricultural yield increase R&D: (BCR of 55).

Increasing agricultural productivity has been critical for reducing poverty and hunger globally. However, Africa has benefited less than other regions from past investments and continues to have low agricultural productivity by global standards.

Broad-based investments in agricultural R&D and rural infrastructure generate very large total economic benefits and big reductions in hunger in Africa. Because of the high cost of physical infrastructures such as roads, electricity, and irrigation, the BCR of a comprehensive package of these investments is lower than for increased investments in agricultural R&D, although it still has a substantial BCR of 10:1. Given the high impacts on economic growth, these investments warrant serious consideration as necessary complements to agricultural R&D and targeted investments in hunger and nutrition programs.

As a stand-alone investment program, increased spending on international agricultural R&D has a very high BCR of 52:1. This result indicates severe underinvestment in agricultural R&D in Africa and the need to substantially increase such investment.

In addition to public expenditures on agricultural R&D, private sector investment in agricultural R&D plays an important role in agricultural productivity growth. In much of the world, private sector investment in agricultural R&D has increased faster than public sector investment, but private sector investment in agricultural R&D remains low in Africa and other low-income regions.

The International Agricultural Research Centers of the CGIAR are well-placed to scale-up agricultural R&D investments in Africa, with research facilities and programs in place in many countries and regional programs across Africa. A phased doubling of investments between 2015 and 2030 is highly feasible.

Vaccination against rotavirus: (BCR of 44).

To achieve healthy and well-nourished citizens, it is necessary to prevent or control diarrhea, which kills 330,000 children each year in Africa. Increased vaccination against rotavirus can save 26,000 children each year and avoid 140,000 hospitalizations. The cost per child vaccinated is just $6, but the social benefits are 44 times higher. For Nigeria, the BCR is 126, and for Cameroon 64.

Scaling up preschool: (BCR of 36).

Only about a third of Sub-Saharan Africa children are enrolled in preschool. Yet, theoretically, preschool is one of the best education investments, because early schooling has higher impacts over a longer time while being cheaper to deliver.

The policy proposes to scale-up two-year preschool across Africa. It assumes an average cost of $119 per student per year, based on estimates from Nigeria.

It is expected that more preschool will lead to higher wages in adulthood. However, there are no long-term studies from Africa following children with and without preschool to adulthood, comparing their earnings. Hence, the brief assumes a 16% wage increase from preschool, based on an average from two long-term studies of preschool-to-adulthood wages in Jamaica (finding 25% earnings increase) and in the US (7%).

Assuming labor earning of $1258, conservatively based on 80% of the average income in Sub-Saharan Africa, that means that preschool will increase the average wage by $201 per year. Of course, the policy will have costs now, whereas the benefits of increased wages will only occur when the child becomes 20, and continue until age 65. It is assumed the wages will grow with the productivity growth of the economy. All benefits are discounted back to today.

Preschool will cost society two times $119 but create a higher social growth stream 17 years later, first worth $301 ($201 with the productivity growth of 17 years), ending in 2079 being worth $875. Discounted till today, the cost is $221, and the benefits worth almost $8,000. Each dollar spent on preschool will deliver $36 of social benefits.

Tobacco control: (BCR of 23, range 5.6-120)

Half of lifetime smokers will die before they reach 70, losing an average of 10 years of life. There is no safe level of tobacco use. More than 1 billion people in the world smoke; 21% of the world's population. While smoking prevalence is still low in most African countries, it is rising in direct response to industry promotion of smoking. The optimal time to institute tobacco taxation is now, before tobacco prevalence increases. This will prevent uptake and prevent onset of diseases. Scaling the intervention to multiple countries in the sub-region is desirable to reinforce positive social norms and health behaviors and because illicit tobacco trade will be discouraged if the retail price levels of tobacco are roughly similar from country to country.

The economic benefits of reducing tobacco consumption through increased taxation are substantial. By raising the tobacco tax to 75% of the retail price, we expect smoking prevalence to drop by 20%. The total health and productivity from reduced smoking are valued at USD 331 million over 15 years for our example country, while cumulative discounted costs are USD 2 million. The result is a BCR of 120.

Raising taxes incurs some costs and benefits beyond the direct administrative and enforcement costs included in this model and the improved health and productivity measured. First, traditional economics literature includes the purported social welfare costs of "coercing" smokers to pay more for their desired product or stop purchasing it. This concept, called "deadweight loss", is relevant to situations where consumer sovereignty is being sacrificed for social gain and is a premise behind the rationale economic model. Incorporating this cost into the analysis lowers the BCR to a range between 5.6 to 23 depending on the methodology used to valuing the smokers' loss. However, in regard to addictive substances such as tobacco, the existence and amount of DWL is debated among economists. The arguments against including deadweight loss are that smokers are time inconsistent causing them to act against their own interest in not smoking.

Facilitating trade within ACFTA: (BCR of 20).

With the signing of the African Continental Free Trade Area in March 2018, Africa can increase its trade and capture economic gains. But the continent still has more than 3,000 so-called non-tariff measures (NTMs) that hinder growth. The policy proposal will extend the UNCTAD/African Union crowdsourced regional database on NTMs. This will make it easier for traders to trade and though the information it will help national trade facilitation committees and the annual ministerial meetings of the corridor authorities to push for easing or elimination of NTMs. It will help increase trade and over the next 10 years grow Africa's GDP about $5 billion per year. The information collection will cost a trivial $15m, but as with any trade increase, there will be some shorter-term adjustment costs. Even under a high-end estimate of costs for adjusting to increased trade at $250m, the benefits will outweigh the total costs 20-to-1.

Increased access to bednets: (BCR of 16).

Much progress has been made in the fight against malaria in sub-Saharan Africa (SSA). Incidence rates (the number of cases/1000 population) have dropped from 278 (2010) to 219 (2016 and 2017). Though, in comparison to the global malaria incidence rate (59), there is still some work to be done.

Long-lasting insecticide-treated nets (LLIN) are generally considered the most cost-effective control. Despite bednets being distributed en masse and often for free, in 2017 175 million LLINs were distributed, the percentage of the population with access to an LLIN is estimated at only 56%.

Owning a bednet does not necessarily mean you sleep under one, the ownership to usage ratio is around 0.89, nevertheless, most bednets are used, and the cost is less than $5 per distributed bednet. However, increasing access to 75% in high-malaria-burden regions of Western and Central SSA would need an additional 55 million bednets at a cost of $268 million. However, the payoffs in terms of averted death and disability, and lowered malaria treatment expenses are huge, in total worth $4.4 billion. The social yield is on average 16 times the investment.

Breastfeeding promotion: (BCR of 15)

More than 2.5 million children under the age of five years die every year in sub-Saharan Africa from preventable causes (UNICEF, 2019a). Increasing exclusive breastfeeding prevalence from the continent's 46% baseline to 95% can avert help avert thousands of deaths. Approximately US$1.9 billion can be gained every year in terms of health benefits and treatment and care seeking costs averted.

Training; supervision; salaries; transportation; information, education and communication (IEC) materials; materials and supplies for community health workers. Several costing studies have been undertaken to estimate the costs of community interventions promoting breastfeeding, with estimated costs ranging between US$139 to US$230 per mother. The estimated benefit-cost ratio is 14.50.

Good policies that can be immediately scaled up (expected BCR between 5 and 15)

Package to avoid undernutrition: (BCR of 14).

Africa's future success lies in increasing human knowledge. Mostly, this means education, but there is another, possibly more effective way. Malnourished children suffer cognitive impairment, leading to lower schooling and lower productivity. Children, that are better nourished during the first 1000 days (in utero and the first two years of life), will do better. In Zimbabwe, shifting a child from being stunted to well-nourished is equivalent to increasing schooling by 1.25 grades. In general, avoiding stunting increases adult wages by a whopping 66%.

The policy proposes to ensure well-nourished children by investing in 10 interventions from salt iodization, over micronutrients, calcium and energy supplementation during pregnancy, to vitamin A, zinc, breastfeeding promotion, free food supplementation and feeding education, along with management of severe acute malnutrition. All of this will cost an additional $130 per child. The benefit will be to avoid stunting for 20% of children.

Every child helped by this package will on average see 12% higher wages. As the new generations make their way into society, it will increase national wealth. Yet, these higher wages will only occur when the children become adults, and continue way into the second half of this century. The present-day value of the increased productivity is $1,768 per child. Each dollar spent will produce almost $14 of social benefits.

It is likely the real BCR is higher, as the current analysis only look at wage increases until 50, whereas most will work longer, and does not include the benefits of avoided premature deaths.

Lower household air pollution with improved cookstoves: (BCR of 12).

Household air pollution kills more than 400,000 in Africa each year, and two-thirds are due to the use of solid cooking fuels, such as wood. The pollution could be reduced with more efficient cook stoves, either burning wood better (improved cookstoves) or with gas (LPG), but this is only used by 12% of the population in Sub-Saharan Africa.

The policy provides two improved stoves, replaced every 5 years, and include costs for maintenance and promotion to increase attention and demand. Over ten years, this will cost $111 per household or about $13bn over the next decade for full coverage of the entire continent. It will reduce household air pollution by 35-50%, and avoid 67,000 premature deaths each year. It will save 20 minutes of cooking time, freeing up valuable time, often for the women. Finally, because the improved cookstove is more effective, it needs 40% less wood. Given that an average household uses 2.1 hours a day collecting wood, this frees up 50 minutes. The saved time is valued at half the average wage rate. Over a decade, a family with two improved cookstoves sees slightly lower death risk worth $200, while saving half a year worth of time from cooking and collecting firewood, worth about $1,100. In total, each dollar spent delivers $11.7 in social benefits.

Gas, while much cleaner, is also much more expensive, and will likely deliver $2.5 of social benefits on each dollar spent.

Integrated Soil Fertility Management from cell phone: (BCR of 10, range of 3-18).

Can a mobile phone app on integrated soil fertility management practices increase the productivity and yield of smallholder farmers in Africa? An integrated approach that is adapted to local conditions, traditions and practices has recently been noted as a high impact approach to increasing yield. Several studies have shown that such Integrated Soil Fertility Management (ISFM) has a high impact on crop yield.

A challenge is the ability to reach the numerous smallholder farmers. Attempts at using local media e.g. radio broadcasts have their own shortcomings; the broadcast time may be inconvenient for the farmer, feedback sessions, troubleshooting issues will be difficult to incorporate in a radio broadcast.

The suggested intervention involves developing a mobile phone application and loading it with information and feed-back mechanisms for specific a crop and a specific agricultural zone, which is estimated to cost $193,000 per application with an annual maintenance cost of $34,000. This cost is held up against the value of the potential yield increase for the users of the application.

The benefit to cost ratio over a 5-year period varies from 3 to 18 with the number of smallholder farmers served (900 to 2,000) and the yield value for the crop increase. However, the benefits exceed the costs already after the first year for all analyzed mobile applications.

Voluntary medical male circumcision: (BCR of 10 in a range of 1.2-45).

At $90 per person in Sub-Saharan Africa, male circumcision is one of the most effective and cost-effective HIV prevention interventions. However, benefits depend strongly on age of circumcision, prevalence and treatment coverage. Circumcision of 15 years olds will help avoid HIV infection for the male, his female and possible male partners, along with consequent mother-to-child transmission across entire sexual career. The effectiveness declines sharply for individuals older than 20.

With higher HIV prevalence, circumcision protects more and lead to higher benefits. With higher treatment coverage, circumcision has less to prevent and hence has lower benefits. With 20% HIV prevalence, 81% treatment coverage and focusing on 15-year olds, each dollar spent delivers $10 of social benefits. (Botswana has 22.8% prevalence and 84% treatment.) With a lower treatment rate of 50% at 20%, the benefits reach $45 per dollar spent (South Africa is close at 18.8% prevalence and 61% treatment). With 81% treatment and 10% prevalence, like Zambia, the benefits drop to $5, and with just 5% prevalence, like Kenya, it drops to $3. This is not a policy for nations with negligible HIV prevalence.

Reduced adolescent pregnancy through education: (BCR of 10).

More than 20,000 girls under the age of 19 years give birth every day in low- and middle-income countries, and while declining globally, it has remained constant in Sub-Saharan Africa. Adolescent pregnancy has higher risks for mother and child, with the young mother three times more likely to die during pregnancy, and making pregnancy the second-leading cause of death for 15-19 year old girls. It also school drop-outs, and lost productivity.

The policy proposes comprehensive sexual and reproductive health education from grade 4-8, taught one hour per week by health extension workers. Based on estimates from rural Ethiopia, the annual costs are $2 per girl. The benefits for a million girls by postponing adolescent pregnancy a few years will be to avoid 359 maternal deaths and 980 infant deaths, along with saved health care costs, valued at 10.2 times the cost.

10% Marine Protected Areas: (BCR of 9).

Marine ecosystems provide services like nutrition, coastal protection, recreational opportunities and climate regulation. Unfortunately, they are degrading around Africa, with currently just 0.02% of Africa's territorial waters protected. The policy proposes to increase Marine Protected Areas to 10% in 561 MPAs. The costs would consist of $90m per year in management of the MPAs, and about $1,220 m per year in lost fishing incomes from the areas closed to fishing, especially livelihoods for small-scale fisheries. However, the benefits would be substantial, at about $12.4bn a year. These come from increased benefits to fisheries elsewhere, as the MPAs act as hatcheries to sustain fisheries elsewhere along with tourism and recreation and coastal protection, biodiversity, and carbon sequestration. In total, each dollar spent will provide $9.2 in social benefits. In addition, the analysis shows that increasing protection further to 30% is unlikely to provide benefits much larger than the costs.

Rural access to basic water: (BCR of 9).

Water is crucial for life and health, and central to the promises of the SDGs. Basic water means an improved water source with collection time (including queuing) of no more than 30 minutes. Yet, Africa is trailing other regions in access, with 17% of rural households using more than 30 minutes and only 46% of rural areas in Sub-Saharan Africa having at least basic water access.

Ensuring full access to basic drinking water for rural areas in Africa by 2030 will cost $26.7bn or about $2.5bn per year, with half being capital cost, the other half capital maintenance and annual operations cost. Yet, the benefits are much higher at $243bn, meaning each dollar spent provides $9.1 of social benefits. The benefits relate to both health benefits and time savings of reduced time spent collecting water (for mainly women and children), and financial savings related to seeking less health care.

Fair policies that can be immediately scaled up (expected BCR between 1 and 5)

Community Health Workers for Tuberculosis control: (BCR of 4.8).

Africa saw 417,000 dead from tuberculosis in 2016, causing 5% of all deaths. The policy proposes to four-fold increase the funding for Community Health Worker platforms, based on evidence from South Africa, one of the nations with the highest African TB rates. It estimates the total costs over 10 years at $378m, but saving 44,000 lives. The costs include paying CHWs the national minimum wage, systematic ongoing training, dedicated supervision, computer-aided planning, patient monitoring and data analysis by team supervisors, mobile phones for both supervisors and the CHWs and the adequate refilling of job kits and airtime. In total, the social benefit is five-times the cost. The author estimates that BCRs will be similar for most other countries.

Treating childhood cancer: (BCR of 4.6).

About 170,000 children below 15 will get cancer in Africa in 2020. Half will not be diagnosed, and only about 10,000 will survive. If Africa had the diagnosis of the rich world with97% diagnosed and 80% survive, it could save another 120,000 children next year. It would also signal that cancer is survivable and reduce stigma.

A comprehensive cancer care center, based on a study in Accra, Ghana, shows that the cost per child diagnosed is $10,540 (regardless of type) and $1,491 of indirect costs to families (travel, accommodation costs associated with seeking treatment; and lost work time of the parents). The social benefits per child is 4.6 times higher, because each child will increase its survival chances by 35% and live an extra 57 years.

The paper also suggests that higher BCRs (9-19) could be obtained if focus on treatment of five highly curable childhood cancers, which represent relatively low cost and feasible interventions (acute lymphoblastic leukemia, Burkitt lymphoma, nephroblastoma, non-Hodgkin lymphoma, and early stage retinoblastoma). However, costs are somewhat unrealistically low, given assumptions of zero diagnosis costs, although these childhood cancers would be very rare, and no indirect family costs. If efficiency improves over time, it is also likely that the BCR could increase.

Urban access to basic water: (BCR of 4.5).

Water is crucial for life and health, and central to the promises of the SDGs. Basic water means an improved water source with collection time (including queuing) of no more than 30 minutes. Yet, Africa is trailing other regions in access, with only 84% of urban areas in Sub-Saharan Africa having at least basic water access.

Ensuring full access to basic drinking water for urban areas in Africa by 2030 will cost $38.4bn or about $3.5bn per year, with half being capital cost, the other half capital maintenance and annual operations cost. Yet, the benefits are much higher at $175bn, meaning each dollar spent provides $4.5 of social benefits.

Resilience to drought: (BCR of 3.6).

Responses to catastrophes often come late, cost more and help less. Since 1900, the Horn of Africa has experienced more than 18 famine periods.

The policy proposes an alternative to a late and ineffective response. Over a 15-year period it estimates the costs of establishing an early humanitarian response, a safety net for poor in areas affected by drought, and investment in resilience building household incomes. The costs are estimated for 15 million people across Kenya, Ethiopia and Somalia, but could likely be extrapolated to other chronically food insecure areas.

The total cost is $2.9 billion, with more than 95% from household transfers. The benefits would run to $10.3 billion, with half from avoided late and ineffective aid, almost all the rest from the actual benefits from transfers and from avoided income and livestock losses.

The benefit-cost ratio is likely somewhat underestimated, as it only includes benefits in drought situations.

SME training & credit: (BCR of 3.1).

African small- and medium-sized enterprises (SMEs) often have a hard time growing. The policy suggests more training and better credit support. It estimates the costs and benefits with a concrete example of a SME taking scrap metal and turning it into agricultural equipment like millers, threshers, ploughs, canning, steel and metal processing. Based on 5-year estimates from Ghana, Kenya and Malawi, the costs produce 3.1 times in social benefits.

Scale-up solar energy for unreliable urban grids: (BCR of 3).

Power-outages have huge costs in terms of lost production and sales, along with extra costs and pollution from diesel generators. Based on case studies from Ghana and Kenya, the policy proposes to install solar panels (PV) and battery storage to help increase reliability in unreliable, urban power girds. It will also include smart meters, charging ports, water dispensing facilities, charging points, solar coolers and solar pumps. In total the costs for an energy park increasing reliability for 8,000 people will cost about $3m. The benefits sum to $9m, with two-thirds from avoided power outage losses and improved power quality, about $1m from environmental benefits of less pollution and CO_2, and half a million in avoided diesel costs. Each dollar spent will produce $3 of social benefits.

Community Health Workers for Hypertension control: (BCR of 2.3)

Hypertension ranks among the main causes of mortality in sub-Saharan Africa (SSA). A principal contributor to cardiovascular disease, a costly and debilitating occurrence, in which many African households find themselves undertaking significant expenditures, in some cases considered catastrophic vis a vis their disposable income. The Pan-African Society of Cardiology (PASCAR) has identified the screening and treatment of hypertension as the first priority to reduce the burden of cardiovascular diseases in sub-Saharan Africa (SSA). Hypertension detection in Africa currently relies on opportunistic screening at health facilities. With the non-existence of health facilities in remote/rural areas and the shortage of staff willing to go to those areas, task-shifting or task-delegation has been positioned as a practical solution for improving hypertension control. Thus, the benefits and costs associated with the scaling-up of the screening and treatment of hypertension using community health workers as active case-finders have been analyzed. Screening everyone, that is potentially hypertensive, reveals itself to be an expensive proposition, as prevalence rates in SSA average 46%. The model analyzed is active case detection by professional community health workers, which results in modest benefit-cost ratios of 4.3 in South Africa, Nigeria 2.1, and Kenya 2.3.

Graduation from ultra-poverty: (BCR of 1.9).

Tackling poverty is the first SDG and the priority area for the first goal of the African Union's Agenda 2063. Yet, globally there are still 736m people living in extreme poverty, half of whom live in Sub-Saharan Africa. One important way to address poverty is through the Graduation Model, which create self-employment with seed capital and a transfer of asset (usually livestock). It is supported by early cash stipends, financial inclusion, training and coaching to help protect the asset and maximize profitability of the micro-enterprise.

Based on randomized control trials in seven countries, we have good information about costs and benefits. Typically, the benefits are only measured in increased consumption. If this only last for a year, the policy is not worthwhile, but as studies show It is likely to persist for many years and some up to 14 years, the average benefit discounted over 15 years outweigh the costs by $1.89 for every dollar invested. Some studies indicate that there are also other benefits like reduced stunting, which could make the BCR somewhat higher.

Improved sanitation: (BCR of 1.6).

Lack of sanitation leads to more disease and death, yet only 30% of Sub-Saharan Africa had access to basic or safe sanitation in 2017. The brief estimates the effectiveness of rolling out Community-Led Total Sanitation (CLTS) to an average African population. The program is not

just about teaching people about the health benefits, but about CLTS facilitators conducting community participatory exercises that aim to "trigger" behavioral change, engendering shame and disgust among village residents who engage in open defecation.

The costs are program delivery, latrine construction, and the time households spend participating. If everyone in a village of 500 people participates, the total cost is $8,365. Two-thirds of this cost comes from the CLTS program and the time spent participating, with a third costs to latrine construction and maintenance.

The benefit is more than three times as high, with almost half the benefits from avoided death, 30% from avoided disease and 20% from less time spent having to walk to an open defecation site.

However, not all villages will participate fully, with the low-uptake villages still incurring all the program costs and some of the latrine costs but achieving only a small fraction of the benefits, leading to poor return of 60¢ on the dollar.

Using data to estimate the relative proportion of low- medium and high-uptake villages, the brief estimate that on average, the costs run to $6,600 per village, and delivers social benefits 1.6 times that.

High speed train network: (BCR of 0.9-1.5).

Investment in transport is viewed as a way of boosting economic growth, linking cities, accelerating urbanization and strengthening regional integration. With Africa land total area of about 30.37 million km², the vast distance between North and South as well East and West, makes movement of cargo and passenger even more difficult.

The AIHSRN is expected to connect 54 countries, the study only provides the case for only 10 countries where 44 links estimated at 42,657 km are identified and are projected to meet a freight demand of between 156,325 - 225,637 million tonnes per year between 2020 and 2063. The project is expected to be constructed between 2020- 2024 and has a lifespan of 50 years. The capital cost for the subset included in this study is $878 billion, more than a third of the combined African GDP. This is before any cost increases, which accompany many large infrastructure projects. In addition, the annual recurring costs are estimated at $2.4 billion.

The value of time savings, reliability and reduced road traffic injuries have all been estimated, but are dwarfed by the benefits from increased trade and economic contribution of the high-speed rail industry following the investment. Together these two factors make up 97-98% of the total benefits.

For policy decisions, it is important to take considerations of the country specific CBRs and also the link/track specific CBRs. Among the links/tracks with the highest CBR are in Nigeria and South Africa at 5.5-8.8 and 2.8-4.5 respectively. Subsequently several risks factors such as capital costs, construction costs, and operating costs, traffic demand, economic growth level, value of time and discount rates are critical for investment decisions. Mozambique is among the countries with links that have the lowest CBR of about 0.03 to 0.06

Poor policies that can be immediately scaled up (expected BCR between 1 and 5)

Off-grid rural electrification: (BCR of 0.3-0.9)

"Off-grid rural electrification" reminds most of us about bringing solar lanterns to rural communities who otherwise use kerosene for lighting. The menu of technological options is, however, much broader than solar lanterns, including mini-grids, energy kiosks, and individual systems.

Past studies have listed a range of benefits associated with electrification, these benefits include education, health, safety, income, economic development, and time-savings. Recent studies, however, provide conflicting evidence on the realized impacts. Studies in Kenya report no impact, while other studies report significant impact in South Africa, Kenya, Mozambique, Rwanda, Tanzania, and Uganda. However, the internalized portion of the benefits can be captured by Willingness to Pay (WTP) studies.

The investment costs for solar home systems range from 13 to 182 USD for 0.5 Watt, a 3.3 Watt, and a 20 Watt device. However, the willingness to pay is significantly lower, between 38% and 55% of the price of each device, or about 70 cents to 1.05 USD per month and household. But this consumer-based estimate is unlikely to incorporate longer term educational and health benefits.

Studies in Rwanda, Burkina Faso, and Indonesia show report that access to electricity has no impact on the total number of hours studied. A recent evaluation report in El Salvador (2017 MCC), however, reports the health impacts of electrification due to improved home air quality. This study uses the relative risk published by 2017 MCC for cardiovascular disease and lung cancer, along with the Disability-Adjusted Life Years estimated reported by 2018 Lancet and the value of statistical life reported by 2017 Viscuzi to calculate the value of health benefits. The value of DALYs averted per household per month in Sub-Saharan Africa is 2.05 USD.

In total the revealed benefits and health benefits do not exceed the cost of serving this demand using micro-grids, which is 3.45 to 9.44 USD per month. Resulting in every dollar invested in off-grid rural electrification using the studied technologies only generates 30 to 90 cents worth of benefits.

Family Planning

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Summary

The impact of population growth has received increased recognition within the post-2015 global development agenda as a key challenge to human and socioeconomic development (1,2). While much of the world's population is now estimated to live in regions with either rapidly declining or achieved low fertility, many low- and middle-income countries, particularly in Sub-Saharan Africa, continue to experience high rates of fertility and unintended pregnancy, premature mortality, and poor reproductive health outcomes (3,4).

Expanding access to family planning and reproductive health services play an important role in empowering women, men, couples, and adolescents to realize their reproductive rights and intentions by allowing them to avoid unintended pregnancy and choose whether and/or when to have a child. Family planning is beneficial to individuals, families, and societies alike, and investing in the expansion of family planning and reproductive health services has been recognized as an essential step to achieving many of the Sustainable Development Goals (SDGs) (5). Reducing global unmet need for contraception would prevent an estimated 40 percent of maternal deaths, reduce child mortality by up to 20 percent, and avert 36 million years of healthy life lost each year (6,7). Additionally, investments in family planning would also contribute to expanded access to education, women's empowerment, the prevention of HIV, poverty reduction, and environmental sustainability, making it one of the most cost-effective global health and development interventions (8).

Problem Identification and Scope

Economic evaluations that assess both costs and effectiveness of interventions are receiving increased consideration in the decision-making process in low- and middle-income countries. These evaluations allow for the effective prioritization of competing needs in resource-constrained settings. While some studies have assessed the effectiveness as well as cost effectiveness of approaches to improving maternal and child health, the synthesis of evidence on cost effective strategies in early interventions, such as family planning, is limited, particularly in the Sub-Saharan African context (9).

This brief outlines the benefits and costs of scaling up investments for family planning programs in Sub-Saharan Africa, where contraceptive use is low relative to the rest of the world (only 23.9 percent of women of reproductive age in Sub-Saharan Africa use a modern method of contraception (10)) and unmet need for family planning is relatively high (more than 1 in 5 women of reproductive age in Sub-Saharan Africa report having an unmet need for family planning (7)).

Types of Family Planning Programs and Interventions

Comprehensive family planning programs and interventions include components that target both family planning demand (e.g. sexual and reproductive health behavior change communication (BCC) approaches, information campaigns, counseling) and supply (improving access to and quality of contraceptives and family planning services) (11). More recently, the number of family planning programs that have undergone more rigorous impact evaluation has increased, and more studies have begun to utilize experimental and quasi-experimental methods to assess the health and broader socioeconomic effects of family planning programs. Family planning interventions can be generally classified into one or more of the following domains:

a) Interventions that aim to improve client access to services through price or cost reduction mechanisms, e.g. voucher schemes, providing free or subsidized access to contraceptives and services, microcredit financing schemes for family planning, etc.

b) Interventions that seek to improve contraceptive use and generate demand by increasing awareness, counseling, access to reliable information, and access to education resources.

c) Interventions that seek to directly increase supply and effective distribution of contraceptives and services to end users.

d) Interventions that promote family planning through community level engagement by improving community-based distribution channels and increasing local capacity.

e) Interventions that seek to improve FP use and access through social franchising mechanisms.

f) Interventions that focus on training of FP health personnel as a means to improve service delivery.

Costs of Family Planning Programs

Costs related to the provision of family planning services, both from the perspective of the client (demand side) and service provider (supply side) can be classified into the following categories:

a) **Direct medical costs for seeking family planning services to the supply (provider) side,** which include 1) costs for contraceptive commodities, commodity-related supplies (gloves, pregnancy tests, etc.), and procurement of equipment; 2) supply chain costs, including shipping, storage, and distribution of supplies; 3) health personnel and service provider costs, which include costs of counseling clients, method provision, and method follow-up (particularly for resupply methods).

b) **Direct non-medical costs for seeking family planning services to the supply (provider) side,** which include overhead / administrative costs and other capital costs for out-patient care.

c) **Direct medical and non-medical costs for seeking family planning services to the demand (client) side,** which include transportation costs and all out-of-pocket expenditures for seeking family planning services (consultation fees, follow-up fees, expenses related to the treatment and management of contraceptive-related side effects, etc.).

d) **Indirect costs to the supply (provider) side,** which can mainly be classified as program and systems costs and include costs related to program management, supervision and training of personnel, monitoring and evaluation, human resources development, transport and telecommunications, health education, outreach and advocacy, infrastructure improvements, and health management information and commodity supply systems.

e) **Indirect costs to the demand (client) side**, which include costs related to the loss of time and productivity from seeking care, adherence costs (for clients who use resupply methods), productivity losses from contraceptive-related complications, and costs related to contraceptive failure, including pregnancy and pregnancy-related complications (both direct and indirect).

COST ESTIMATES

From Adding It Up (7): Expanding contraceptive coverage to 100 percent (covering all unmet need) for all women in all LMICs from status quo would cost $12.1 billion per year in both direct and indirect costs, compared to current $6.3 billion per year expenditures on FP. There are 214 million women in LMICs with an unmet need for FP, which means that the additional cost per woman to fully cover FP (and cover unmet need) would be ($12.1 billion - $6.3 billion) / 214 million women per year = $27.10 per woman per year.

Alternative estimate: FP2020 ROI PPT states that the regional average cost of FP is $11.20 per couple-year of protection (CYP) in Sub-Saharan Africa.

21 percent of 214 million women with an unmet need for FP are from Sub-Saharan Africa, implying a total of 44.9 million women in Sub-Saharan Africa with a continued unmet need for FP. Covering all FP related costs (direct and indirect) for these 44.94 million people would cost: $27.10 * 44.94 million = $1.22

billion per year to cover all FP services for women in Sub-Saharan Africa. Costs in future years depend on changes in fertility desires and thus demand for family planning, changes in the population size and age structure, and changes in marriage and human capital levels. These factors interact, and in the absence of detailed estimates of unmet family planning need in Sub-Saharan Africa, we assume that the same expenditures can be applied over a longer time horizon (1).

Benefits and Benefit-Cost Ratios

Universal access to reproductive health services and voluntary family planning provides several benefits for women, children, families, and communities. These benefits include:

a) **Health benefits to women and children:** Family planning minimizes life-threatening complications for mothers and their children by reducing fertility-related risks, which include reduction of high-risk pregnancies, pregnancies that are too closely spaced, pregnancies that end in unsafe abortion, and overall fertility.

b) **Increased Education, Employment of Women:** Family planning lowers the opportunity cost of childbearing for women, which in turn allows them to stay in school, complete more schooling, seek employment, and be employed.

c) **Empowerment of Women:** Through the creation of new opportunities for women and the securing of reproductive rights

d) **Poverty Alleviation through Demographic Dividends:** At a population level, family planning enables population shifts through lower childbearing, lower population growth, and an increase in the share of working age adults relative to young children (dependents), which contribute to poverty reduction and are conducive for individual, household, and country-level development.

ESTIMATES OF BENEFITS

Benefit 1: Cost savings from reduced health, education, and other societal expenditures from increased populations. Between 4:1 and 7:1 cost savings (1), so take the average to be 5.5:1 benefit-cost ratio.

Benefit 2: Aversion of infant mortality and maternal mortality: Adding It Up predicts that modern contraceptive use prevented 188 million unintended pregnancies, 1.2 million newborn deaths, and 230,000 maternal deaths and other negative health outcomes that would have occurred in the absence of any modern method use. $110 billion in benefits (taking a conservative $1,000 saved per DALY, 3% discounted, with average LE at birth for infant deaths and at age 28 for maternal deaths) (2). With $6.1 billion in costs, yields a 18.3:1 benefit-cost ratio.

Benefit 3: Demographic Dividend benefits – hard to assess and account for directly. In addition to the effect of family planning programs towards reducing fertility and reducing maternal/child mortality, these programs have been shown to result in higher levels of female (mother's) education, improvements in women's general health (e.g., as indicated by BMI) and longer-term survival, increases in female labor force participation and earnings, increased child health (up and beyond the effect on reducing child mortality) and increased child human capital (including higher schooling levels. Several of these program effects will affect individual's well-being because in large-scale family planning programs—the only ones that we evaluate here—these effects will make contributions to economic growth, which in turn will affect future income levels.

From Karra-Canning-Wilde Model: a one-birth reduction in fertility in Nigeria over a 15-year time horizon yields a doubling of income per capita within 50 years ($11,114 under the high fertility variant and $21,938 under the low fertility variant), with persistent doubling of income per capita over 90-year time horizon (up to 2100). Extrapolating from the Matlab field experiment, a 37 percentage point increase in contraceptive prevalence (from 20 percent CPR in 1977 to 57 percent CPR in 1990), equivalent to a 2.9 fold increase, translated to a 15 percent decline (equivalent to a one birth decline) in TFR over the period (12–14). So, extrapolating for Nigeria, which has a 28

percent CPR, increasing CPR by 2.9 times would result in a doubling of GDP per capita.

From HPP DemDiv Model: an increase in contraceptive prevalence from 39.4 percent to 70 percent (a 77 percent increase in CPR) through expansion of FP services would yield an additional $2,540 in income per capita over a 40-year time horizon in Kenya (from $8,748 without FP investments to $11,288 with FP investments). This is a 29 percent increase in GDP per capita as a result of a 77 percent increase in CPR over 40 years.

The average CPR in Sub-Saharan Africa is 23.9 percent (10). The average GDP per capita in Sub-Saharan Africa is $1573.94 (World Bank National Accounts Data) (15). In order to achieve 70 percent CPR by eliminating unmet need, this would amount to a 192 percent increase in CPR, or almost a tripling (2.9 times) higher CPR than what was projected by HPP DemDiv in Kenya. If the relationship between CPR growth rates and GDP per capita growth rates are linear (excluding interaction effects), then a 2.9-fold increase in SSA's CPR over a 40-year time horizon, from 23.9 percent to 70 percent, would result in (at minimum) a 2.9 fold increase in GDP per capita, from $1573.94 to $4609.86, just from the Demographic Dividend effect. This is roughly a 3-fold increase in GDP per capita for a 3-fold increase in CPR (increase of $3035.92 per person).

Based on estimates from Karra-Canning-Wilde and DemDiv, a 3-fold increase in CPR (to close the unmet need for FP) in Sub-Saharan Africa, would yield a 2- to 3-fold increase in GDP per capita. Let us assume 2.5-fold increase in GDP per capita.

Cost per capita for Africa: $6.1 billion per year in costs to close unmet need gap / 1.078 billion in Sub-Saharan Africa = $5 per Sub-Saharan African per year

2.5-fold increase in GDP per capita of Sub-Saharan Africa, with a population of 1.078 billion, is a $3035.92 increase in GDP per capita per year over a 40-year period. If we bring this down to a present value increase (assuming a 5 percent discount rate), it is a $431.23 increase in GDP per capita per year. This implies a benefit-cost ratio of 431.23 / 5.01 = 86.1:1 benefit-cost ratio from the Demographic Dividend

BCR ANALYSIS

From FP2020 PPT: BCRs in Sub-Saharan Africa ranging from 2.03 to 6.22.

Calculations from just the societal cost savings and aversion of infant and maternal mortality estimates above would yield a (5.5 + 18.3) = 23.8:1 benefit-to-cost ratio (a BCR of 23.8) for Sub-Saharan Africa. This is a conservative estimate because it excludes the Demographic Dividend benefits, other welfare benefits, and the other longer-run / life-cycle benefits of increased investment in FP.

Discussion

- Family planning is highly cost-effective, with a high ROI
- The ROI in FP is likely to be much higher than what we have estimated.
- It is important to consider the relative cost effectiveness of family planning not only within the health domain but also across other domains. A comparative assessment of the cost-effectiveness of FP relative to, say, improving girls' education or building roads, would be helpful in understanding the true ROI to FP, and would also serve as a point for advocacy for FP with policymakers and the Ministries of Finance by showing that FP is not only the best buy in health but the best buy more generally.
- Including the Demographic Dividend estimate of 86.1:1 BCR, and combining it with the cost-saving + IM/MM BCR, we would get a total estimated BCR of 109.8:1.

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Women's Empowerment Collectives (self-help groups)

Courtney Cabot Venton

Summary

Women's Empowerment Collectives – also known as Self Help Groups (SHGs) - are voluntary groups, typically comprised of 15-25 women who meet every week to save, start small business activities, and grant loans to one another. They have been used in a wide range of contexts, adapted for refugees, caregivers of orphans and vulnerable children, people living with HIV/AIDs, adolescents, as well as layered with maternal, neonatal, child, and sexual and reproductive health support.

Importantly, these groups use a combination of empowerment, collective action and economic strengthening to yield a range of substantial outcomes. A person's social capacities have been shown to be one of the strongest determinants of whether a person is able to escape and remain out of poverty, and a mounting evidence base that layers women's collectives with health messaging has yielded very significant reductions in maternal and neonatal mortality. While the evidence is still nascent, Self Help Groups offer the potential to catalyze and leverage poverty reduction efforts.

Identification of the problem

Strategies to reduce poverty are founded in the notion that poverty arises because of a resource constraint. It therefore follows that providing people with access to resources will reduce poverty. However, a growing evidence base suggests that economic strengthening is only one component of a poverty reduction strategy, and that a person's aspirations and sense of control over outcomes may have a determining effect on their pathway out of poverty. For example, a 2018 USAID evidence review[2] finds that a range of social capacities are some of the strongest determinants of whether a person or household is able to escape and remain out of poverty, including social capital, aspirations, self-efficacy, confidence to adapt, women's empowerment and gender equality. These social capacities are, in turn, variously linked to improved food security, avoidance of negative coping strategies, and ability to recover, as well as longer term outcomes such as greater access to savings and credit, child school enrollment, spending on schooling and agricultural inputs.

This narrative has played out in health investments in developing countries. Maternal and child mortality rates are unacceptably high. About 830 women die from pregnancy- or childbirth-related complications around the world every day, and 99% of all maternal deaths occur in developing countries.[3] Worldwide, the mortality rate in children younger than 5 years is still unacceptably high at 7.7 million to 8.8 million per year, and includes 3.6 million deaths in newborn babies.[4,5] More than half of all maternal deaths occur in Sub-Saharan Africa (SSA)[6], and SSA remains the region with the highest under-five mortality rate in the world. By 2050, an estimated 60 per cent of under-five deaths will occur in SSA.[7]

Most births in African countries occur at home, especially in rural areas. Health investments have taken a strong focus on supply side interventions historically, focusing on ensuring the provision of resources such as the supply of medical equipment, good facilities and trained health workers. However, supply side

[2] USAID, 2018. "Resilience Evidence Forum Report".
[3] https://www.afro.who.int/health-topics/maternal-health
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[6] https://www.afro.who.int/health-topics/maternal-health
[7] United Nations Inter-Agency Group for Child Mortality Estimation (2018). "Levels and Trends in Child Mortality"

interventions need to be complemented by demand side interventions, stimulating people's demand for health services - for example, via women's collectives - to ensure that supply side investments are used by the populations that they are intended to serve.

The proposed solution

Women's Empowerment Collectives – also knows as Self Help Groups (SHGs) - are voluntary groups, typically comprised of 15-25 women who meet every week to save, start small business activities, and grant loans to one another. They have been used in a wide range of contexts, adapted for refugees, caregivers of orphans and vulnerable children, people living with HIV/AIDs, adolescents, as well as layered with maternal, neonatal, child, and sexual and reproductive health support. This briefing note does not review one specific type of Self Help Group, but rather looks at the outcomes of a variety of Self Help Groups, some focused specifically on building social and economic capacities, others combining this with health messaging.

Evidence indicates that participation in women's groups can result in increased aspirations[8], economic[9] and political[10] empowerment, as well as improved governance and service delivery[11]. Women's groups have also been shown to help people cope in a shock or stress. Women's groups layered with health content have seen substantial decreases in maternal and neonatal mortality, as well as significant improvements in health practices.[12] A systematic review of 36 evaluations of women's groups and nutrition outcomes in Asia found promising outcomes on infant and young child feeding practices, and an analysis of the national district level household survey in India found that villages with a Self Help Group present were 19% more likely to have delivered in an institution.[13]

Despite this evidence base, in Africa, almost no trials of community mobilisation through women's groups have been done to assess effects on poverty and health outcomes.

Identification of the costs and benefits

Costs:

- A Tearfund study in Ethiopia estimated costs of GBP 50 per person (2013 GBP) comprised of overall project costs and 2 years of facilitation support to the group (or approximately 100 meetings).
- The average cost of a women's participatory group health intervention is $2.6 per person, ranging from $ 1.1-$4.5 (2016 INT$).[14] This cost is comprised of overall project costs, training of facilitators and facilitation of 20 groups meetings.

These estimates do not include the cost of the participating women's time.

Benefits

The evidence base for the impact of these collectives is nascent but highly promising. Only one study estimates BCRs, while several rigorous evaluations have estimated cost effectiveness.

[8] Sanyal et al. 2015

[9] Field et al.2016; Feigenberg et al.2013; Woolcock and Narayan 2000

[10] Parthasarathy et al. 2017; Prillaman 2018; Datta 2015; Kumar et al. 2019

[11] Casini et al. 2015; Das et al, 2016; Kumar et al. 2019

[12] Kumar, Neha, Samuel Scott, Purnima Menon, Samyuktha Kannan, Kenda Cunningham, Parul Tyagi, Gargi Wable, Kalyani Raghunathan, and Agnes Quisumbing (2018). "Pathways from women's group--based programs to nutrition change in South Asia: A conceptual framework and literature review." Global Food Security

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A 2013 cost benefit analysis of Self Help Groups in Ethiopia found that the intervention yielded benefits between $58 and $173 for every dollar spent. The methodology was not based on a quasi-experimental design, and therefore should be viewed with some caution. However, the data used was drawn from 65 Focus Group Discussions (FGDs) with 544 Self Help Group members, and 34 FGDs with 324 non-SHG members (control group). These interviews were used to gather data on income, school attendance, access to low-interest loans and stress sales of livestock.[15]

Rigorous research evaluations in Asia have shown that women's groups can have profound health outcomes. For example, a systematic review of Randomized Control Trials in multiple countries to assess the impact of women's groups on maternal and child mortality in Asia found that participation in women's groups was associated with a 37% reduction in maternal mortality, a 23% reduction in neonatal mortality, and a 9% reduction in still births.[16] A quasi-experimental design in India found that women's Self Help Groups that received additional training around maternal, neonatal and child health found that women's health practices improved, with women more likely to use contraception, practice skin-to-skin care and breastfeed.[17]

Along similar lines, an evaluation of women's groups combined with health education by peer counsellors in Malawi found that, for women's groups, maternal mortality fell by 74% and neonatal mortality by 41%. The cost of women's groups was US$114 per year of life lost (YLL) averted and that of peer counsellors was US$33 per YLL averted, using stratified data from single intervention comparisons.

Implications for scale up

These findings are likely to be highly replicable at scale, and across countries. A single Self Help Group can deliver gains across a wide range of measureable outcomes, including income generation, education, health, livelihoods, and peacebuilding, to name a few. Hence economies of scale are likely to be very high. Further, inherent to the Self Help Group model is a scalable federated structure, represented by Self Help Groups members, that are able to engage at a systems level, with formal legal recognition, the ability to take out large scale loans on behalf of group members, and able to advocate for access to basic services.

Self Help Groups and Women's Empowerment Collectives are numerous and widespread, but have received little visibility or investment. The intervention is already widespread, and may be replicated at scale. Self Help Groups can saturate at 70% of a community population, and replicate organically and virally.

However, the model is also founded in peer support, solidarity, and trust. These core principles are essential for successful Self Help groups, and therefore there is a risk that these groups will fail if they are expanded rapidly or with external financial incentives to achieve scale. Rather, a programmatic approach should focus on mapping and investing in the very large ecosystem of Self Help Groups that exist already, and facilitating investments in the systems that can support them to thrive, for example by ensuring that access to markets,

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health facilities and education are readily available.

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Investments in agricultural yield increase in Africa

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Introduction

The population of Africa is projected to increase by more than 50% between 2010 and 2030, from 1.03 billion persons to 1.54 billion (Mason D'Croz et al. 2019). This rapid population growth together with strong income growth in Africa will result in big increases in food demand, putting strong pressure on food production. Food production growth also faces challenges from climate change, with higher temperatures and changing precipitation patterns as well as likely increased weather variability. With limited scope for expansion of crop and pastureland, increased agricultural productivity growth will be required to meet growing food demand, boost incomes, and reduce hunger.

As noted in Mason-D'Croz et al. (2019), since the 1960s, increasing agricultural productivity has been critical for reducing poverty and hunger globally (Pingali 2012; Dercon & Gollin, 2014; McArthur, 2015). However, Africa has benefited less than other regions from past investments and continues to have low agricultural productivity by global standards (GYGWPA, 2017). It is therefore important to understand the potential for alternative agricultural and rural sector investments to meet the challenges to food production growth in Africa through higher productivity, and to evaluate the economic returns to these investments. This note estimates the benefit-cost ratios of alternative investments to increase food production and reduce hunger.

Methodology

IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) is utilized here to explore the impacts of alternative agricultural investment scenarios on agricultural yield and production and hunger in Africa. The IMPACT modeling system allows analysis of socioeconomic and climate pathways with different assumptions about policy, agricultural research and development (R&D) investments, and investments in rural infrastructure and irrigation and water management. IFPRI's IMPACT model is an integrated modeling system that links information from climate models (Earth System Models), crop simulation models (for example, Decision Support System for Agrotechnology Transfer), and river basin level hydrological and water supply and demand models linked to a core global, partial equilibrium, multimarket model focused on the agriculture sector and a global general equilibrium model, GLOBE (see Robinson et al. 2015 for a detailed description of IMPACT). The linkage with the GLOBE model enables the assessment of the economy-wide impacts of climate change and agricultural investments, including gross domestic product (GDP) and per capita income, which are essential for determining the rate of return to investments.

The IMPACT and GLOBE model baseline scenarios are calibrated with respect to agricultural productivity, GDP, prices and economy-wide GDP. To accomplish this calibration, IMPACT variables including GDP growth, population growth, agricultural land supply and endogenous agricultural price projections from IMPACT are aggregated to match with the regional and sectoral aggregation structure of the GLOBE model. Once the models are calibrated, to assess the economy-wide general equilibrium economy-wide effects from any given IMPACT scenario, and to evaluate the resulting aggregate income and welfare effects, the agricultural productivity changes simulated in IMPACT are translated into corresponding productivity changes at the GLOBE region and activity level and are then replicated in GLOBE.

For example, climate shocks on agricultural productivity and prices simulated in IMPACT

scenarios are transmitted from IMPACT to GLOBE, and GLOBE then simulates the impact on the rest of the economy. An additional iteration is then done to transmit the economy-wide effects on GDP back to IMPACT, so that the income effects on food demand are also captured. The same procedure is followed for investment scenarios (Willenbockel et al. 2018).

Scenario Specifications

For the application in this note, the linked IMPACT and GLOBE models are used to simulate projected agricultural outcomes under a reference scenario that includes baseline agricultural productivity growth together with climate and economic scenarios drawn from work developed for IPCC's fifth assessment report. These scenarios are defined by two major components. First, Shared Socioeconomic Pathways (SSPs) are global pathways that represent alternative futures for economic and population growth (O'Neill et al. 2014; O'Neill et al. 2015). Population growth and GDP growth are drawn from SSP2, which is a middle-of-the-road scenario that follows historical trends on economic and demographic growth. The SSP2 rates of population and initial GDP growth are maintained as the exogenous rates for the alternative investment scenarios. The changes in GDP growth under the different scenarios are made endogenous to the specified scenarios through the linkage to GLOBE that is described above.

The second component is the Representative Concentration Pathways (RCPs), which represent potential greenhouse gas emission levels in the atmosphere and the subsequent increase in solar energy that would be absorbed (radiative forcing). There are four RCPs, which are named according to the approximate level of radiative forcing in 2100, which ranges from 2.6 watts per square meter (W/m^2) to 8.5 W/m^2. RCP8.5, which is the strongest climate change scenario, is utilized here as the climate change scenario. In 2030 the differences between these four RCPs are very small in carbon dioxide equivalent concentrations and radiative forcing (Mason-D'Croz, et al. 2019, Figure 2). Major divergences across the RCPs occur after 2030.

Following establishment of the reference scenario, two investment scenarios are run. First, a comprehensive investment scenario (COMP) is simulated for agriculture and the rural sector, which combines increased investments in agricultural R&D, irrigation expansion, water use efficiency, soil and water management, and rural infrastructure in developing countries. Rural infrastructure includes rural roads, rail, and rural electrification. These investments generate economic benefits through several pathways. Increased agricultural R&D boosts crop and livestock yields, reduces food prices, and increases farm income and economy-wide GDP through multiplier effects on the non-agricultural sectors. Irrigation and water use efficiency investments increase crop yields and reduce prices, thereby generating higher incomes. Enhanced rural infrastructure reduces post-harvest losses and marketing margins, improving the profitability of farm production, and boosting supply to consumers for any given level of production. These effects also increase farm and broader income. The COMP scenario is described in more detail in Mason-D'Croz et al. (2019), which also provides the key underlying results required for the computation of economic returns to investment.

Second, the impact of agricultural R&D is assessed separately in a scenario that simulates increased investment in international agricultural R&D (the HIGH scenario), which is described in detail in Rosegrant et al. (2017). This HIGH agricultural R&D scenario here is specified as increases in expenditures on crop and livestock breeding and supporting activities in the International Agricultural Research Centers of the Consultative Group on International Agricultural Research (CGIAR) in Africa. In addition to public expenditures on agricultural R&D, private sector investment in agricultural R&D plays an important role in agricultural productivity growth. In much of the world, private sector investment in agricultural R&D has increased faster than public sector investment, but private sector investment in agricultural R&D remains low in Africa and other low-income regions. Whereas private firms in rich countries spent $1.10 for every

dollar of public agricultural R&D in 2011, private investment in low income countries was only $0.15 for every dollar of public investment in agricultural R&D (Pardey et al. 2016a). Projected growth in private sector investment in agricultural R&D reflecting recent growth trends is included in the reference scenario. Alternative scenarios for private sector investment in agricultural R&D are not simulated here, since the focus of this report is on public investments.

Among the results generated by these simulations are the projected per capita income for Africa in 2030 under the reference scenario and the COMP and HIGH scenario. Through the utilization of the GLOBE CGE model, the net economic benefits represented by per capita income, account for changes in costs and returns to inputs not only in the agricultural sector, but also income effects in the broader economy that are induced by the increased productivity growth due to agricultural research and development. In the model, producers in each sector and region combine primary factors (that is skilled and unskilled labor, physical capital, land and other natural resources) and intermediate inputs obtained from the same and other production sectors at home and abroad to produce outputs. The production process generates factor income in the form of wages, other in-kind returns to labor, land and natural resource rents and returns to capital as well as producing tax income for the government (Willenbockel et al. 2018). These results are then utilized to compute the net present value (NPV) of the stream of income benefits, 2015-2030. The benefit-cost ratio of additional agricultural investments is then computed as the ratio of the NPV of benefits to the NPV of the stream of additional investment costs.

Results

The COMP investment portfolio has a total annual additional cost for all developing countries to be about $52 billion per year from 2015 to 2030 (Mason-D'Croz et al. (2019), Table 5). The total annual investment cost for Africa and West Asia is almost $15 billion per year, or 29 percent of total investment across all developing countries (Mason-D'Croz et al. (2019), Table 5).

The stream of additional investments is shown in Table 1 here. The per capita GDP benefits of the additional investments are projected to be $228 per capita GDP in 2030 compared to the reference scenario (Mason-D'Croz et al. (2019), data underlying Table 6). The increase in total GDP is $350 billion in 2030 compared to the reference scenario, computed by multiplying the gain in per capita GDP in 2030 by the projected population in 2030. The annual stream of GDP benefits between 2015 and 2030 is computed as proportional to the cumulative increase in investments and is shown in Table 1. The NPV of incremental investment costs at a 5% discount rate is $171 billion and the NPV of income benefits is $1,747 billion. The benefit-cost ratio is therefore 10:1, showing high economic returns to investment in agriculture and rural infrastructure.

The HIGH agricultural R&D scenario has a much higher benefit-cost ratio. The average annual incremental investment in international agricultural R&D of the HIGH scenario is $0.67 billion per year from 2015 to 2030 (Mason-D'Croz et al. (2019), Table 5), which is double the average investment in the reference scenario (Mason-D'Croz et al. (2019), Table 4). The GDP benefits of the additional investment in R&D are projected to be $69 per capita GDP in 2030 compared to the reference scenario (calculated from Rosegrant et al. 2017). Following the procedure described above, the increase in total GDP is $106 billion in 2030 compared to the reference scenario, computed by multiplying the gain in per capita GDP in 2030 by the projected population in 2030. The annual stream of GDP benefits between 2015 and 2030 is computed as proportional to the cumulative increase in investments and is shown in Table 2. The NPV of incremental investment costs at a 5% discount rate is $5.6 billion and the NPV of income benefits is $290 billion. The benefit-cost ratio is therefore 52:1. Investments in agricultural R&D have very high rates of economic returns in Africa. This result can be compared to the findings in Pardey et al. (2016b), which reviews existing studies of economic returns to agricultural R&D between 1975 to 2014. The review included 129 benefit-

cost ratios (BCRs), which averaged 30:1. However the comparison of these BCR results is not fully comparable, since the discount rates used in these BCR computations reviewed in Pardey et al. (2014) are not provided. The high BCR estimates here, and in the literature, indicate that investments in agricultural R&D in Africa are far too low.

Hunger-Calorie Pathway

Schofield (2014) finds that an increase in per capita calorie consumption by 700 calories per person in a low-calorie population results in an increase in income by 10%. The COMP scenario results in an average national increase of 250 calorie per person in 2030 (Mason-D'Croz et al. 2019, Figure 8). Assuming that the 220 million persons classified as hungry in 2010 achieve the same average increase in calorie consumption, per capita income of hungry people will increase by 3.6% (250/700 times the 10% increase in per capita income from Schofield (2014)). Next, assume that the per capita income of hungry people is one-half of the national average in the reference scenario, or $2,550 per capita in 2030. The increase in per capita total income for this cohort is then $91 (3.6% times $2,550) in 2030. Multiplied by the 220 million hungry people who achieve this gain, the increase in total income amounts to $20 billion in 2030. The annual stream of GDP benefits between 2015 and 2030 is computed as proportional to the cumulative increase in investments, at a 5% discount rate and at a 0% discount rate. The benefit-cost ratios for these hunger-calorie benefits cannot be estimated separately from the yield-income benefits computed above, because they are joint outcomes of the COMP investment scenario. Adding the two streams of benefits generates a benefit-cost ratio of 10.8:1 if the hunger-calorie benefits are discounted at 5%, and 11.1:1 if these benefits have a 0% discount rate.

The HIGH scenario results in an increase in annual calorie consumption of 88 calories per capita in 2030, as calculated from Rosegrant et al. (2017). Following the method described above for COMP, the increase in total income in 2030 is $7 billion. The benefit-cost ratios of the combined yield-income and hunger-calorie benefits under HIGH are 55:1 with the hunger-calorie benefits discounted at 5% and 58:1 with these benefits discounted at 0%.

Conclusions

Broad-based investments in agricultural R&D and rural infrastructure generate very large total economic benefits and big reductions in hunger in Africa. Because of the high cost of physical infrastructure such as roads, electricity, and irrigation, the BCR of a comprehensive package of these investments is lower than for increased investments in agricultural R&D, although it still has a substantial BCR of 10:1. Given the high impacts on economic growth, these investments warrant serious consideration as necessary complements to agricultural R&D and targeted investments in hunger and nutrition programs. As a stand-alone investment program, increased spending on international agricultural R&D has a very high BCR of 52:1. This result indicates severe underinvestment in agricultural R&D in Africa and the need to substantially increase such investment. The International Agricultural Research Centers of the CGIAR are well-placed to scale-up agricultural R&D investments in Africa, with research facilities and programs in place in many country and regional programs across Africa. A phased doubling of investments between 2015 and 2030 is highly feasible. As with any increase in investments, there are risks, including the rate of success of generating well-adapted new technologies, and the rate of adoption of these technologies. To address these risks and achieve the large potential benefits of increased investment in agricultural R&D (and rural infrastructure), key stakeholders, such as governments, non–government organizations, international donor agencies, and the private sector should be involved. And, as with all interventions, enabling conditions should be improved, including access to credit and risk insurance, extension services, and complementary inputs.

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TABLE 1. ANNUAL INVESTMENT COSTS AND ECONOMIC BENEFITS OF COMPREHENSIVE INVESTMENT (COMP) IN AGRICULTURE AND INFRASTRUCTURE IN AFRICA, 2015-30, US$ BILLION.

Year	Costs	Benefits
2015	27.7	10.9
2016	58.7	34.1
2017	58.8	57.2
2018	58.9	80.5
2019	58.9	103.7
2020	59.0	126.9
2021	59.1	150.2
2022	59.2	173.6
2023	59.3	197.0
2024	59.4	220.4
2025	59.5	243.8
2026	59.6	267.3
2027	59.8	290.9
2028	59.9	314.5
2029	60.0	338.2
2030	32.5	351.0

TABLE 2. ANNUAL INVESTMENT COSTS AND ECONOMIC BENEFITS OF INCREASED INVESTMENT IN AGRICULTURAL R&D IN AFRICA, 2015-30, US$ BILLION.

Year	Costs	Benefits
2015	0	0
2016	0.05	0.5
2017	0.1	1.6
2018	0.16	3.3
2019	0.23	5.8
2020	0.31	9.1
2021	0.4	13.4
2022	0.49	18.6
2023	0.59	25.0
2024	0.7	32.5
2025	0.82	41.3
2026	0.94	51.3
2027	1.07	62.8
2028	1.2	75.7
2029	1.34	90.0
2030	1.49	106.0

Vaccination against rotavirus

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Summary

The third African Union Agenda 2063 (healthy and well-nourished citizens) cannot be achieved without the prevention or control of diarrhoea which is a major leading cause of death especially in children under 5. This study employed a simulation based decision analytic Markov model using retrospective data from eight Africa countries that have high diarrhoeamortality rate to evaluate the cost-benefit of implementing rotavirus vaccination in Africa to prevent diarrhoea. The median BCR obtained was 44.

Background

Diarrhoea remains one of the simplest diseases to prevent and manage but yet remains a major killer of children under 5 years(UNICEF, 2018). In a recent survey, it was ranked as the fifth leading cause of death globally and still ranks as the third leading cause of death among childhood diseases. Africa remains the continent with the second highest prevalence and mortality after Asia (WHO/IHME, 2017).

Gastroenteritis (a bowel infection) is a common cause of diarrhoea in both adults and children although the disease can result from other causes such as food allergy, medication or irritable bowel syndrome. Gastroenteritis can be caused by virus (rotavirus), bacteria (Escherichia coli, campylobacter) and parasite (giardiasis). These infections are contacted particularly in areas with poor standards of public hygiene typical in developing nations. Rotavirus vaccine protects against rotavirus infections, the leading cause of severe diarrhoea among young children(WHO, 2013). The vaccine can prevent up to 96% of severe diarrhoea (Soares-Weiser et al., 2010).

Statement of Problem

With healthcare budgets decreasing and costs of interventions increasing, governments and health organisations are under pressure to ensure that they achieve the best value for money while maintaining high quality healthcare delivery. Payers and decision-makers require information about the impact of an intervention on diarrhoea prevention to know if it would be worthwhile to scale-up the treatment in Africa. As decision-makers desire to get the best value for money, they are faced with the challenge of choosing the best preventive approach for childhood diarrhoea among several alternatives.

Study Justification

The third African Union Agenda 2063 (healthy and well-nourished citizens) cannot be achieved without the prevention or control of diarrhoea which is a major leading cause of death especially in children under 5. Considering rotavirus vaccination as an option that can prevent diarrhoea based on WHO recommendation and other research findings (Okafor & Ekwunife, 2017), it will be necessary to determine if the benefits of vaccinating the greatest number of African children at risk out-weighs the cost if implemented. Besides, WHO-CHOICE recommends economic evaluation in order to inform the best option in terms of maximum health gain with minimal expenditure, hence the need for a cost-benefit analysis of implementing rotavirus vaccination.

Study Objective

The principal objective of this study was to evaluate the cost-benefit of implementing rotavirus vaccination in Africa to prevent diarrhoea. Also to determine if there would be need for scale-up of the vaccination program in Africa.

Methods

This study employed a simulation based decision analytic Markov model using retrospective data from eight Africa countries (Chad, Angola, Somalia, DR Congo, Benin, Nigeria, Burundi and Cameroun) which have highdiarrhoea mortality rate of at least 10% for children under 5 and with high prevalence of diarrhoea(WHO/MCEE, 2018).

The intervention used in the study was a monovalent rotavirus vaccine (RV1). The RV1 requires two doses for complete vaccination whereas the pentavalent rotavirus vaccine (RV5) requires 3 doses for complete vaccination. The RV1 will save time and cost and thus, was used in our evaluation. The cost calculation was carried out for population under one year since the vaccination with RV1 is for children between 6 to 32 weeks of age. We used DTP3 coverage rate for each of the countries as the intervention target rate(WHO/UNICEF, 2018). Effectiveness of the vaccine (relative risk ratio) was obtained from Cochrane data base(Madhi et al., 2010). The transition probabilities of moving to the different health states (Asymptomatic, moderate or severe diarrhoea) were obtained from literature (Walker et al., 2013), (Lamberti, Fischer Walker, & Black, 2012), (UNICEF, 2015), while the transition probabilities to diarrhoeal death at under 1 year, 1 – 4 years, and under 5 years old children were obtain from 2017 GBD (Institute for Health Metrics and Evaluation, 2018).

The WHO 'Guidelines for estimating costs of introducing new vaccines into the national immunization system was adopted to estimate the resource use and costs associated with rotavirus vaccine implementation (World Health Organization Department of Vaccines and Biologicals, 2002), (Tan-Torres Edejer et al., 2003). Mixed (top-down and bottom-up) costing approach was used in the analyses. Cost was estimated from the payer's perspective which includes: cost of the vaccine (2 doses), logistic cost (which include salaries to health care professionals and health assistants, cost of vaccine storage in cold chain, vaccine transportation and vehicles maintenance), advocacy and social mobilization cost, surveillance cost, wastage and management cost. Cost of RV1 was obtained from international drug price indicator guide(WHO/MSH, 2015). Cost of tradable and non-tradable items were obtained from WHO-CHOICE(WHO, 2005), (WHO-CHOICE, 2008). The cost of providing health education to the mother/caregiver on 'diarrhoea prevention' by health professionals on vaccination days was built in their salary. Surveillance, advocacy and social mobilization cost per child was obtained from a demonstration study in Malawi (Madsen et al., 2014).Cost of utilities and equipments were calculated for period of 44 years (2020 – 2063) and annuitized.

The benefit of the intervention was measured in terms of Disability Adjusted Life Years (DALY) averted. DALY was calculated as the sum of the years of life lived with disability (YLD) from morbidity and the years of life lost (YLL) from mortality. The infant mortality, diarrhoeal mortality, percentage of diarrhoeal death, diarrhoeal infant mortality rate, diarrhoeal incidence and disability weights were obtained from 2017 GBD and (Troeger et al., 2017), (Troeger et al., 2018), (Institute for Health Metrics and Evaluation, 2018), (WHO, 2016). In calculating the monetary value of a DALY, we used the Harvard led guideline for conducting Benefit-Cost Analysis project(Robinson, Hammitt, & O'Keeffe, 2019). The valuation was based on ''value of statistical life year'' (VSLY) with one DALY avertedvalued at 1.3 times the GNI per capita of a country in sub-Saharan Africa.

Cost of vaccination was calculated for each country and averaged. The benefit was also calculated and averaged for each country based on the percentage of children at risk and the GNI per capita. The benefit was estimated over of the children's first 5 years (260 weeks) of life. The cost and benefit (YLD and YLL) were discounted at the rate of 5%. The median benefit-cost ratio per child will be used to estimate BCRs for other African countries.

Probabilistic Sensitivity Analysis (PSA) was used to assess simultaneous uncertainty in many variables. This approach is well suited to express overall parameters uncertainty (Briggs, Claxton, & Sculpher, 2006). To assess how simultaneous change of several variables affects the cost and benefit, a Monte-Carlo simulation (1000 iterations) was performed (a type of multivariate sensitivity analysis). This technique runs a large number of simulations by repeatedly drawing samples from probability distributions of input variables. Beta and gamma distributions were used for relative risk ratio and unit cost respectively.

Results

Cost of the Intervention

From the excel calculation sheet total cost of vaccination per child vary from country to country although not too significant. See table 1 and appendix 1 below for details.

Benefit of the Intervention

The benefit in DALY averted was obtained as the difference between the 'vaccination scenario' and 'no vaccination scenario'. DALY averted also varied from country to country. The BCR for Nigeria, Angola, Benin, Burundi, Somalia, Cameroon, Chad and DR Congo were: 126, 100, 30, 13, 13, 64, 58, and 17respectively. The median BCR was 44. Details are shown in table 1 and appendix 1.

The Monte Carlo simulation performed showed that the result was insensitive to the parameters.Thus, the result is deemed robust.

TABLE 1: UNIT COST, BENEFIT AND BCR FOR RV1 INTERVENTION IN 8 DIFFERENT COUNTRIES

Country	Mean Cost	Mean Benefit	BCR
Nigeria	5.31	668.72	126
Angola	8.58	853.41	100
Benin	7.02	211.90	30
Burundi	4.87	62.55	13
Somalia	6.32	83.23	13
Cameroon	5.68	363.21	64
Chad	7.50	438.12	58
DR Congo	5.79	96.07	17
Median BCR			**44**

The population of Africa in 2018 was approximately 1,288 million (World Population Review, 2018),(Worldbank, 2017). Based on annual birth of 35 per 1000 in Africa (World Population Data Sheet, 2018),(WorldBank, 2018) the number of children at risk of having rotavirus diarrhea and needs the vaccine is about 45 million children each year. Thus, with a BCR = 44 the estimated benefit of vaccinating all children is $12 billion per year (45 million * $44 per dollar spent on vaccination * $6.08 per vaccination per child), while total cost is $0.27 billion per year (45 million * $6.08 per vaccination per child).

Discussion

As the recent GBD 2017 shows the importance of diarrhoea disease especially in Africa, African leaders are faced with the challenge of rational decision making in allocation of fund due to scarce resources. This study provides estimate and implications that will guide decision making.

Some factors have the potential to affect the BCRs. A key factor is the cost of vaccination in each country. A high rate of diarrhoeal death will cause an increase in the benefit component (averted DALY) with use of RV1. High vaccination coverage has the advantage of increasing total benefit and reducing overall cost per infant because some cost components are fixed regardless of the number of infants to be vaccinated.

This study showed that there is a huge benefit if the vaccination program is scaled-up in Africa to reach all children. It will be more beneficial to leverage on already existing vaccination network in each country to save time and logistic cost. Similar results will be obtained for LIC, LMIC and UMIC in Africa. However, some factors can affect the replication of this result which includes corruption, unfavourable policies and poor power supply. The three-year GNI per capita of some UMICs and LMICs like Angola and Nigeria are above the GAVI threshold ($1500), hence they will not be eligible for GAVI support (WorldBank, 2017b). This can affect the scale-up in these regions. The African continental free trade agreement (AfCFTA) will positively affect the implementation of this program, reducing the huge variations in cost across some African countries.

Rotavirus vaccine needs a cold chain system from production to end user consumption. A major contributing factor to the cost of the vaccine is the cost of shipment in cold chain and wastage during transportation. Logistic managers always have a problem of maintaining their 'reserve stock' before new reorder and this can increase the risk of out-of-stock, over-stock, early expiration of some batches due to bulk supply etc. Although the WHO has a guideline for estimating vaccines needed per annum, the accuracy cannot be

guaranteed due to unforeseen circumstance. In a bid to lower the cost of scale-up, it will be worthwhile to establish one or two WHO-GMP certified vaccine manufacturing plants in Africa. This will reduce the cost of transportation, wastage cost, excessive stocking which leads to early expiration. The set-up of these plants will ease the production planning and maintain good stock level at all time. Since the project will be effective for at least 40years based on African Union projection, the plant set-up will in the long-run be highly beneficial as they will not only produce RV1 but also other vaccines like DTP, Pneumococcal vaccines etc needed in the regions.

The analyses have some limitations. Due to short-time frame, we could not conduct a one-way sensitivity analysis but a PSA. It will be worthwhile in further research to study how the individual parameters can affect the result. This will provide useful information for decision making. BCR for countries in North and Southern African were not evaluated. This would have given a clearer picture of the variation across the different African regions. There was no country specific data for effectiveness of the rotavirus vaccine for the eight countries. Thus we worked with regional estimate. Future study should consider use individual country effectiveness data.

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Appendix 1.

Table showing key components of the analyses

	Nigeria	Angola	Benin	Burundi	Somalia	Came-roon	Chad	DR Congo	
	Projected 2018	Projected 2018	Projected 2018	Projected 2018	Projected 2018	Projected 2018	Projected 2018	Projected 2018	
Crude birth rate per 1000 population	37.93	40.88	36.23	41.3	42.76	35.25	42.28	41.2	WB (WDI)
Infant mortality rate per 1000 live birth	62.66	51.73	62	40.9	77.49	53.64	71.83	68.04	WB (WDI)
Population	195.9M	30.8M	11.5M	11.2M	15.0M	25.2M	15.5M	84.1M	WB (WDI)
Births	7.4M	1.3M	0.4M	0.5M	0.6M	0.9M	0.6M	3.5M	
Infant deaths	465,535	65,155	25,798	18,876	49,729	47,679	47,006	235,663	
Population u1 yr	7.1M	1.2M	0.4M	0.4M	0.6M	0.9M	0.6M	3.4M	GBD 2017
Infant deaths (all causes)	330,000	37,985	13,900	12,500	23,000	22,870	36,454	89,048	GBD 2017 (approx. for 2018)
Diarrheal death under 1	55,000	5,750	1,900	1,600	4,020	4,150	8,950	11,400	GBD 2017
Diarrheal Mortality rate under 1	0.0077	0.0047	0.0047	0.0036	0.0065	0.0048	0.0145	0.0034	
Diarrheal death by age 1 - 4	48,088	4,231	1,684	1,434	2,577	3,524	11,087	7,493	GBD 2017
Diarrheal Mortality rate by age 1 - 4	0.0068	0.0035	0.0042	0.0032	0.0042	0.0041	0.0179	0.0022	
Diarrheal death by age 5	103,922	10,191	3,604	3,037	6,670	7,904	20,028	19,464	GBD 2017
Diarrheal Mortality rate by age 5	0.0146	0.0083	0.0090	0.0068	0.0108	0.0091	0.0324	0.0058	
% diarrheal deaths under 1	17%	15%	14%	13%	18%	18%	25%	13%	
Diarrheal infant mortality rate	7.56	5.88	5.52	4.71	6.36	5.27	13.3	6.25	Approximate
Diarrheal incidence	20.8M	4.3M	1.1M	2.5M	1.9M	3.1M	3.0M	15.8M	GBD 2017
YLDs	28,958	6525	1320	1800	2982	4597	5670	17,500	GBD 2017
YLDs	43,860	9870	3297	3520	4066	6030	5111	29,597	Markov Model Calculation
Diarrheal prevalence	33.5M	6.7M	2.3M	3.6M	292.7M	4.6M	4.6M	21.9M	GBD 2017
Income Classification	**LMIC**	**UMIC**	**LIC**	**LIC**	**LIC**	**LMIC**	**LIC**	**LIC**	GBD 2017
Disability weight (Moderate/Severe)	0.188/ 0.247	0.188/ 0.247	0.188/ 0.247	0.188/ 0.247	0.188/ 0.247	0.188/ 0.247	0.188/ 0.247	0.188/ 0.247	GBD 2017
Vaccination coverage (DTP3)	57%	59%	76%	90%	41%	79%	41%	81%	WHO-UNICEF 2018
Cost per child full immunization	5.31	8.58	7.02	4.87	6.32	5.68	7.50	5.79	Estimate
Effectiveness of vaccine	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	Madhi et al, 2010
DALY averted per case	0.262	0.195	0.187	0.172	0.206	0.194	0.503	0.151	Estimate
GNI per capita	1,960	3370	870	280	311	1440	670	490	Estimate
Value of DALY averted	668.72	853.41	211.90	62.55	83.23	363.21	438.12	96.07	Estimate
BCR	**126**	**100**	**30**	**13**	**13**	**64**	**58**	**17**	Estimate

Preschool education in sub-Saharan Africa

George Psacharopoulos

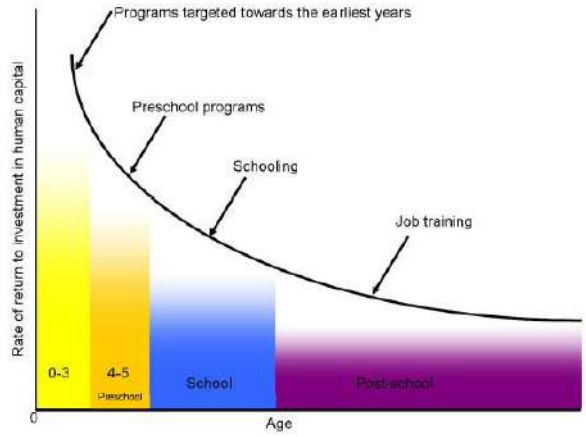
Introduction

Early childhood education has recently received increased attention among policy makers based on the research findings of two different disciplines – neuroscience and economics.

- According to neuroscience, cognitive, emotional and social behavior is formed very early in life. Brain synapses are formed in the first few years of life. Brain scans have shown abnormal development for children who have been maltreated in very young ages.
- According to economics, interventions at early ages are more cost-effective than interventions later in life and are associated with high rates of return and cost-benefit ratios.

Much of the related research has been compiled and disseminated by economics Nobel Laureate James Heckman and illustrated in a famous graph.

FIGURE 1. HECKMAN'S SUMMARY OF PRIORITY INVESTMENTS



Source: Heckman (2008)

More recent research has confirmed the importance of investing in preschool (e.g., Gertler et al., 2014). "Preschool" is defined as programmes at ISCED level 0, comprising the initial stage of organized instruction are designed primarily to introduce very young children to a school-type environment.

Cost-benefit analysis of investments in early childhood require a follow-up of children who have attended preschool to adult life and comparison of their earnings to a control group of children who have not attended preschool. Longitudinal tracing over several decades is a tall-order research design, hence the scarcity of cost-benefit estimates in the literature.

Most of the research has been conducted in the United States showing typical results in Table 1.

TABLE 1. RATE OF RETURN AND BENEFIT-COST RATIOS OF PRESCHOOL PROGRAMS IN THE UNITED STATES

Preschool program	RoR	BCR (3% rate)
Chicago parent-child	18	6.9
High Scope Perry	10	7.2
Abecedarian	7	2.7

Source: Wall Street Journal (2013), p. A2; Temple and Reynolds (2007).

Table 2 presents benefit-cost ratios of preschool programs in Africa. Preschool programs typically contain a nutrition element and affect lifetime earnings through better health, reduced grade repetition, higher educational attainment, increased cognitive skills and adult earnings.

TABLE 2. BENEFIT-COST RATIOS OF PRESCHOOL PROGRAMS IN AFRICA

Country (discount rate)	BCR	Source
Kenya (6%)	50.6	Orazem et al. (2008)
Sub-Saharan Africa (5%)	28.0	Psacharopoulos (2018)

Preschool in sub-Saharan Africa

Data on preschool coverage in sub-Saharan Africa are scarce and conflicting between sources. The UNESCO Institute of Statistics database has dots, meaning missing values, for many countries in the region. The Word Bank database gives a more complete picture of preschool coverage as in Table A-1 in the Annex.

Scaling-up preschool

According to the latest data, preschool enrollment in sub-Saharan Africa covers 32% of the age group corresponding to 24m students (UNESCO, 2019). The Africa Union Agenda target year is 2063. By that time, sub-Saharan African countries could have 39m preschoolers corresponding to the *52%* enrolment ratio of now middle-income countries in the region. This would require a significant expansion of the school system raising the question on its cost-effectiveness.

Cost

The cost of preschool in the literature varies enormously between estimates, from a few dollars to the thousands. We $119 per preschool student/year as estimated in a Nigerian study (Ogunyinka, 2013). This cost includes tuition fees, learning materials, uniforms, accessories, school lunches, transportation, sports and health care. We assume a two years preschool duration. The resource cost is all inclusive, in the sense that there are no foregone earnings for that age group.

Benefits

The benefits side is even trickier, as there are no studies in sub-Saharan Africa that have followed preschool children to adulthood and compare their earnings to children of similar ages who have not attended preschool. Thus we use a 16% earnings increment that is an average of the 25% earnings increment reported in Gertler et al. (2014) for Jamaica, and 7% in the United States (Chetty et al.,2011).

The earnings increment is applied to average labor earnings of $1258 that is 80% of average income in sub-Saharan Africa (World Bank, 2019c), yielding $201 per preschool graduate. We assume that earnings would start at the age of 20.

Cost-benefit

The attached spreadsheet shows the calculations resulting in a cost-benefit ratio of 7 using 5% discount rate, and a 13% internal rate of return on the preschool investment, (Annex 2).

Making a further assumption that earnings would grow over time at an annual rate of 2.4%, as estimated by the World Bank (2019b), the benefit-cost ratio increases to 36.

Thus, the return on preschool investment in sub-Saharan Africa ranges from a low benefit-cost ratio of 7 to a high of 36.

Qualifications

Today, there is there broad academic consensus regarding the socio-economic benefits accruing from an intervention of the above type. However, several qualifications are in order.

The above calculations were based on strong assumptions regarding the costs and benefits of the investment. They also raise a flag for the need of better education statistics in the region and evaluation of interventions.

One risk is quality. Expanding education is not just infrastructure, but getting the right teachers in place. Where do the teachers come from? What would be their training?

Another risk is affordability and sustainability. Preschool may be relatively low cost, but do the governments have adequate funding not just for the initial investment, but for the recurrent costs? Governments should be encouraged to adequately budget for it

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World Bank, 2019c. "GDP per capita". https://data.worldbank.org/indicator/ny.gdp.pcap.cd

Annex

TABLE A-1 . GROSS PRESCHOOL ENROLLMENT IN SUB-SAHARAN AFRICA (%)

Country	Year	Preschool enrollment ratio (%)
Chad	2016	1
Central African Rep.	2017	3
Burkina Faso	2017	4
Congo, Dem. Rep.	2015	4
Mali	2017	5
Guinea-Bissau	2010	7
Cote d'Ivoire	2017	8
Niger	2017	8
Zambia	2016	8
Mauritania	2015	10
South Sudan	2015	10
Mozambique	1986	11
Sierra Leone	2017	12
Congo, Rep.	2012	13
Burundi	2017	14
Uganda	2017	14
Eritrea	2017	15
Guinea	2011	15
Senegal	2017	16
Botswana	2014	20
Comoros	2017	20
Rwanda	2017	21
Togo	2017	21
Benin	2016	25
Eswatini	2011	25
South Africa	2016	25
Ethiopia	2015	30
Lesotho	2016	33
Namibia	2017	33
Gabon	2011	35
Cameroon	2017	37
Madagascar	2017	38
Gambia, The	2017	39
Angola	2016	40
Nigeria	2010	42
Tanzania	2017	42
Zimbabwe	2013	42
Equatorial Guinea	2015	43
Sudan	2017	47
Sao Tome and Principe	2016	51
Cabo Verde	2017	71
Kenya	2016	77
Malawi	2015	81
Seychelles	2017	100
Mauritius	2017	101
Ghana	2017	115
Liberia	2016	157
Sub-Saharan Africa average	Latest year	32

Source: World Bank (2019a)

Tobacco control in Africa

Rachel Nugent, RTI International

Summary

The proposed intervention is to raise the excise tax on tobacco to 75% of the retail price, following guidance from the World Health Organization. We used a pre-existing model that measures ROI of multiple tobacco control policies called the MPOWER package (WHO) but calculated the effects of only the tax increase intervention. According to traditional economic practice, we calculated the welfare cost of taxation – deadweight loss (DWL) – under 3 scenarios. The BCR of 5.6 includes the DWL which occurs in the year following the tax increase and based on cumulative tax increases from 2020 to 2033. The BCR of 23 includes the DWL, based the incremental tax increases from 2020 to 2033. The third is the ROI of tobacco tax increase without DWL based on more recent economic theory. The calculated BCR range is 5.6 to 120 (no deadweight loss). The costs of implementing the tax are purely administrative and enforcement. They are extracted from the WHO NCD Costing Tool. Benefits are the value of reduced mortality and illness plus the associated avoided medical expenditures and productivity increases. Not included is expected increased tax revenue.

Opportunities for scaling up this intervention are high as many countries are signatories to the Framework Convention on Tobacco Control – a legally binding multi-country agreement to control tobacco consumption. The FCTC Secretariat provides support to countries for policy implementation of tobacco control policies, including taxation. In addition, a high-level Task Force on Fiscal Policy issued a strong report in April 2019 advocating for health taxes.[18] The challenges of raising taxes are fierce opposition from industry and resistance among public finance economists in ministries of finance. There is abundant evidence that tobacco taxes work to achieve health goals but the implementation of the FCTC framework and policies has been unsatisfactory and must be strengthened for these goals to be achieved in practice.

The problem

Seven million people die each year from tobacco use, an estimated 13% of all deaths worldwide. Half of lifetime smokers will die before they reach 70, losing an average of 10 years of life. There is no safe level of tobacco use. More than 1 billion people in the world smoke; 21% of the world's population. 80% of smokers live in LMICs and, while smoking prevalence is still low in most African countries, it is rising in direct response to industry promotion of smoking. Unlike in Asia, smoking among adolescent girls appears to be rising at similar rates to smoking among adolescent boys.

Smoking substantially increases the risk of death from lung and other cancers, heart disease, stroke, respiratory disease and tuberculosis. Excise taxation can be used to raise prices, curb unhealthy consumption, promote health, and, in turn, enhance economic growth. Excise taxes are relatively simple to implement, and most governments already levy them on tobacco products. The empirical evidence on the effectiveness and cost-effectiveness of these taxes in reducing consumption and its consequences is well established for tobacco. WHO has identified tobacco taxation as among the 'best buys' for preventing NCDs. At the same time, these taxes generate considerable revenues that can be used to support complementary evidence-based cost-effective interventions to reduce NCDs. Tobacco use in Africa lags other regions of the world but is increasing fast as global tobacco companies target the largely naive populations in many African countries where tobacco control is in early stages. Due to rising concerns about worsening noncommunicable

[18] "Health Taxes to Save Lives," April 2019. Task Force on Fiscal Policy for Health. New York. https://www.bbhub.io/dotorg/sites/2/2019/04/Health-Taxes-to-Save-Lives.pdf (accessed July 20, 2019)

diseases and interest in revenue-increasing policies, African countries are motivated to implement proven tobacco control measures, especially taxation.

The analysed solution

Tobacco taxes are an effective health promotion policy because they increase the price of the harmful good leading directly to reductions in consumption. This leads to reduced prevalence, both by deterring prospective smokers and by reducing consumption of current smokers. We combine these effects in a model designed to measure the broad impacts of tobacco control policies.

We apply the tobacco tax increase in a setting that approximates Zambia in many, but not all respects. We average tobacco consumption levels from four other countries for our assumption of 7 sticks per day per smoker. In our baseline model taxes represent 37.3 percent of the retail price of an average priced pack of cigarettes. We model an average annual 13 percent real tax increase leading to a tax share of 75 percent by 2027, followed by more gradual increases until the tax share reaches 80 percent in 2033. The baseline price is USD 1.78 and by year 15 of the model (2033) the price is USD 5.56.

We estimate the impacts over a 15-year time horizon. Based on global experience, the toll of tobacco-related illnesses will rise rapidly in Africa contributing to the already burdensome problem of non-communicable diseases (NCDs) that countries are struggling to manage. Tobacco taxation has been proven across many countries to be the most effective tobacco control policy: it raises revenues; can be progressive if it reduces smoking more among the poor than the rich as recent literature suggests; and confers benefits across the population from pregnant women and young children who are especially susceptible to second-hand smoke to the productivity of working people.

The costs and benefits

The economic benefits of reducing tobacco consumption through increased taxation are substantial. By raising the tobacco tax to 75% of the retail price, we expect smoking prevalence to drop by 20%. We estimate cumulative discounted benefits of USD 331,134,838 over 15 years for our example country, while cumulative discounted costs are USD 2,759,523. The result is a BCR of 120. This compares to much higher BCRs obtained by modelling tax increases in other countries. For instance, Sri Lanka shows a BCR of 724 for a tax increase to the same level, Jordan shows a BCR of 1547, and Colombia shows a BCR of 1196. These differences arise from differences in baseline smoking prevalence, initial taxation levels, other tobacco control policies in place, and assumptions about enforcement. The central take-away however, is that the BCR for tobacco tax increases is consistently very high.

Raising taxes incurs some costs and benefits beyond the direct administrative and enforcement costs included in this model and the improved health and productivity measured in the model. First, traditional economics literature includes the purported social welfare costs of “coercing” smokers to pay more for their desired product or stop purchasing it. This concept, called “deadweight loss”, is relevant to situations where consumer sovereignty is being sacrificed for social gain and is a premise behind the rationale economic model. However, in regard to addictive substances such as tobacco, the existence and amount of DWL is debated among economists. The arguments against including deadweight loss are that smokers are time inconsistent causing them to act against their own interest in not smoking. Since taxation leads to their reduced smoking, they are benefited rather than harmed by the tax.

As the empirical basis for deadweight loss to be included or not is unsettled (see references in spreadsheet), we offer three scenarios for the ROI. The BCR of 5.6 includes the DWL which occurs in the year following the tax increase, based on cumulative tax increases from 2020 to 2033. The BCR of 23 includes the DWL, based on incremental tax increases over the same period. The third does not reduce the benefits of taxation to account for a deadweight loss. The ROI is 120.

Finally, we anticipate about discounted USD 200 million in increased tax revenues during the 15-year period which we do not add into the benefits, according to standard economic practice, but which are generally seen by governments as an inducement to raise tobacco taxes. Table 1 shows the costs and benefits included in the calculations.

TABLE 1: COSTS AND BENEFITS FROM RAISING TOBACCO TAX, USD2017

Costs (,000 US$)	
Operations and maintenance	2,759

Benefits (,000 US$)	
TOTAL Benefits	331,135
13,353 avoided deaths	148,475
Averted health care expenditure	20,046
Averted absenteeism	26,515
Averted presenteeism	79,668
Reduced smoking breaks	56,430

Discussion

Tobacco taxation is a valuable tool for all governments to achieve reduction in NCD mortality and morbidity. The SDG 3.4 target aims to reduce premature NCD mortality by one-third by 2030 but more than 100 countries are far from on track to reach that goal. Because of low coverage of NCD health services, African countries are in special jeopardy of missing the target and experiencing a continuing double burden of ill-health. The optimal time to institute tobacco taxation is now, before tobacco prevalence increases. This will prevent uptake and prevent onset of diseases. Scaling the intervention to multiple countries in the sub-region is desirable to reinforce positive social norms and health behaviors and because illicit tobacco trade will be discouraged if the retail price levels of tobacco are roughly similar from country to country. Challenges of tobacco taxation include tax avoidance (such as consuming hand rolled cigarettes or other forms of tobacco not easily taxes) and tax evasion (illicit imports that are difficult to detect and tax), and maintaining the real price of tobacco at the desired level.

Trade Facilitation in the African Continental Free Trade Area

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Overview of the problem and proposed intervention

The African Continental Free Trade Area (AfCFTA) was signed by 44 African countries in March 2018. To date, 24 countries have ratified this major regional trade agreement (RTA), which entered into force for these countries in May 2019. The AfCFTA seeks to boost intra-regional trade by supporting free cross-border movement of goods and people along regional corridors throughout Africa. Removing barriers to trade is a pre-requisite for realizing Agenda 2063 aspirations for interconnected and sustainable transport infrastructure systems. These will necessitate an additional US$2 billion each year. With prevailing high transaction costs these investments are unlikely to materialize; if they do, they will have a much lower rate of return than they would have if trade barriers were not substantially removed.

The AfCFTA has prioritized the removal of import tariffs on intra-AfCFTA trade. As important is to dismantle non-tariff measures (NTMs) affecting intra-African trade. Both types of policies increase trade costs by driving a wedge between consumer prices in the importing country and producer prices in the exporting country. Often NTMs are associated with domestic regulation, and trade costs arise due to regulatory heterogeneity. But NTMs may also reflect a policy to protect domestic firms, or rent-seeking behavior by officials at the border. As many NTMs have legitimate social goals the aim cannot be simple elimination as in the case of tariffs. Trade stakeholders must work together to reduce the trade restrictive effects of NTMs. To do so they require information on a broad range of NTMs and mechanisms to determine their effects and incidence. Transparency is both a critical input and output, needed to determine priorities for action, assess progress in reducing trade costs, and accountability for results (monitoring and evaluation).

This brief argues that simple, low cost interventions to improve collection and use of information on the prevalence, intensity and incidence of trade costs associated with NTMs have the potential to greatly increase the economic gains from the AfCFTA. The premise – based on global experience – is that the extent to which the AfCFTA will be effective to reduce trade costs depends importantly on governments addressing NTMs, including in services markets. Current technologies permit information on the effect of NTMs to be collected from traders – whether firms, farmers, truckers, or day traders. Real time data on NTMs that is fed into/used to inform the activities and deliberations of national and sub-regional trade facilitation institutions will help target actions on trade policy areas that generate the highest trade costs. As the relative importance of different NTMs will change over time as the AfCFTA is implemented, real-time information is also important to ensure high BCR interventions are pursued over time as opposed to a single point in time.

The proposed intervention capitalizes on a new UNCTAD/Africa Union initiative to collect and record data on NTMs using cell phones and an online portal. We propose building on and extending that mechanism to include services, as it is currently limited to goods. In addition, the intervention will support monitoring and evaluation of the CFTA implementation, as well as future developments in the integration of services markets across the continent. We very conservatively assess the BCR of action to measure trade costs from 'NTMs at work' and putting in place mechanisms to help traders advocate, discuss and monitor progress in reducing trade costs at 20.[19]

[19] The appendix provides references to some of the recent literature documenting the importance of NTMs and model-based assessments of the potential welfare benefits of the AfCFTA. The latter generate higher estimates of gains than our assessment, reflecting different methodologies.

Probable benefits of scaling up efforts to reduce trade costs

The benefits from the proposed intervention include an increase in the return to investments to reduce the infrastructure gap and the impact of implementation of the CFTA on economic transformation. Increased trade will promote economic welfare gains, job creation and contribute to several of the SDGs. Recent global trade modeling has made progress in estimating the trade and economic welfare impacts (measured as real GDP) of RTAs. In previous work, such agreements have typically been assessed using Computable General Equilibrium models. While useful, these models suffer from the limitation that they do not directly include data on NTMs or services barriers, so results in those areas are dependent on strong assumptions as to likely impacts, which then determine overall effects to a large extent. By contrast, ongoing work builds on recent methodological advances and uses a global gravity model to assess the impacts of RTA membership on trade flows and economic welfare, based on analysis of the trade effects of existing trade agreements that have been implemented in the past. There is no assumption, for instance, that all NTMs are reduced with a particular impact on trade costs. Instead, the approach is to estimate an average effect of RTA implementation in addition to tariff liberalization, which is modeled explicitly, and to infer the observed trade effect must be due to reductions of NTMs and services barriers. In a final step, an additional variable captures EU-style 'deep integration', where institutions and mechanisms have been explicitly developed to deal with NTMs and services barriers.

Initial model results indicate that removal of all tariffs on intra-African trade could boost exports by 1.74%, which would be associated with an increase in real GDP of USD$4.6 billion, or 0.15%. If, in addition, the agreements were to take action on NTMs and services barriers similar to what is seen on average in extant trade agreements, the numbers would increase to 2.22% and 0.19%. Going beyond this average effect, in a scenario dealing with NTMs and services as completely as the EU has, would see an export gain of 3.7% and a welfare gain of 0.31% ($9.8 billion), or more than double the tariffs only gain. These effects are conservative relative to the gains reported by other modeling efforts, so they bias the benefit cost ratio (see below) downwards. The ratio would be higher if we used the findings of Abrego et al. (2019) (who conclude tariff removal plus NTM reduction leads to a 2.1% increase in economic welfare) or Vanzetti et al. (2018) (tariff removal leads to a 1.0% increase in GDP). In assessing projects, we believe it is important to state the likely gains as conservatively as possible.

For cost-benefit estimation purposes, we use the figure of $5.2 billion (current USD) as the total amount of gains that could be reaped by focusing on NTMs and services barriers in AfCFTA. This is the amount of additionality relative to the core tariff removal obligation already accepted by AfCFTA ratifying countries. This is a very conservative measure of regional integration benefits. It ignores many other potential welfare benefits associated with faster border crossings/fewer checkpoints along transport corridors, such as less corruption and red tape ("social waste"), less scope for harassment of women informal cross-border traders (consistent with SDG 5 on gender equality), and the disproportionate importance of trade cost reduction for small firms, helping to promote economic inclusion (SDG 9). Moreover, it is a static assessment based on a counterfactual simulation, not a forecast. So again, in the interests of being conservative, we allow the total gain to build up over ten years using an exponential decay function with a half-life of five years, on the assumption that in the early years, there will be "low hanging fruit" in terms of NTMs to remove, but that the exercise will become more difficult over time. However, we have, in accordance with CCC practice, assumed that

Ours is more conservative. Relative to the literature our estimates are similar in magnitude to those of Mevel and Karingi (2012).

the counterfactual gain from our model continues to exist over time.

Nature of the Intervention

Firms and individuals that benefit from trade barriers often have a significant stake in maintaining it. A key to supporting regional integration efforts is to focus on interventions that change the political economy equation by empowering firms and industries that benefit from trade. A key constraint in mobilizing actors with a stake in regional trade liberalization is that they may be unaware of the policy measures and other practices that increase their trade costs. Similarly, governments may be unaware that particular measures impose economic costs, or the extent of those costs. Transparency is thus an important first step in changing the balance between defenders of status quo rents and reformers.

The proposed intervention in this case is to extend and build on the UNCTAD/African Union crowdsourced regional database on NTMs to include barriers to trade facilitation related services, including temporary cross-border movement of service providers. Building on the existing framework based on cell phones and an online interface, a core team would be responsible for cross checking and cataloging the reported measures, which could serve as the basis for a regular report to governments and the basis of regular interactions between stakeholders (traders) and governments.

The intervention will capitalize on data collection efforts by UNCTAD/African Union, and the CMIs, including the Dar es Salaam, Northern and Central Corridors in Eastern Africa, the Borderless Alliance and the Abidjan Lagos Corridor organization in West Africa; the Walvis Bay Corridor Group and the Maputo Corridor in Southern Africa. The project connects with national trade facilitation committees that have the mandate to oversee implementation of the 2013 WTO Trade Facilitation Agreement. One output of the intervention will be to generate comparable data on NTMs and a coherent set of indicators for monitoring and evaluation of AfCFTA implementation from a trade cost reduction perspective. Reports and analysis will be prepared jointly with the CMIs, be presented at their statutory meetings with trade facilitation stakeholders and disseminated through CMI newsletters and websites.

The intervention will consolidate and expand on extant efforts to collect information on NTMs. A key element/source of added value in addition to generating rich and timely data on trade costs will be the analysis of progress/lack of progress in implementation of trade facilitation elements of the AfCFTA. The analysis will be done in collaboration with local institutions and feed into/be the basis for policy dialogues (e.g. at the annual ministerial meeting of the corridor authorities); this in-built capacity building of local analysts and institutions will ensure progressive transfer of competence and sustainability of the intervention. A specific feature of the proposed intervention will be to focus on multi-country transport corridors and associated gateway ports of entry as these are a primary channel for market integration. The basic concept is to create and support a knowledge platform that provides a repository of trade cost data and related information that can support realization of the CFTA and AU2063 visions by generating analysis and mobilizing dialogue and pressure for reform by stakeholders at the national and regional level.

The intervention will be designed to complement efforts by the AUC African Trade Observatory, which has a continental focus, the UNECA, which works with regional economic communities in Africa, and ongoing trade facilitation initiatives supported by donor organizations such as UNCTAD, ITC, TradeMark and USAID. It will add value because extant efforts do not focus on transaction-level sources of trade costs and do not seek to build a unified trade cost reporting and tracking system. A key piece of value added is that it would cover trade in services, including movements of people, in addition to NTMs affecting trade in goods. As such, it would help build a case in the public domain for moving forward in integrating African services markets.

Benefit Cost Ratio

The benefit side of the calculation comes from the global gravity model referred to above. The total change in real GDP associated with tariffs only integration is subtracted from the total change in real GDP associated with EU-style integration that makes real progress on NTMs, trade facilitation, and services. The result, as noted above, is $5.2bn for the continent as a whole. For the Northern Corridor, the corresponding figure is $0.4bn. For the Southern Maputo Corridor, it is $1.0bn. For the Abidjan-Lagos Corridor (ALCO) in West Africa, it is $0.9bn. The differences in these figures are driven by the distinct economic size of each sub-region, as well as their pre-intervention level of trade integration (barriers). The corridor figures do not cover all the examples listed above for analytical clarity as we want to avoid double counting of potential benefits. As noted above, we assume that it takes ten years to fully realize the benefits of the intervention, and so apportion the gains according to an exponential decay function with a half-life of five years, assuming the GDP effects remain in line with CCC practice. In an additional effort to be conservative, we have assumed that only 50% of the estimated gains would in fact be realized. This assumption is arbitrary, and not based on an empirical assessment of experience with other trade agreements, but is made in light of past difficulties that have characterized regional integration efforts in Africa.

For the cost side of the calculation, it is important to distinguish one off investment costs from ongoing operating costs. The main up-front cost, namely development of a reporting system, has already been engaged by UNCTAD and the African Union. This intervention would extend the system to cover services policies, which would be significantly less costly than the initial development. Development along with requisite oversight and inputs by a team of analysts comprise some $0.4m. Ongoing operating costs include training programs for transport operators and traders, a core team of professionals to curate the database and produce regular reports for stakeholders, and a budget for dissemination and regular engagement with CMIs, chambers of commerce/business associations and government bodies responsible for trade and investment promotion. This recurring cost is estimated at $0.2m per year per sub-region, on the basis that part of the total cost would be absorbed by UNCTAD and the African Union. On a ten-year basis total costs for 5 sub-regions would be some $10.4m.

A final consideration relates to adjustment costs associated with reallocation of capital and labor following trade liberalization. In the case of tariff removal such costs can be substantial relative to the benefits. The economics of our proposal is different. NTMs typically create a pure loss of economic resources without any accompanying revenue gain for the government. Part of the resource loss are absorbed as rents by “gatekeepers” including border officials, but the largest share constitutes pure economic waste. The effect is to inflate consumer prices and deflate producer prices relative to a no NTM equilibrium. The reforms supported by our program would reduce the size of that wedge, thereby adding to GDP without bringing about major reallocations across sectors of the type that cause adjustment costs following tariff liberalization. We therefore believe adjustment costs would be much smaller in this case. However, in line with CCC practice, we err on the side of conservatism by assuming that adjustment costs amount to 25% of benefits in the first year, 20% in the second year, 15% in the third year, 10% in the fourth year, and 5% in the fifth year. These figures are based on an UNCTAD analysis of *tariff* reductions, which, as noted, are fundamentally different in terms of impacts from the reforms that are the focus here. As a sensitivity exercise, if adjustment costs were thought to be significantly lower, e.g., 5% of the benefits in the first five years, the BCR would more than double.

Based on the assumption of high adjustment costs, the continent-wide BCR is 20; under the sensitivity assumption on adjustment costs just discussed, it is 50. Even if rollout were to be limited to a single corridor in one sub-region only, with full absorption of the initial investment cost by that corridor alone, the BCR remains approximately 20 for all corridor

examples, as the cost side of the equation is fundamentally driven by the assumption on adjustment costs. As a result, if the intervention was to be rolled out on a trial basis to a single corridor, it would still represent good development 'value'.

Risks and challenges

The success of the intervention depends upon the effective mobilization and empowerment of relevant regional trade stakeholders through the proposed deliberation and dialogue mechanisms, informed by the data that will be collected. The data collection and analysis effort is designed to complement current corridor performance monitoring programs of CMIs. The sustainability of CMIs, which are envisaged to play a significant role in policy dialogue around trade costs, are generally tied to externally funded infrastructure projects and thus may have a time bound nature. A trend towards providing CMIs with multi-year funding attenuates this risk. A precondition for the cost estimate costs is that it will be possible to coordinate the intervention with the recently announced UNCTAD and AU initiative to develop a mobile app-based reporting system.

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Expanded malaria intervention

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Summary

Despite the progress made against malaria throughout the world, malaria prevalence has not fallen: in ten (10) Sub-Saharan African (SSA) countries, the number of malaria cases reported has an increase of more than 20% between 2016 and 2017. Long-lasting insecticide-treated nets (LLIN) are generally considered the most cost-effective of vector control strategies, and, despite several campaigns of mass distribution, the percentage of the population with access to a LLIN is estimated at only 56%. The intervention analyzed is to scale-up the coverage of LLINs; that is, to increase the percentage of the SSA population with access to a LLIN, from 56% to 75% via one (1) mass distribution (door-to-door) campaign, during the course of a calendar year. The benefit-cost ratios calculated for four regions of SSA are: Southern (0.4), Eastern (2.9), Western (11.6), and Central (27.5).

The problem

The World Malaria Report 2018 concisely depicts the progress made in the fight against malaria in sub-Saharan Africa (SSA). Incidence rates (the number of cases/1000 population) have dropped from 278 (2010) to 219 (2016 and 2017). Though, in comparison to the global malaria incidence rate (59.1) and that of South-East Asia (7.3), there is still some work to be done. There has also been a slight decrease in deaths reported between 2016 (413,000) and 2017 (403,000). The malaria mortality rate/100,000 population-at-risk in SSA is 44% and globally it is 11.7%. However, malaria prevalence has not fallen: in ten (10) SSA countries, the number of malaria cases reported has a >20% increase between 2016 and 2017. In Nigeria, Madagascar and the Democratic Republic of the Congo (DRC), the number of malaria cases exceed 500,000 in each. Eighty (80) percent of global malaria deaths in 2017 were concentrated in 17 countries in the WHO African Region and India; 7 of these countries accounted for 53% of all global malaria deaths: Nigeria (19%), DRC (11%), Burkina Faso (6%), United Republic of Tanzania (5%), Sierra Leone (4%), Niger (4%) and India (4%) (WHO 2018; 2017).

The high malaria-burden countries in SSA by Global Burden of Disease-assigned regions and their corresponding share of total malaria cases worldwide (World Malaria Report, 2018) are shown in Table 1.

TABLE 1: HIGH MALARIA-BURDEN COUNTRIES IN SUB-SAHARAN AFRICA

South	
East	Mozambique, 5%, Uganda, 4%, Tanzania, 3%, Rwanda, 3%, Malawi, 2%
West	Nigeria, 25%, Burkina Faso, 4%, Ghana, 4%, Niger, 4%, Cameroon, 3%, Mali, 3%, Guinea, 2%, Benin, 2%
Central	DRC, 11%, Angola, 2%

Children under 5 years of age are the most vulnerable group affected by malaria accounting for 61% (266 000) of all malaria deaths (435,000) worldwide in 2017 (WHO 2018; 2017).

TABLE 2: INCIDENCE OF MALARIA AND DEATHS

Regions, SSA	South	East	West	Central
Population, millions	63.2	405.5	362.8	156.5
Incidence rate, U5	1.1	29	59	69
Incidence rate, >5	0.9	8.7	16.2	17
U5 deaths of total malaria deaths, %	45.8	35.7	53.8	45.4

Sources: State of Africa's Population (2017); Global Burden of Disease

The academic literature is replete with studies demonstrating that long-lasting insecticide-treated nets (LLIN) are the most cost-effective of vector control strategies. LLINs are mosquito

nets that are treated with insecticides by the manufacturers and do not require any re-treatment. These nets are designed to preserve their efficacy against mosquito vectors for a minimum of 3 years or 20 standard washes under laboratory conditions (Sousa et al. 2019).

In 2017, 254 million LLINs were reported by manufacturers as having been delivered globally. In the same year, 220 million LLINs were distributed globally by national malaria programmes, of which 175 million (81%) in SSA; 85% of LLINs were distributed freely through mass campaigns. However impressive, this number appears insufficient, as the percentage of households in SSA owning at least one LLIN is estimated at 72%; yet, the percentage of the population with access to a LLIN was only 56% (World Malaria Report, 2018). This is known as the ownership gap, the percentage of households owning nets but not having enough for its occupants.

The effectiveness of a LLIN is also conditional upon its use. The percentage of the SSA population sleeping under a LLIN is estimated at 50%, rendering an ownership-usage ratio of 0.89.

The analysed solution

The intervention analyzed is to scale-up the coverage of LLINs; that is, to increase the percentage of the SSA population with access to a LLIN, from 56% to 75% via one (1) mass distribution (door-to-door) campaign, during the course of a calendar year.

Cost and benefits

The costs of mass (door-to-door) distribution were taken from Winskill et al (2019), who estimated the cost/net at $2.24 and in-country delivery cost/net at $2.65, for a total of $4.89. It is assumed that the number of people who can be protected from a net is 1.8 (Winskill et al, 2017); the use life of an LLIN is three (3) years (Winskill et al. 2019), and the costs of LLINs or delivery do not increase with coverage.

TABLE 3: COSTS OF THE MASS DISTRIBUTION

	South	East	West	Central
Target population	6.7M	42.8M	38.3M	16.5M
Total costs, regional, USD, millions	$33	$209	$187	$81

The benefits of the mass LLIN distribution were identified as averted malaria treatment expenditures and averted deaths. Due to the vulnerability of children under age 5, benefits were calculated separately for those under 5 (U5) and the rest of the population at risk (>5).

The campaign would avert 4,715.54 million U5 death and disability across the continent and the total averted treatment expenditures over the three-year use life of an LLIN (discounted at 5%) at $40.79 million.

The use of LLIN for the portion of the population older than 5 years would avert 189.99 million death and disability across the continent and save 64.67 million (discounted at 5%) in treatment costs over the three years use-life of an LLIN . The benefit cost ratio (BCR) is as low as 0.4 in the southern region compared to a high BCR of 27.5 in the central region (Table 4).

TABLE4: ESTIMATED BENEFIT AND COST OF LLIN MASS DISTRIBUTION

South	East	West	Central	Total
BENEFITS USD millions				
(a) Averted malaria treatment expenditures, U5				
0.0	10.6	19.8	10.4	40.8
(b) Averted malaria treatment expenditures, >5				
0.3	19.0	31.3	14.1	64.7
(c) Averted death and disability, U5				
13.9	547.3	2,049.6	2,104.7	4,715.5
(d) Averted death and disability, >5				
0.1	20.3	72.9	96.8	190.0
(e) **Total benefit** (a+b+c+d)				
14.3	**597.2**	**2,173.5**	**2,225.9**	**5,011.0**
COSTS USD millions				
(f) LLIN distribution and delivery				
32.7	209.3	187.3	80.8	510.0
Benefit cost ratio (e/f)				
0.4	**2.9**	**11.6**	**27.5**	**9.8**

Discussion

The analysis is sensitive to incidence rates. The Southern region has the lowest BCR (0.4). This is not a surprise because of its low malaria incidence rate for both U5 and >5 (1.1 and 0.9,

respectively), as compared to those of the Central region, 69 and 17, respectively.

The regions are not homogenous where it relates to malaria transmission settings. Generally, in the Southern region, transmission rates are low. While LLINs are the most cost effective across transmission settings and at low coverage levels, Winskill et al. (2019) show that in low and medium transmission settings, the marginal impact of LLINs declines and treatment becomes a relatively cost-effective choice. This holds even before reaching universal coverage of LLINs. This is because the marginal impact of LLINs declines as the use of LLINs reduces the disease burden and consequently reduces transmissions. And in lower transmission settings, the marginal benefit of LLIN coverage, which is measured here as the reduced treatment costs and averted deaths diminishes.

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Breastfeeding promotion

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Summary

This study undertakes a cost-benefit analysis of breastfeeding promotion among children 0-6 months in six African countries: Botswana, Cameroon, Equatorial Guinea, Gabon, South Africa and Somalia, which have the lowest rates of exclusive breastfeeding on the continent. The focus is on the costs and benefits arising from reduced morbidity and mortality from diarrhoea and pneumonia.

The study shows that increasing exclusive breastfeeding prevalence from baseline to 95% can avert 227,000 DALYs due to diarrhoea and 376,000 DALYs due to pneumonia annually in the selected countries. Approximately US$1.9 billion can be gained every year in terms of health benefits and treatment and care seeking costs averted. The estimated benefit-cost ratio is 14.50 (for all six countries combined).

In this study we make the case for increasing breastfeeding prevalence, considering that conservative estimates of health benefits have been made. Other health benefits associated with increased breastfeeding were not considered, including lowered risks of chronic conditions later in life, such as obesity, high cholesterol, high blood pressure, diabetes, childhood asthma and childhood leukaemias. Further, we only consider costs and benefits in the first 6 months of birth, even though optimal breastfeeding can be beneficial for children up to 2 years of age and over their lifetime.

The results of this study transcend health and have wider socio-economic implications. In sub-Saharan Africa where the opportunity cost of resource use is high, breastfeeding promotion can free up much needed resources that can be used in other investments to improve livelihoods. To make this analysis even more meaningful, the study must be expanded to all sub-Saharan African countries, which have the most deaths of children under the age of five years.

Identification of the problem and its scope

More than 2.5 million children under the age of five years die every year in sub-Saharan Africa from preventable causes (UNICEF, 2019a). Approximately 70% of these deaths are of children under the age of one. Among the major causes of deaths are malaria, pneumonia and diarrhoea. Malnutrition is an underlying cause in approximately 45% of all child deaths.

Of all preventive interventions, optimal breastfeeding has the highest potential impact on child survival and globally can prevent more than 800,000 child deaths annually (Cesar GV et al, 2016). However, breastfeeding remains sub-optimal in many African countries. On the continent, the prevalence of exclusive breastfeeding is 43%.

Description of the intervention

This study undertakes a cost-benefit analysis of breastfeeding promotion in the first 6 months after birth. The WHO recommends: initiation of breastfeeding within the first hour of birth; exclusive breastfeeding for the first six months; and continued breastfeeding for two years. Interventions to promote breastfeeding are either facility-based or conducted at the community level and can take many forms including: peer support (paid or voluntary), breastfeeding support centres, antenatal education workshops, healthcare assistants, qualified breastfeeding counsellors/supporters, education/training for healthcare professionals. In many settings across Africa, the standard of care for breastfeeding promotion is facility based antenatal and postnatal care services, where pregnant women and lactating mothers are educated on the importance of breastfeeding. The effectiveness of facility-based breastfeeding promotion is however debatable (Lumbiganon P et al, 2016). Proponents thus suggest a combination of facility and community based interventions, which have been shown to be cost-effective (Chola L et al, 2015; Desmond C et al, 2008; Pugh LC et al, 2002).

In this study, we consider a community based breastfeeding promotion that encourages breastfeeding in pregnant and lactating mothers, using lay counsellors to deliver messages to mothers individually and in groups at various intervals in the first 6 months. This has been shown to be effective for increasing breastfeeding rates in low and middle income countries settings (Haroon S et al, 2013; Sinha B et al, 2015). The intervention could be delivered as a single community based intervention, or in integrated with other interventions delivered in the health system (Sinha B et al, 2017).

The analysis is done for six African countries with less than 60% continued breastfeeding (12-23 months) and less than 32% exclusive breastfeeding (0 to 6 months): Botswana, Cameroon, Equatorial Guinea, Gabon, Somalia, South Africa (UNICEF, 2019b). However, the analysis can be extended to any country, since the health benefits of breastfeeding are many and any magnitude of change in the level of breastfeeding can be beneficial to children, mothers and the wider community (Weimer JP, 2001).

In the analysis, exclusive breastfeeding rates are scaled up from baseline to 95% in the selected countries.

Identification of principal costs of the intervention

The main cost categories for the breastfeeding promotion intervention at community level include: Training; supervision; salaries; transportation; information, education and communication (IEC) materials; materials and supplies for community health workers. Several costing studies have been undertaken to estimate the costs of community interventions promoting breastfeeding, with estimated costs ranging between US$139 to US$230 per mother/child pair (Desmond C et al, 2008; Chola L et al, 2011; Nkonki L et al, 2014). These unit costs were applied to the countries in this study, adjusting for differences in gross national income (GNI). The following costs per woman were estimated: Botswana – US$159; Cameroon – US$64; Equatorial Guinea – US$158; Gabon – US$154; South Africa – US$137; Somalia – US$54.

For the six countries included in this study, we estimated that breastfeeding promotion could cost approximately US$180 million every year.

Identification of benefits

Principal benefits of increased breastfeeding prevalence include significantly reduced cost of illness as a result of the health benefits of breastfeeding; reduced deaths from acute respiratory infection and diarrhoea; lowered risks of chronic conditions later in life, such as obesity, high cholesterol, high blood pressure, diabetes, childhood asthma and childhood leukaemias (Lambeti et al, 2011; Cesar GV et al, 2016).

Benefits also accrue to mothers, including reduced risks of type 2 diabetes and breast, uterine and ovarian cancer (Chowdhury R et al, 2015). Approximately 20,000 annual deaths of breast cancer can be averted by breastfeeding (Cesar GV et al, 2016)

Increasing breastfeeding rates can thus lead to economic gains to the health system, resulting from reduced disease treatment costs; to families as result of averted out-of-pocket expenditures for care seeking; and to the economy in terms of increased productivity as work absenteeism related to childcare reduces (Weimer J, 2001). Other cost savings that may accrue to families include reduced expenditures on formula and replacement feeding supplies. Similarly, in-hospital feeding programmes will save on formula, bottles, glucose solution, oxytocin, etc.

This study estimates the economic benefits of breastfeeding, focusing on averted morbidity and mortality due to pneumonia and diarrhoea in six sub-Saharan African countries. Exclusive breastfeeding has a protective effect against diarrhoea and pneumonia. Among children 0-6 months, not breastfeeding results in excess diarrhoea mortality in comparison to exclusive breastfeeding [RR 10.52] and any breastfeeding [RR2.18], (Lamberti L et al, 2011). Pneumonia mortality is 14 time higher in children who are not breastfed, compared to those exclusively breastfed (Lamberti L et at, 2013).

We find that approximately US$1.1 billion can be gained every year by scaling up exclusive breastfeeding rates to 95% among children 0-6 months old. The overall benefit-cost ratio (all countries combined) was estimated to be 14.50. The BCR for each country are: Botswana – 9.29; Cameroon – 10.51; Equatorial Guinea – 10.26; Gabon – 11.27; South Africa – 17.49; Somalia – 10.01.

Discussion

The health benefits estimated here are conservative, as breastfeeding is associated with health gains from morbidity and mortality with other conditions, including otitis media, meningitis, AIDs and lowered risks of chronic conditions later in life, such as obesity, high cholesterol, high blood pressure, diabetes, childhood asthma and childhood leukaemias. Furthermore, only costs and benefits in the first six months are considered, even though optimal breastfeeding can be beneficial for children up to 2 years of age and over their lifetime.

The study should be extended to all sub-Saharan Africa countries, since the health benefits of breastfeeding are many and any magnitude of change in the level of breastfeeding can be beneficial to children, mothers and society at large.

Thus further analyses can be undertaken estimate the economic implications of breastfeeding, considering wider health benefits over a lifetime time horizon in all sub-Saharan African countries. The study can be used to advocate for increased breastfeeding promotion in sub-Saharan Africa where the opportunity cost of resource use is high; and breastfeeding promotion can free up much needed resources to be used in other investments to improve livelihoods.

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Reduce malnutrition in Sub-Saharan Africa

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Summary[20]

Reducing malnutrition in Africa has both intrinsic and instrumental value. Better nourished populations are more economically productive. Children better nourished during the first 1000 days (*in utero* and the first two years of life) will be more productive as adults, increasing country GDP. Interventions that prevent malnutrition are excellent investments; for the median African country in our sample, the Benefit: Cost Ratio (BCR) for investments that reduce chronic undernutrition in children is 13.6.

Background

Nutrition has always been important to development. Good nutrition allows for healthy growth and development of children, inadequate nutrition is a major contributing factor to child mortality and obesity leads to poor health and premature death. Put simply, improving nutrition is intrinsically valuable. A large and growing body of evidence now shows that good nutrition is also important for economic development.

Malnutrition encompasses both undernutrition (see Box 1) and overweight/obesity.[21] While there have been improvements since 2000, undernutrition in sub-Saharan Africa remains pervasive. Across Africa, 58 million (31 percent) of children under the age of 5 are chronically undernourished and as of 2013, no country had a stunting prevalence of less than 13 percent (WHO, 2017). More than 14 million are acutely undernourished (6.1 percent) (WHO, 2017). Micronutrient deficiencies in children under five are also widespread: 41 percent of children are Vitamin A deficient; 40 percent are iodine deficient; 20 percent suffer from iron deficient anemia; and 24 percent are zinc deficient (Black et al, 2013).

Africa's future economic success lies in increasing human capital – schooling, knowledge and skills that will allow Africans to compete and thrive in a global economy. Human capital is an important determinant of labour productivity; raising labour productivity lies at the heart of raising incomes across Africa. In debates regarding African economic development strategies, it had long been assumed that increasing human capital comes about through investments in the formal education system, but this is only partially true. Investments in nutrition – particularly in the nutrition of very young children – are equally important.

To understand the economic effects of malnutrition, consider chronic undernutrition in the first 1000 days (pregnancy and the first two years of life). There is abundant evidence that this has long term adverse consequences. One manifestation of these is attained stature in adulthood. Data from several countries including Senegal, South Africa and Zimbabwe (Stein et al, 2010; Alderman et al, 2006) show that growth failure in the first 24 months of life is associated with reduced stature in adulthood. The economic consequences are captured by evidence showing associations between height and outcomes in the labor market.

Box 1: What do we mean by undernutrition?

Undernutrition reflects inadequate intake of nutrients: calories, proteins and micronutrients. There are two manifestations of undernutrition: anthropometry (height and weight); and micronutrient deficiency. The World Health Organization (WHO) has developed and validated anthropometric standards for children. One important measure pertains to chronic

[20] This paper draws heavily on text found in Hoddinott (2016) but provides updated BCR calculations. I thank Bjorn Larsen and an anonymous reviewer for helpful comments on an earlier draft.

21 While the prevalence of obesity across much of sub-Saharan Africa is low, there are places and groups (such as adult women in southern Africa) where it is rising rapidly (Ng et al, 2014).

undernutrition. A child is considered chronically undernourished, or stunted, if - relative to WHO reference standards for healthy, well-nourished children - a child is too short given her age and sex. A second is acute undernutrition. A child is considered acutely undernourished, or wasted, if – again relative to WHO reference standards for healthy, well-nourished children – she is too thin given her height. The human body needs approximately 20 different micronutrients of which four – iodine, Vitamin A, iron and zinc – are especially important.

More importantly, chronic undernutrition has neurological consequences that lead to cognitive impairments – see Box 2. These cognitive impairments result in children starting school later, dropping out earlier and attaining fewer grades of schooling. Longitudinal studies that have followed individuals for several decades show that, in adulthood, those persons who were chronically undernourished as pre-schoolers scored poorly on tests of cognitive ability. They earned lower wages and, for women, had more children (Hoddinott et al, 2013b).

These links – poor nutrition to damaged cognitive abilities to poorer schooling outcomes to poor cognitive abilities in adulthood to lower economic productivity – are the economic rationale for investing in efforts to reduce malnutrition.

Do economic benefits justify investments that reduce undernutrition?

How strong is the economic case for investments that reduce undernutrition? There are three complementary ways of answering this question: Measuring the cost of doing nothing in terms of lost GDP; measuring the benefits of working towards the World Health Assembly targets for nutrition; and by calculating BCRs associated with investments in nutrition.[22] This requires:

- Identifying a set of interventions that have been demonstrated to reduce dimensions of undernutrition
- Costing these interventions
- Calculating the economic benefits derived from their implementation
- Comparing the ratio of benefits to costs

Box 2: How does chronic undernutrition affect cognitive abilities, schooling and wages?

Undernutrition in early life damages children's brains. Early life malnutrition damages the hippocampus by reducing dentrite (branch like structures, which receive signals sent along axons) density. This adversely affects spatial navigation and memory formation. In severely malnourished children, dentrites in the occipital lobe (responsible for the processing of visual information) and in the motor cortex are damaged, leading to delays in the evolution of locomotor skills. Malnutrition results in reduced myelination of axon fibers thus reducing the speed at which signals are transmitted. The cognitive impairments experienced in early life have long-term effects on children's ability to learn. Two studies – one in Guatemala and one in Zimbabwe – have traced children from infancy (when their nutritional status was first measured) to adulthood. In both countries, a one standard deviation increase in Height-for-Age z (HAZ) scores increases grade attainment by approximately 0.75 grades; in Zimbabwe, shifting a child from being stunted to being well-nourished would increase schooling by 1.25 grades. In Guatemala, a one standard deviation increase in HAZ increases *adult* test scores for reading and nonverbal cognitive skills by 0.28 and 0.25 SDs respectively.

Work by Bhutta et al (2013) has identified 10 interventions that will significantly reduce undernutrition. The logic behind these is that well-nourished children require well-nourished mothers and so measures to reduce

22 Seven African governments estimated the costs of hunger and malnutrition in terms of GDP lost because of illness, avertable mortality, grade repetition, school dropout and reduced productivity (see costofhungerafrica.com). The median estimate was a loss of 7.7 percent of GDP. Hoddinott (2016) calculates the cumulative addition to GDP associated with accelerating investments to meet the World Health Assembly 2025 target for stunting reduction for 15 African countries over the period 2035 – 2060, finding that of these targets were met, GDP would increase by $83 Billion (2016) US.

undernutrition should focus primarily on these two groups. The interventions they identify are:

1. Universal salt iodization
2. Multiple micronutrient supplementation during pregnancy
3. Calcium supplementation during pregnancy
4. Energy protein supplementation during pregnancy
5. Vitamin A supplementation during childhood
6. Zinc supplementation during childhood
7. Breastfeeding promotion
8. Complementary feeding education
9. Complementary food supplementation
10. Management of severe acute malnutrition

Bhutta et al (2013) estimate that scaled up at 90 percent coverage, this package of interventions would reduce severe acute undernutrition by 61 percent, stunting by 20 percent and, globally, would save nearly one million deaths per year.

The per-child cost of this package is currently estimated to be $130; see Appendix 1 for details. What about the economic benefits? In this note, we focus on chronic undernutrition. The best estimate of its malign economic impact comes from Hoddinott et al (2013b) who show that in adulthood, per capita incomes of individuals who were not stunted at age 2y were 66 percent higher compared to individuals who were stunted at age 2y. This increase comes about through the impact of improved nutrition on income through higher schooling, better cognitive skills, greater height, reduced fertility and other channels (Hoddinott et al, 2013b). But this package of interventions only reduces stunting by 20 percent and coverage is estimated to be 90 percent. So, on average, implementing this package would raise incomes by 11.8 percent.

Now consider the following. Suppose a country, say Senegal, were to fully implement this package over time; specifically, that the package is scaled up gradually over a nine-year period (see Appendix 1 for details). As instructed, we use as a base year 2018. We assume the beneficiaries of this package, children under the age of two, enter the labour force in 2037. Median per capita income in Senegal in 2037 is projected to be $2,874. (See Appendix 1 for full details on these calculations.) If this package were implemented, median incomes would be 11.8 percent higher. This implies a gain of $258; in present value (2018) terms using a five percent discount rate, this is an increase of $134. However, we adjust this number to account for the gradual scale up of coverage so for 2037, the present discounted value of the gain is $7 (because coverage in the first year that the package is implemented is assumed to be only 5%). Adding these up from 2037 to 2063 yields an increase in income of $2,374. Given a cost of $130, the benefit cost ratio is 18.3.

Note that the calculation of this BCR is sensitive to the discount rate, the costing of the 10 interventions, assumptions regarding the magnitude of the impact on incomes, how quickly these programs are scaled up and the duration over which benefits are calculated.[23] Generally, these calculations are constructed so as to be conservative: the cost of the interventions has been raised relative to the data described in Bhutta et al (2013), a relatively high discount rate is used and we only count these benefits until middle age. These estimates do not account for additional monetary benefits that certain components of the package generate. For example, universal salt iodization and iron supplementation have direct effects on economic productivity (through improved cognition and work effort respectively) which are not accounted for here. Further, no monetary value is ascribed to reduced morbidity or mortality that results from these interventions.

Table 1 shows BCR calculations for 15 African countries with a total population of 515 million people. The BCR for the median country is 13.6.

Any investment with a benefit: cost ratio that exceeds one is a good investment. By this standard, investments to reduce chronic

23 For example, using a more conservative income gain and a longer period to scale up interventions, Galasso and Wagstaff (2019) come up with a population weighted BCR estimate of 9.

undernutrition are excellent investments. Even under conservative assumptions –the benefit: cost ratios are high.[24] These economic benefits derive largely because averting chronic undernutrition gives children greater capacity to learn, learning is rewarded in the labour market with higher wages.

TABLE 1: BENEFIT: COST RATIOS ASSOCIATED WITH REDUCTION IN STUNTING IN 15 AFRICAN COUNTRIES

Country	Benefit: Cost ratio
Benin	14.0
Chad	18.6
Ethiopia	14.6
Lesotho	9.3
Madagascar	5.1
Malawi	6.0
Mali	12.2
Niger	14.8
Nigeria	14.5
Rwanda	9.9
Senegal	18.3
Togo	13.6
Uganda	15.0
United Republic of Tanzania	12.0
Zambia	10.9
Median BCR	13.6

Source: Author's calculations.

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Appendix 1:

Estimating Benefit: Cost Ratios associated with reduction in stunting:

These benefit: cost ratios (BCRs) focus on the economic benefits associated with the reduction of stunting created by investing in nutrition-specific interventions. Calculating these requires the following information and assumptions:

- What is the time frame over which these calculations are made?
- How much does the intervention cost?
- What percent of the population will it reach?
- How effective is the intervention?
- By what percent does it increase income?
- What is the counterfactual – what would incomes be in the absence of this intervention?
- Because benefits accrue in the future, what discount rate is used to estimate the present value of these benefits?

What is the time frame over which these calculations are made?

Following the instructions provided by the Copenhagen Consensus Center, these calculations are based on a cohort of individuals born in the year 2018. It is assumed that they enter the workforce in 2037. I calculate benefits based on their employment in the labour force until the year 2063. Allowing benefits to accrue over a longer period will increase the BCRs; reducing the time period would reduce them.

How much does the intervention cost?

The 10-item intervention package described in Bhutta et al (2013) is estimated to cost on a per child basis, for African countries, $102.50 in 2013. Hoddinott (2016) assumed that by 2018, because of inflation this cost would increase by 15% to $118. To bring this up to date, it is assumed that this has further increased in cost by 10 percent to $130. Bhutta et al (2013) note that the costs of this package of interventions do not differ across African countries; we adopt their assumption here.

What percent of the population will it reach?

In the work by Bhutta et al (2013), they assume that these interventions, scaled up, would reach 90 percent of children. We assume that the package is scaled up gradually: 5% coverage in the first year; 10% coverage in the second year; 15% coverage in the third year; 20% coverage in the fourth year; 40% coverage in year five; 50% coverage in year six; 60% coverage in year seven; 70% coverage in year eight before reaching 90% coverage in the ninth year.

How effective is the intervention?

Bhutta et al (2013) estimate that this package of interventions would reduce stunting by 20 percent if coverage was 90%.

By what percent does it increase income?

Hoddinott et al (2013b) show that switching someone from being stunted at age 24 months to being not stunted at age 24 months raises their per capita consumption in adulthood (consumption is a proxy for income; it is less susceptible to measurement error and is a less volatile measure) by 66 percent. But recall that the implementation of this intervention package reduces the prevalence of stunting by only 20 percent and that coverage in practice is estimated to be 90 percent. Thus, the implementation of this package raises incomes by (66% x 0.20 x 0.90) = 11.8%.

What are counterfactual incomes?

We begin with a current estimate of per capita incomes, specifically median per capita incomes reported in PPP dollars as calculated by Diofasi and Birdsall (2016) for countries where current estimates (2010 or later) are available. Earlier work (Hoddinott et al, 2013a) used mean per capita incomes but this is problematic for countries with significant levels of inequality as it overstated the benefit streams from investing in nutrition. The median tells us how much the "typical" African earns (or consumes) in a year. These data are reported in PPP dollars; the PPP conversion factors reported in the World Bank development indicators database to convert the median per capita incomes to nominal US dollars.

Next, recall that the individuals benefitting from these interventions do not start working until the year 2037. What will their incomes be in that year in the absence of these interventions? We begin by taking these median per capita incomes and applying the projected economic growth rates for Africa for the period 2037-2063. This growth rate, calculated by the IMF and World Bank (and used on other projection exercises such as those associated with climate change projections), is 3.5 percent per year. Using this growth rate, we estimate per capita median income in 2037. As an example, for Senegal we estimate that per capita median income in 2037 will be $2,874.

What would their incomes be in that year if these interventions were implemented? Based on the estimated impact of investing in this package of interventions, they raise incomes by 11.8 percent. So if these interventions in Senegal took place, per capita median income in 2037 would be ($2,874 + ($2,874 x 11.8%)) = $3,199. The increase in income is $339.[25] (Note that when we do our calculations, we need to adjust this so that it is expressed in present value terms and that we need to take into account that coverage of the package of interventions in the first year is only 5%). We calculate these increases in income for every year from 2037 to 2063.

What discount rate is used?

Following the instructions provided by the Copenhagen Consensus Center, these calculations are based on setting the discount rate at 5%. Discounting is done back to 2018 so all monetary figures are expressed in 2018 US dollars.

Which countries can this increase be calculated for?

These calculations require data on median per capita consumption dated 2010 or later, data on population size and projected population growth and data on the prevalence of stunting dated 2010 or later. Twenty African countries meet these criteria. However, for several countries there are reasons to expect that these median incomes are not a good guide either because of subsequent health crises (Ebola in Guinea), civil unrest (Democratic Republic of Congo; Guinea-Bissau) or because the economy is heavily reliant on mining (South Africa, Namibia). This leaves the following countries: Benin; Chad; Ethiopia; Lesotho; Madagascar; Malawi; Mali; Niger; Nigeria; Rwanda; Senegal; Togo; Uganda; United Republic of Tanzania; and Zambia.

[25] Note in the accompanying spreadsheet, the income gains reported adjust for the gradual increase in coverage.

Lower household air pollution with improved cookstoves

Bjorn Larsen

Summary

The benefit-cost ratios (BCRs) of the assessed interventions are 11.7 for improved cookstoves for wood and 2.4-2.5 for cooking with Liquefied Petroleum Gas (LPG). The quantified benefits are health improvements, and cooking time and solid fuel savings. The quantified costs are cost of stove, stove maintenance, LPG fuel, and intervention promotion program. Benefits and costs are estimated per household that adopts the interventions. Total benefits and costs are not estimated because predicting intervention adoption rates is very difficult.

Improved cookstoves for wood is a short to medium term intervention because of its relatively moderate health benefits. LPG, or other clean options such as electricity, is as incomes grow the longer-term solution in order to achieve substantial health benefits.

The Problem

Cooking with solid fuels in inefficient traditional cookstoves is imposing an enormous burden on African households. Fine particulate (PM2.5) household air pollution from these fuels caused over 400 thousand deaths in Africa in 2017 according to the Global Burden of Disease 2017 (GBD 2017). As many as 60% of these deaths were from acute lower respiratory infections (ALRI), of which 60% were among children under the age of five years.[26] And a survey of 22 countries in Sub-Saharan Africa found that households spend on average 2 hours per day on fuelwood collection, ranging from 0.8-1.0 hours in Zimbabwe, Tanzania and Kenya to 4-5 hours in Niger and Sierra Leone (World Bank, 2014). This totals 100 billion hours, or 50 million man-years of work, for the 63% of the Sub-Saharan African population using wood as primary cooking fuel.

Clean fuels and technologies for cooking include electricity, gas, ethanol, solar and high-performance biomass gasifier stoves. Kerosene is not considered a clean fuel (WHO et al, 2018).[27] In the range of 93-99% of the population in North Africa[28] had access to clean fuels and technologies for cooking in 2016. However, only 14% of the population in Sub-Saharan Africa had such access (World Bank, 2019). In the low-income countries of Sub-Saharan Africa, only 5% had access to clean fuels and technologies for cooking.

Forty national household surveys in Sub-Saharan Africa from 2012-2017 provide an overview of the primary cooking fuel used by the populations in the region.[29] These surveys represent 93% of the population in Sub-Saharan Africa. The surveys find that 7% of the populations used LPG and equally many used electricity for cooking[30]; 4% used kerosene; 63% used wood; 15% used charcoal; and 4% used other solid fuels. In the low-income countries of Sub-Saharan Africa as many as 71% used wood for cooking.

Interventions

Two interventions are assessed in terms of benefits and costs:

- Improved cookstove using wood; and
- LPG stove.[31]

[26] See Stanaway et al (2018) and www.healthdata.org and http://ghdx.healthdata.org/gbd-results-tool

[27] Clean fuels and technologies are defined in relation to the immediate household environment.

[28] Algeria, Egypt, Libya, Morocco, Tunisia.

[29] Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS).

[30] And very minor amounts of other gaseous fuels.

[31] An alternative to LPG is electricity. An electric stove will have similar magnitudes of benefits as LPG. The main difference can be the cost, depending on marginal cost of electricity supply. Unreliable service of electricity can be a deterrent to switching to electricity for cooking in some countries.

Benefits and costs are assessed for a period of 10 years from 2020 to 2030. The interventions are assessed for the low-income countries of Sub-Saharan Africa as 2/3rd of deaths from household air pollution on the continent resulting from the use of solid cooking fuels occur in this group of countries.

The motivation for the choice of interventions are:

- Over 70% of the population in the low-income countries of Sub-Saharan Africa use wood for cooking;
- As of recent assessments, only approximately 12% of the population in Sub-Saharan Africa use improved cookstoves of varying quality (World Bank, 2014); and
- Only 5% of the population in the low-income countries of Sub-Saharan Africa use clean fuels and technologies for cooking.

The first intervention is an improved cookstove for wood that provides more efficient and cleaner burning (e.g., Rocket stove), and thus lower PM2.5 emissions than a traditional cookstove or cooking over open fire.[32]

The second intervention conforms with "clean cooking fuel and technologies", and is far more effective in reducing household air pollution and health effects than improved cookstoves using wood, but is also much more expensive than improved cookstoves due to the cost of LPG fuel. This intervention is assessed under two scenarios: i) LPG being only partially adopted in a community and exposure levels therefore remains fairly high; and ii) LPG being fully adopted in a community and exposure levels are therefore substantially lower by avoiding the community pollution effect of solid fuel use.

Both interventions involve stoves with a minimum of two burners or plates so that households are less likely to continue using their old traditional solid fuel stove.

The pre-intervention scenario is a household that uses a traditional cookstove with wood. Post-intervention exposure levels are 35-50% lower (depending on household cooking location) with the use of improved cookstove and about 50-90% lower with the use of LPG (see Table A2 in annex). The exposure reduction from the use of LPG is influenced both by cooking location as well as by the degree of adoption of LPG in the community.

Intervention Costs

Four costs of the interventions are quantified in monetary terms: i) cost of stoves; ii) stove maintenance and repair; iii) fuel cost (LPG); and iv) stove promotion program.

Cost of stoves: The economic cost of an improved cookstove for wood (i.e., Rocket stove) as well as LPG stove, both with two burners, is expected to be around US$ 50. This is the price exclusive of any import duties and taxes.[33] The useful life of the improved cookstove and the LPG stove is 5 and 10 years respectively. The improved cookstove is therefore purchased twice during the 10-year assessment period while the LPG stove is purchased once. Additionally, US$ 25 is applied for the upfront cost of LPG cylinder and connection hose.

Maintenance and repair: Annual cost of maintenance and repair is assumed to be 5% of initial stove cost. Cost is assumed constant over the 10-year assessment period.

Fuel cost: The improved cookstove does not entail any additional fuel purchases (only fuel savings from improved stove efficiency). However, the LPG stove involves the purchase of LPG fuel, here assumed at 25 kg per person per year, or 125 kg per year for a 5-person household.[34] A survey of LPG retail prices in 21

[32] Benefits and costs of improved charcoal stoves are not assessed here although about 15% of the population in Sub-Saharan Africa uses charcoal as primary cooking fuel.

[33] Import duties and taxes are simply a transfer from consumers to government and are therefore not part of economic cost.

[34] This is the approximate energy requirement for cooking, based on an LPG stove efficiency of 55%.

Sub-Saharan African countries in 2011-12 found that prices ranged from US$ 0.4 to 3.1 per kg (World Bank, 2014). Retail prices were on average US$ 2.0 in 11 low-income countries and US$ 1.5 in 7 middle-income countries. These prices include any import duties and taxes. The economic retail cost of LPG today is on the order of US$ 1.0-1.2 per kg depending on transport cost. A cost of US$ 1.1 is applied in the assessment here, and is assumed constant over the 10-year assessment period.

Stove promotion program: Stove promotion is needed to increase the demand for improved cookstoves and use of LPG for cooking. A cost of US$ 5 per household is applied here.[35] The program is repeated every 5 years to promote sustained use of improved cookstoves and LPG. Program cost is assumed to increase at the rate of GNI per capita growth to account for increase in real wages.

TABLE 3. PRESENT VALUE OF COSTS OF INTERVENTIONS, 2020-2030 (US$ PER HOUSEHOLD)

	ICS	LPG
Stove cost	85	71
Stove maintenance and repair	17	17
Fuel cost	-	1,142
Stove promotion program	10	10
Total costs	**111**	**1,240**

Source: The author.

Intervention Benefits

Three benefits of the interventions are quantified in monetary terms: i) health benefits in terms of averted mortality and morbidity; ii) cooking time savings; and iii) solid fuel savings.[36]

Health benefits: The health risk functions associated with PM2.5 exposure from the Global Burden of Disease 2017 (GBD 2017) are applied for assessing health benefits of the interventions (see Stanaway et al, 2018 Supplement). These health risk functions are also used by the WHO.

The improved cookstoves for wood are estimated to provide 23% reduction in health effects compared to the use of a traditional cookstove for wood. LPG is estimated to provide 40% reduction in health effects in the scenario with partial adoption of LPG in the community and 56% reduction in the scenario with full adoption of LPG.[37]

Health benefits are valued at 1.3 * GNI per capita per year of life saved and per year of disability from illness averted. GNI per capita growth of 4.9% per year is assumed for the low-income countries in Sub-Saharan Africa over the assessment period.

Cooking time savings: Households often spend multiple hours a day on cooking activities. The use of traditional stoves or open fire adds to the cooking time. A time saving of 20 minute per day is applied for the improved cookstove with wood and 40 minutes per day for LPG. These time savings are valued at 50% of average wages rates.[38] Wage rates are assumed to increase at the rate of GNI per capita growth.

[35] The program cost may be higher depending on the stove intervention adoption rate aimed for. A tripling of the cost will reduce the benefit-cost ratio for the improved cookstove for wood by only about 15% and substantially less for the LPG stove.

[36] Greenhouse gas emissions reduction benefits of interventions are not quantified. Reductions depend on the unsustainable share of fuelwood harvesting. The unstainable share has been estimated at below 30% in most parts of Sub-Saharan Africa, with shares reaching over 50% in several East African countries (Bailis et al, 2015). At 30% unsustainability, an improved cookstove for wood and an LPG stove could save about 0.5 tons and 0.75 tons of CO2 per year per household, respectively. The global benefit of this reduction, at for instance a damage cost of US$ 25 per ton of CO2, is less than 10% of total quantified health and time benefits of the interventions.

[37] This is estimated using the PM2.5 exposure levels in Table A2 in the annex, the health risk functions from the GBD 2017, and the so-called "Potential Impact Fraction" equation. Reductions in non-acute health effects (IHD, stroke, COPD, and diabetes type II are assumed to be fully realized over a 10 year period, while the reductions in ALRI is realized within a year of the interventions.

[38] Average wage rates are estimated from GNI per capita, labor income share of GNI or GDP from PENN Tables 9.0, and labor force participation rates.

Solid fuel savings: An improved cookstove for wood can save 40-50% of fuelwood used for cooking due to increased stove efficiency (IEA, 2017). A fuel saving of 40% is applied here for the improved cookstove. The exclusive use of LPG will save 100% of solid fuel use. Some fuelwood is purchased at various prices while much of the fuelwood is self-collected by the households. The fuel savings are here valued in terms of collection time savings valued at 50% of average wage rates, with wage rates increasing at the rate of GNI per capita growth. A survey of 22 countries in Sub-Saharan Africa found that households spend on average 0.8 to 5 hours a day on fuelwood collection (World Bank, 2014). The average for the 22 countries is 2.1 hours per day, and 2.4 hours per day in the low-income countries of Sub-Sharan Africa.

TABLE 4. PRESENT VALUE OF BENEFITS OF INTERVENTIONS, 2020-2030 (US$ PER HOUSEHOLD)

	ICS	LPG Partial	LPG Full
Health benefits	200	336	481
Cooking time savings	286	573	573
Solid fuel savings	817	2042	2042
Total benefits	**1303**	**2951**	**3096**

Note: LPG Partial and LPG Full refers to the two adoption scenarios of the intervention. Source: The author.

Benefit-Cost Ratios

The benefit-cost ratios (BCR) range from 2.4-2.5 for LPG to 11.7 for improved cookstoves for wood. These BCRs are based on the cost and benefits presented above. While the health benefits of LPG with full community adoption is substantially higher than with partial adoption, the BCRs are very similar due to the main benefits being non-health.

A sensitivity analysis has also been undertaken with respect to the largest benefits and the largest costs, i.e., in relation to fuelwood collection time (sold fuel savings) and LPG fuel cost. Applying a fuelwood collection time of 1.5 hours instead of the average of 2.4 hours per day reduces the BCRs by about 25%, and so does an increase in the cost of LPG from US$ 1.1 to US$ 1.5 per kg. And an increase in the cost of LPG to US$ 2.0 per kg reduces the BCRs to 1.35-1.4, demonstrating the sensitivity to the LPG fuel cost.

TABLE 5. BENEFIT-COST RATIOS OF INTERVENTIONS

	ICS	LPG Partial	LPG Full
Base case	**11.7**	**2.4**	**2.5**
Case: Fuel collection time 1.5 hours	9.0	1.8	1.9
Case: LPG fuel cost US$ 1.5 per kg	11.7	1.8	1.9
Case: LPG fuel cost US$ 2.0 per kg		1.35	1.4

Note: LPG Partial and LPG Full refers to the two adoption scenarios of the intervention. Source: The author.

Discussion

The high prevalence of cooking with solid fuels in Sub-Saharan Africa has substantial health effects, and the use of clean cooking fuels and technologies in the low-income countries of Sub-Saharan Africa has only increased by 1 percentage point of the population from 2000 to 2016.

The BCR for improved cookstoves for wood is five times higher than the BCR for LPG. Improved cookstoves is therefore a reasonable intervention in the short to medium term, but not in the long term as the health benefits of improved cookstoves are only moderate. The longer-term solution is the use of LPG or other clean cooking energies such as electricity. And added health benefits will come from a community focus with the aim of achieving "solid fuel free" communities, along the lines of "open defecation free" communities.

For improved cookstoves, promotion programs must focus on dimensions and consumer preferences of stoves that enhance initial uptake as well as ensures high rates of continued use and proper maintenance of stoves.

To scale-up and speed-up implementation of interventions for cleaner cooking, it is important to eliminate price distortions that discourage uptake, such as import duties and taxes on stoves and LPG. It is also important to facilitate term financing for the purchase of improved cookstoves and LPG stoves and LPG connection equipment. Supplying smaller volume LPG cylinders has also been introduced in some countries to smooth the cost of LPG

fuel. Well targeted subsidies for LPG for poorer households may also need to be considered.

The use of electricity for cooking may be the preferred choice over LPG for many households in countries with increased access to electricity at affordable prices. The use of block tariff rates, with lower rates for small users (often poorer households), can be an added incentive for adoption of clean cooking with electricity.

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Annex

TABLE A1. HOUSEHOLD AIR POLLUTION (HAP) AND ACCESS TO CLEAN FUELS AND TECHNOLOGIES FOR COOKING IN AFRICA

Group	Countries	GDP per capita, US$, 2017	Population, Million, 2017	Deaths from HAP, 2017	Access to Clean fuels and technologies for cooking, % of population in 2016
SSA - LIC	27	639	576	265,250	5%
SSA - LMIC	14	1,899	390	125,184	15%
SSA - UMIC	7	5,681	96	12,802	71%
SSA - HIC	1	15,504	0.1	4	90%
N-Africa	5	3,148	193	1,150	97%
Africa total	55	1,807	1,255	404,388	26%

Source: World Bank (2019) and GBD 2017 (www.healthdata.org).

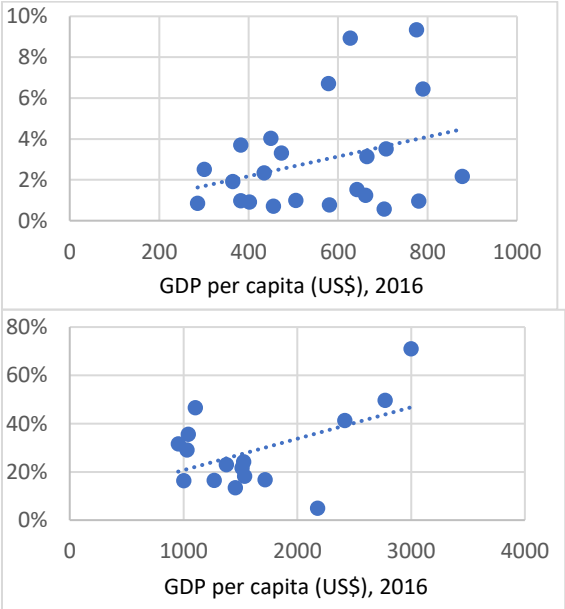
Household use of solid fuels for cooking and other purposes - such as wood, agricultural residues, dung, and charcoal/coal –causes elevated fine particulate air pollution (PM2.5), often with household member exposures of 100-200 µg/m^3 or 10-20 times the WHO annual guideline of 10 µg/m^3.

PM2.5 is the pollutant that globally is associated with the largest health effects of air pollution. Health effects include ischemic heart disease (IHD), stroke, chronic obstructive pulmonary disease (COPD), lung cancer, diabetes type 2, and acute lower respiratory infections (ALRI) (Stanaway et al, 2018).

An overview of income level, population, deaths from household air pollution (HAP), and access to clean fuels and technologies for cooking in Africa is provided in Table A1.

The use of clean fuels and technologies for cooking rises with higher GDP per capita as indicated by the upward sloping trend lines in Figure A1 for low-income (LI) and lower middle-income (LMI) countries in SSA. This relationship is also evident among the 8-upper middle-income (UMI) and high-income (HI) countries (not presented in Figure A1). But GDP per capita is not the only determinant of the use of clean fuels and technologies for cooking, as can be seen by the wide range of use at any given level of GDP per capita. For instance, at GDP per capita of a little less than US800, only 1% of the population in Mali is using clean fuels and technologies, while over 9% do so in Comoros. Similarly, at GDP per capita of US$ 1,000-1,100, 16% of the population in Eritrea uses clean fuels and technologies while 47% do so in Mauritania. As kerosene is not classified as a clean cooking fuel, only 5% of the population in Nigeria with a GDP per capita of US$ 2,176 in 2016 is using clean fuels and technologies. Nearly 13% of the population used kerosene as primary cooking fuel in 2016-17 according to NSB/UNICEF (2018).

FIGURE A1. USE OF CLEAN FUELS AND TECHNOLOGIES FOR COOKING IN SSA IN RELATION TO GDP PER CAPITA (% OF POPULATION, 2016)



Note: Includes low-income (LI) and lower-middle income (LMI) countries. Source: World Bank (2019).

National Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) of households in 40 countries from 2012-2017 provide an overview of the primary cooking fuel used by the populations of SSA countries (Figure A2). The surveys find:

LPG and electricity: 7% of the population used LPG and equally many used electricity for

cooking.[39] LPG is used by 25-79% in 7 countries (Cote D'Ivoire, Ghana, Lesotho, Senegal, Mauritania, Angola and Gabon). Electricity is used by 25-77% in 4 countries (Zimbabwe, Eswatini, Namibia and South Africa).

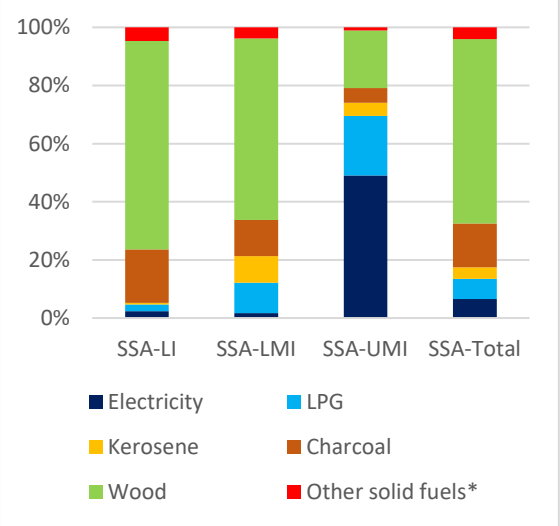
Kerosene: 4% of the population used kerosene. The fuel is used by 10-55% of the population in 6 countries (Congo Rep, Kenya, Nigeria, Comoros, Equatorial Guinea, and Sao Tome and Principe).

Charcoal: 15% of the population used charcoal. It is used by more than 20% of the population in 15 countries.

Wood: 63% of the population used wood. Wood is the predominant fuel is both LI and LMI countries. It is also used by 30-50% of the population in several UMI countries (Angola, Equatorial Guinea and Namibia).

Other solid fuels: 4% of the population used other solid fuels, such as coal, agricultural crop residues, animal dung and straw/grass/shrubs.

FIGURE A2. PRIMARY COOKING FUEL IN SSA, 2012-2017 (% OF POPULATION)



* Coal, agricultural residues, animal dung, straw/grass/shrubs. Source: DHS and MICS household surveys from 40 SSA countries, covering 93% of the SSA population.

The DHS and MICS surveys find that 72% of the population in SSA cook indoors (in the house or in a separate building) and that 26% cook outdoors. In the LI countries of SSA, 69% cook indoors and 29% outdoors. [40] While outdoor cooking reduces overall exposure to PM2.5, exposures are still many times the WHO guideline for the cook as well as for other household members as smoke from cooking enters the buildings in the community.

Personal exposures are highest for adult females who traditionally cook in the household, followed by young children who tend to spend much of their time in the household environment, and lowest for adult males who tend to spend a substantial part of their time further away from the household environment. The range in exposure within each group of household members reflects household cooking location, with highest exposures in households cooking indoors and lowest in households cooking outdoors.

TABLE A2. HOUSEHOLD MEMBER PM2.5 EXPOSURES (MG/M3)

	Pre-intervention TCS	Post-intervention ICS	Post-intervention LPG
Females (adults)	120-200	80-100	25-50
Males (adults)	70-120	45-60	25-35
Children (under 5 years)	100-170	65-85	25-50

Source: The author.

[39] And very minor amounts of other gaseous fuels.

[40] 2% cook elsewhere or do not cook in the household environment.

Soil fertility and livestock management from cell phone

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Summary

This brief documents the potential impact of a digital mobile based app on integrated soil and livestock fertility management practices as an intervention to increase the productivity and yield of smallholder farmers in Africa. Estimates show that the intervention results in a benefit cost ratio (BCR) of 3.23 in two years when applied to maize farming in Ghana. The benefits consist of the increase in yield amounting to USD 413,045 from the impact of soil fertility management practices. The mobile application is estimated to cost USD 170,000, in design, an additional USD13,600 in integration of Integrated Soil and Livestock Fertility Management (ISFM) documentation and a USD 8,500 sensitization cost. It has an annual maintenance cost of USD 34,000 after deployment. The potential for this intervention is high given the BCR and there is room for rapid scale-up from the low intervention cost. The potential for scaling across Africa is also possible albeit with some variation in terms of BCR-Kenya (BCR of 10.49) and Malawi (BCR of 2.00). Overall the benefits are substantially higher and the intervention costs are spread thin when one estimates with a 5-year horizon. A major challenge though is the rather wide variation in the estimated impact on yield of ISFM practices. Nonetheless there is still a potential higher benefit if more smallholder farmers' benefit.

The problem

There are two main problems that this intervention addresses. First is the issue of low productivity and yield and the second is the associated cost of investing in widely scalable interventions. These are elaborated on further. Economic activity and social livelihood in most African countries is driven mainly by agricultural activity (African Development Bank 2019, FAO 2019). Majority of households' welfare is thus dependent on smallholder crops, fish and or livestock farming. The agricultural sector is however wrought with many inhibitions and challenges, ranging from gaps and segmentations in productivity, and market access which have prevented the sector from growing rapidly out of its largely subsistence base. Poor soil and livestock fertility as well as poor production management and generally low access to quality agricultural extension advice appears to be some of the inhibiting factors to productivity and yield. Agriculture in Africa is therefore reduced to an activity within a poor ecosystem of management, poor yield and subsequently poorly linked value chains or in some cases no value chain at all. For this reason, households derive relatively low and uncompetitive incomes from agricultural activity. This in turn reduces the potential development and growth impact of agriculture in Africa. For agriculture to grow out of its challenges and contribute more towards economic development and household welfare, it needs to attract much higher yield and productivity. Attempts to increase productivity have been largely around use of fertilizers, improved seedlings, soil/crop management, pest control. In the case of livestock, it has been largely around feedstock, breeding disease and pest control and extension officers. A critical issue in dealing with productivity and yield is the ability to link all sectors of the smallholder farmer's farm activity in a manner which reduces the segmentation and information problems across the production, processing and market access. A well-structured information system provides the actors (including smallholder farmers) with access to and linkages between production, processing and market access information at a regular and affordable cost. The use of Integrated Soil and Livestock Fertility Management (ISLFM[41])-an integrated approach

[41] The usual approach is separated-Integrated Soil fertility Management (ISFM) for crops and livestock fertility management for livestock.

that is adapted to local conditions, traditions and practices has recently been noted as a high impact approach to increasing yield. Several studies[42] have shown that ISFM has a high impact on crop yield. For instance, a study by Roobroeck et al (2015) shows estimates in the magnitude of 60%-188% of increase in maize yield from ISFM interventions in Africa. Work by Adolwa et al (2019) also show that ISFM adoption increases maize yields by up to 27% in Tamale (in the northern region of Ghana and which is not a majority producer of maize) and 16% in Kakamega in Kenya. On the income side some studies (Benin et al 2011, 2012) estimate agricultural income increase of 37%–95% as a result of farmers' training. The same integrated approach is applicable to livestock management. Karen et al (2017) also estimated that milk production in Uganda increased by 20% as a result of farmer training on livestock fertility and production management.

A challenge with this however is the ability to reach the numerous smallholder farmers with such a solution. Andam et al (2018) show that ISFM training may not reach the intended beneficiaries and produce the unintended outcome of no impact. It is also estimated in a report by Roobroeck at al (2015) that a 5 year scale-up programme for smallholder farmers would cost between USD 40 million (dry Sahel regions of Africa) and 60 million (moist savannah regions of west, east and southern Africa) Attempts at using local media e.g. radio broadcasts have their own shortcomings; the broadcast time may be inconvenient for the farmer, feedback sessions, troubleshooting issues will be difficult to incorporate in a radio broadcast. So although ISLFM can help increase productivity, the cost of scaling up across multiple smallholder farmers is however also large.

The analysed solution

A digital approach enables obtain a real time training on productivity management. The approach is a mobile phone application based on Unstructured Supplementary Service Data (USSD) for GSM phones. This mobile phone-based app provides the farmer with learning tools and or videos on ISFLM practices. These include soil productivity, fertilizer management, water, disease, pest etc. management. For livestock, feed supplementation (especially for free-range/semi free range), pasture management, fertility, herd size, animal husbandry-housing and brooding and breed stock management, vaccination and disease prevention. It also provides information on agro pastoralism, mixed crop-livestock farming and pastoralism. It further provides the farmer with and information and communication platform to market her produce as well as access information on prices and markets.

The application does not require the use of smart phones however farmers can run troubleshooting programmes by enquiring and reporting (via MMS, i.e. text and pictures) soil, production, seedlings and feed etc. conditions for feedback via their mobile phone app. They can take advantage of the app to also access market information about prices and available markets. It also creates a large database of information which can be utilized by financial intermediaries in structuring suitable credit products for smallholder farmers. A prime benefit of this intervention is the ability to scale up ISLFM training at a lower cost. In the absence an intervention like this the ability to scale up ISLFM training in a number of African countries is curtailed as a result of the enormous cost implications. Consequently, productivity increase in agriculture will still be meagre in Africa. The intervention is applicable to most if not all African countries (since agriculture is a major contributor to most of the economies in Africa) but is tested with three Ghana, Kenya and Malawi. The choice is based on countries representing different ecological zones in West, East and Southern Africa (Sahel and moist savannah) particularly for an agricultural based intervention. For instance, Ghana's agro-ecological zone consists six types; Sudan Savannah, Guinea Savannah, Coastal Savannah, Forest/Savannah transitional zone,

[42] See Hardwick et al (2005), Katengeza et al (2019) on the impact of ISFM in Malawi, others include Altieri and Nicholls (2003), Place et al (2003), Vanlauwe et al (2011) and Mponela et al (2018)

Deciduous Forest zone and the Rain Forest zone. Kenya also has six agro ecological zone systems but with a different typology consisting of Agro-Alphine, High Potential, Medium Potential Semi-Arid, Arid and very Arid zones. Malawi has four main zones also different from Ghana and Kenya; the Lower Shire valley; the lakeshore plains and the Upper Shire valley. These are different zones but most of which also accommodate maize farming albeit with different yield potentials. A similar case would hold for North and Central Africa as well. These countries also represent the main income groups (low income and lower middle-income groups) and also help to gauge the sensitivity of estimates to the various country contexts. Most of the assumptions as well as all estimates for benefits and costs are based on maize as a sample commodity.

The costs and benefits

The mobile application is estimated to cost USD 170,000, in design, an additional USD13, 600 in integration of ISLFM documentation and a USD 8,500 sensitization cost as shown in the table below. It has an annual maintenance cost of USD 34,000 after deployment. The estimated benefits from this intervention consists of a 49% in yield amounting to USD 413,045 (Table 2) from the impact of soil fertility management practices. One challenge with the benefit is the estimate for yield. Reports on the yield impact of ISFM are quite varied and wide across Africa.

TABLE 1 COSTS

Costs	Value (USD$)
Application design cost	170,000
ISLFM doc integration cost	13,600
Sensitization cost	8,500
Maintenance cost	34,000

The assumption for 49% increase in yield of maize is therefore based on median values taken from the array of estimates. It is also worth noting that the benefits exclude other factors like access to market outlets and market prices and access to credit or generally to financial intermediaries which are not directly estimated. Additionally, another benefit, the reduction in average cost of farming as a result of ISFM, is not estimated.

TABLE 2 BENEFITS

Benefits	Value (USD$)
Increased yield in agriculture (e.g. maize)	413,045

The BCR for the intervention is estimated at 3.23 using the case of Ghana for the period of 2 years. The BCRs for two other countries Kenya (10.49) and Malawi (2.00) are also estimated to show the wide variation (mainly due to the differences in number of farmers and the base yield values for maize per country). For each country there are two other scenarios (a short term-1-year horizon and a relatively longer term-5-year horizon) to assess sensitivity of the intervention to estimates. The lowest BCR is 1.18 for a 1-year intervention in Malawi and in Kenya it is 6.17, whilst the highest BCR is 19.97 for a 5-year intervention in Kenya and 3.81 in Malawi. The variation in the BCRs across countries also serve as an alternative way of sensitivity analysis.

TABLE 3 BENEFIT COST RATIOS

	Ghana	Kenya	Malawi
BCR (5 Years)	5.57	18.07	3.45
BCR (1 Year)	1.90	6.17	1.18
BCR (2 Years)	3.23	10.49	2.00

Following the wide variation in the impact of ISFM on yield, further sensitivity analysis is done by reducing the yield impact to 30% and 15% respectively. The results on Table 4 show that BCR reduces across the countries as expected. From a two-year point of view, the relative benefits from a 15% increase in yield diminish substantially for Malawi (BCR of 0.32) and Ghana (BCR of 0.99). The benefits still remain attractive on a longer-term basis though.

TABLE 4 BCR BASED ON LOWER YIELD

	Ghana	Kenya	Malawi
30% increase in yield			
BCR (5 Years)	3.41	11.18	2.13
BCR (2 Years)	1.98	3.32	1.23
15% increase in yield			
BCR (5 Years)	1.71	5.59	1.06
BCR (2 Years)	0.99	3.24	0.32

Discussion

Due to the low-cost nature and reach of the intervention, there are substantial benefits from scaling up. The productivity gains from effectively practicing ISLFM practices will boost smallholder agriculture and propel it into higher levels. A further advantage is that scaling up will not incur additional design cost except for maintenance and sensitization cost associated with managing higher volumes. The potential for scale-up is also very far and wide reaching in Africa. This is because of the strong presence of agriculture and smallholder farmers in the economy of African countries. An added merit is the already high density of mobile penetration rate in Africa which also makes the application easily accessible to smallholder farmers. A challenge could be the pain points and potential disputes with local Telcos in revenue sharing. Nevertheless, these risks are reducible with higher adoption and advanced discussion with Telcos for their committed support. There is need for protection of privacy and information from the database that will be gathered from farmers. This requires appropriate regulation framework to prevent abuse of the data. There is also the potential extra cost from further electricity use to maintain servers and back-office operations.

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Voluntary medical male circumcision for HIV Prevention

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Summary

Male circumcision for HIV prevention has been a cornerstone in global efforts towards "ending AIDS." It has been recognized as one of the most effective and cost-effective HIV prevention interventions, and as of end-2017, nearly 19 million men had been medically circumcised in 14 "priority countries." Looking ahead, the contribution and cost-effectiveness of male circumcision depends on two factors:

- The continuing expansion of treatment affects the effectiveness of male circumcision for HIV prevention. The higher treatment coverage, and the more effective treatment is in suppressing the virus and preventing HIV transmission, the smaller is the contribution of male circumcision in preventing new HIV infections.
- Following the scaling-up of male circumcision across the male population so far, and reflecting considerations on cost-effectiveness, the focus of programs offering male circumcision has shifted to adolescents and young adults.

The appraisal takes into consideration this changing context, and the variation in the burden of the disease and the state of the response across countries. We distinguish different levels of HIV prevalence (5% to 20%) and treatment coverage (50% to 80%), and offer estimates on male circumcision for adolescents (age 15) and adults at age 30. Estimated benefit-cost ratios range from 1.1 (age 30, HIV prevalence 5%, treatment coverage 80 percent) to 56 (age 15, HIV prevalence 20%, treatment coverage 50 percent).

Identification of problem

HIV has been a dominant health challenge across much of sub-Saharan Africa over the last decades. HIV deaths peaked at 1.6 million across the region in 2005, accounting for 18 percent of all deaths (IHME, 2018), and reducing life expectancy by well over a decade in high-prevalence countries. Mortality has declined steeply because of the expansion of treatment programs, but as of 2017 AIDS was still causing 700,000 deaths annually (10% of all deaths).

Male circumcision is recognized as one of the most effective and cost-effective HIV prevention interventions, reducing the risk of female-to-male HIV transmission by about one-half (Siegfried, Muller, Deeks, and Volmink, 2009). While male circumcision has been shown to reduce male-to-female transmission of some sexually transmitted diseases, the evidence on female-to-male HIV transmission is weak and the effect likely small (Grund and others, 2017). Nevertheless, reduced HIV infections among men mean that fewer sexual partners become infected, and these indirect effects beyond the population circumcised are often estimated at a similar magnitude as the direct effects on the population circumcised (Haacker, Fraser-Hurt, and Gorgens (2016), White (2008)).[43]

Male circumcision for HIV prevention has been recognized as a cornerstone of efforts towards controlling the epidemic, and has been included among the basic program activities under the UNAIDS investment framework (Schwartländer and others, 2011) and the "fast track" strategy on "ending AIDS" by 2030 (UNAIDS, 2014). The WHO and UNAIDS (2011) framework on male circumcision aimed at reaching a target of 80 percent of men being circumcised by 2016 in 14 "priority countries" with high HIV prevalence and a low level of male circumcision. Between 2008 and 2017, 18.6 million men got medically circumcised in

[43] Male circumcision has also been shown to have some protective effect for men who have sex with men, but we focus on heterosexual transmission which is the dominant mode in sub-Saharan Africa.

these countries (WHO Regional Office for Africa, 2018), corresponding to about one-quarter of the male population at ages 15-49.

Looking ahead, it will be important to take note of the progress already achieved, and the ongoing challenges in maintaining or increasing the coverage of male circumcision. It is also important to recognize that effectiveness and cost-effectiveness of male circumcision may differ depending on the state of the epidemic and of the response to it. Specifically, we evaluate the cost-effectiveness of male circumcision under the following circumstances:

- HIV prevalence (ages 15-49) of 5%, 10%, and 20%, broadly spanning the "priority countries," where HIV prevalence ranges from about 5 percent (Kenya, Uganda) to over 20 percent (Botswana, Lesotho, Swaziland).
- Male circumcision at age 30 and age 15.
- Age 30 (about the average age of a male adult in sub-Saharan Africa) proxies a continuation of efforts on scaling up male circumcision across the adult population. However, following the expansion of male circumcision that has already taken place, about three-quarters of new circumcisions now occur at ages 10-19 (Davis and others, 2018).
- The estimate for age 15 therefore reflects thrust of ongoing circumcision programs, because of saturation in older age groups, the need to circumcise males growing into adulthood to maintain high coverage of male circumcision overall, and the fact that male circumcision is most feasible and effective in the young age brackets.
- Treatment coverage at 50 percent (of all people living with HIV), with 80 percent achieving viral suppression, or treatment coverage at 81 percent, with 90 percent achieving viral suppression. Assumptions on treatment coverage broadly span the current situation in the region (e.g., ranging from 55 percent in Mozambique to 85 percent in Botswana, Namibia, Swaziland, and Zimbabwe), according to UNAIDS (2018)). Looking ahead, the assumptions capture how the effects of male circumcision change as treatment is expanded in line with "ending AIDS" 90-90-90 targets.[44]

Costs of the intervention

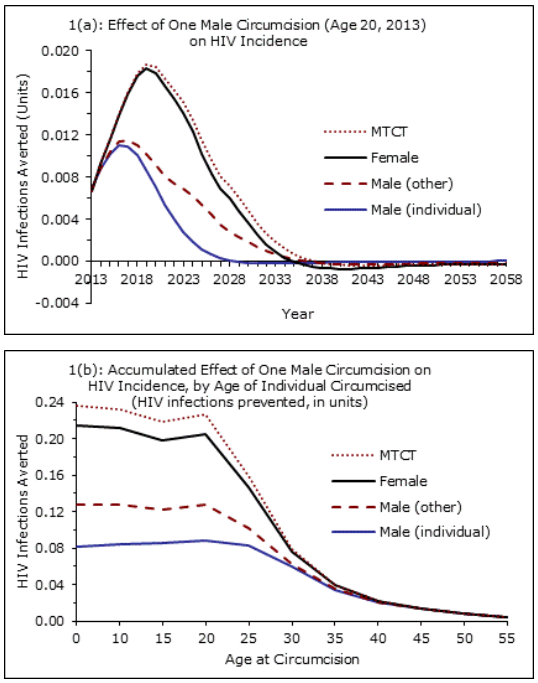
We assume a unit cost for medical male circumcision of US$ 90, close to the average cost estimated for sub-Saharan Africa (Kripke and others, 2016a, 2016b; Bautista-Arredondo and others, 2018). These costs include labor costs, consumables and other facility level-costs, and an allowance for above-facility costs. It does not include demand-creation costs; much of these are bound-up with HIV awareness campaigns overall and attributing some to male circumcision programs is beyond the scope of this note, and private costs of accessing VMMC, estimated at US$ 9 in South Africa (Tchuenche and others, 2016) but arguably lower across the region (in line with GDP per capita).

Identification of the benefits

Male circumcision provides partial and lasting protection against contracting HIV for the population circumcised ("male (individual)" effect in Figure 1). However, as fewer men circumcised become HIV-positive, their female partners also benefit from reduced risk of contracting HIV ("female" effect in Figure 1), and so on ("MTCT" (mother-to-child transmission), HIV infections among "male (other)"). Male circumcision, in terms of the total number of HIV infection averted, is most effective up to about age 20, but the effectiveness declines steeply at higher ages (Figure 1(b)).

44 Whereby 90 percent of people living with HIV are diagnosed, 90 percent of those diagnosed (i.e., 81 percent of people living with HIV) receive treatment, and 90 percent of those receiving treatment achieve viral suppression.

FIGURE 1. EFFECT OF ONE MALE CIRCUMCISION



Source: Haacker, Fraser-Hurt, and Gorgens (2016, on South Africa).

To adapt the estimates described in Figure 1 to other countries, we scale the direct individual-level effects (on men circumcised) in line with key determinants of the risk of contracting HIV for men, namely HIV prevalence in the female population p_F, treatment coverage (c), and its effectiveness in preventing HIV transmission(x). Specifically, we assume that the effects are proportional to the risk of contracting HIV $i_M = a(1-x^*c)p_F$, where a is a constant. The indirect effects are scaled (1) by the same factor as the direct effects and (2) by a factor measuring the life-time odds of passing on HIV, $Y = b(U+(1-x)^*T)(1-p_F)$, i.e., they depend on the expected years spent without treatment (U) and on treatment (T), the effectiveness of treatment in achieving viral suppression, and the share of the female population not HIV positive. For the setting with treatment coverage of 50 percent of all people living with HIV, we assume an average time of 11 years without treatment, 11 years on treatment, and a loss of 22 life years per HIV infection. For the setting with treatment coverage of 81 percent, there are on average 8 years without treatment, 25 years on treatment, and a loss of 11 life years per HIV infection.[45] The lifetime costs of treatment are set at US$ 2,500 (treatment coverage: 81%) or US$ 1,000 (treatment coverage: 50%),[46] and the value of a life year lost is set at US$ 1959 (1.3 times the average level of GNI per capita across sub-Saharan Africa as of 2018, according to World Bank (2019)), and assumed to grow at an annual rate of 3 percent.[47]

45 These estimates are adapted from Haacker (2016), pp. 161-164. We assume that in the setting with 50 percent coverage, treatment is initiated on average between CD4 counts of 100 and 200, and with treatment coverage of 80 percent treatment is initiated at a CD4 count of 350.

46 Based on Haacker (2016), pp. 161-164, also using a discount rate of 5 percent, but applying an annual cost of treatment of US$ 300, close to the median cost for sub-Saharan Africa applied by Kripke and others (2016b).

47 While GNI per capita varies considerably across sub-Saharan Africa, the unit costs of male circumcision vary positively with GNI per capita, e.g., between just over US$ 40 (Kenya, Zambia) and over US$ 100 in South Africa, according to Bautista-Arredondo and others (2018). Differences in benefit-cost ratios by income level are therefore of a much smaller magnitude than the differences in GNI.

TABLE 1 EFFECTIVENESS AND COST-EFFECTIVENESS OF MALE CIRCUMCISION

	Circumcission/ HIV Infection Averted		Benefit-Cost Ratio	
	MC at Age 15	MC at Age 30	MC at Age 15	MC at Age 30
Treatment coverage 50%, viral suppression at 80%				
HIV prevalence 20%	3.9	10.6	45	20
HIV prevalence 10%	7.8	20.5	25	10
HIV prevalence 5%	13.7	40.1	13	5
Treatment coverage 81%, viral suppression at 90%				
HIV prevalence 20%	10.0	24.8	10	4.7
HIV prevalence 10%	18.3	48.0	5	2.4
HIV prevalence 5%	35.1	94.4	3	1.2

We find that male circumcision remains a very effective and cost-effective HIV prevention intervention, especially for adolescents (age 15) where estimated benefit-cost ratios range from 3 to 45. (We obtain similar results up to age 25.) Compared to this, circumcision at age 30 is less effective (in terms of circumcisions required to prevent one HIV infection) by a factor of about 2.5, and returns a benefit-cost ratios between 1.2 (low prevalence, high treatment coverage) and 20.

The ongoing scaling up of treatment diminishes the effectiveness of and returns to investments in male circumcision. Nevertheless, we estimate benefit-cost ratios of between 1.2 (age 30, HIV prevalence 5%) and 10 (age 15, HIV prevalence 20%) in a setting consistent with reaching a 90-90-90 target, reinforcing assessments (e.g., Kripke and others, 2016b) that male circumcision will play an important role in achieving progress towards "ending AIDS" alongside meeting the 90-90-90 treatment targets.

These benefit-cost ratios – based on national averages – likely understate the potential for male circumcision. E.g., the benefits could be higher if efforts could be targeted at sub-populations with higher HIV prevalence, or more intense ongoing HIV transmission. Methodologically, the principal shortcoming of our assessment is the reliance on extrapolation, using summary indicators of the state of the epidemic and the response to it. In particular, we may not capture the complexities of the interactions between improved treatment access and the effectiveness of male circumcision. Economic factors – notably, differences in service delivery costs of male circumcision and treatment, and in the valuation of years of life lost – would also affect the estimates on cost-effectiveness. However, the magnitude of the estimated benefit-cost ratios suggests that the thrust of our findings in robust to more sophisticated and differentiated approaches.

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Reduced adolescence pregnancy through education

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Summary

Adolescent pregnancy is major public health problem in low- and middle-income countries. The younger the age of the mother the higher the chance of developing pregnancy and childbearing complications including maternal and infant death. A cost-benefit analysis of providing structured school-based sexual and reproductive health education (SRHE) was conducted among a cohort of 1 million girls attending grade 4 to 8 in rural schools in Ethiopia. SRHE was delivered for one hour weekly for ten months in a year. Provision of SRHE cost 11 million USD with investment returns of 112 million USD, giving a Benefit-Cost ratio of 10.2. The estimated costs cover salary, educational materials and training. The benefits accumulate from reduced rates of maternal and infant mortalities, cost-savings from reduced incidence of pregnancy and birth-related complications and the value of time saved. The analysis did not include educational costs associated with increased school retention rates and benefits associated with increased future earnings due to more education and reduced rates of stillbirths and years lived with disability (YLD), which may underestimate the investment returns. Therefore, delaying pregnancy to a more appropriate age through SRHE has the potential to prevent undesirable and costly health, social and economic outcomes to the mother and the baby. However, despite the demonstrated good return to investment, there are controversies and disagreements among stakeholders including parents about the contents of the SRHE curriculum, which could negatively affect scale-up plans in different countries.

The problem

About 17 million girls under the age of 19 years give birth every year, mostly in low- and middle-income countries (LMIC) [1]. Simply put, more than 20,000 girls under the age of 19 years give birth every day in LMIC, making adolescent pregnancy to be one of the major development challenges of our time. This problem is largely concentrated in the sub-Saharan Africa, with highest recorded annual birth rates that exceed 200 per 1000 adolescent girls aged between 15-19 years in countries such as Central African Republic, Niger and Chad[48]. The United Nations Development Fund reports that while the prevalence of adolescent pregnancy has decreased globally, unfortunately it has remained relatively unchanged in sub-Saharan Africa. By 2030, the population of adolescent girls in sub-Saharan Africa will grow by 50%; hence, increasing the magnitude of the problem [2]. Ethiopia has a population of about 105 million people, and closer to one million women aged 20-24 years were reported to have given births by age 18. This puts Ethiopia among the top 10 countries with largest number of adolescent pregnancies, and second in Africa after Nigeria [2].

Adolescent pregnancy has far-reaching adverse health, social and economic consequences both to the mother, child and the society. First, adolescents are at much higher risk of pregnancy and childbearing complications such as low-birth-weight, eclampsia and preterm births. Adolescent mothers and their infants are more than three-times likely to die due to pregnancy and birth-related complications compared to older women and their infants [3, 4]. The complications arising from pregnancy and childbirths are the second leading cause of death among adolescent girls aged between 15-19 years in LMIC [1]. Adolescent pregnancy is also the cause of school drop-outs which, in the long-term, may result in lost productivity and income, and is also considered to be the main cause of the pre-existing gender inequality, poor economic prospects of women and poverty [5].

[48] https://data.unicef.org/topic/maternal-health/adolescent-health/

Adolescent pregnancy is attributed to a complex interaction of various factors, hence there are many interventions that have been tested to reduce child marriage and pregnancy. They include conditional or unconditional cash transfers to keep girls in school, community sensitization to address cultural norms, provision of contraceptives, counselling and school-based programs [5, 6]. However, WHO strongly recommends the provision of sexuality and health education, life building skills, curriculum-based sexuality education combined with promotion of contraceptive among others [7, 8]. Cash transfers are considered to be effective, but they are expensive to scale-up to large populations especially in poor countries [9, 10].

The proposed solution

Comprehensive sexual and reproductive health education is a curriculum-based process of teaching and learning about the cognitive, emotional, physical and social aspects of sexuality. It addresses SRH issues, including sexual and reproductive anatomy, puberty and menstruation, delay of sexual debut, use of modern contraception, training in life skill training (decision making skills, setting goals for life and how to say no to sex), pregnancy and childbirth, STIs, including HIV and AIDS etc. School-based SRHE enhances self-efficacy related to refusing sex or condom use, improving use of contraceptives, reducing number of sexual partners and delaying the initiation of first sex [11, 12].

To demonstrate economic impact of SRHE, we modelled a cohort of one million girls as they transition from grade 4 to 8 in primary schools in rural Ethiopia. A lot of these girls are overage, hence we assumed that 3% were already sexually active in the 4th grade[49]. At each level the girls receive age-appropriate SRHE. Thus, the time horizon of this analysis is five years. Costs and benefits except mortalities are discounted at 5%. Comprehensive SRHE will be delivered by Health Extension Workers each week for one hour over 10 months of school time.

The costs and benefits

The annual cost of providing SRHE in rural Ethiopia was 2 USD per girl, which covers the cost of training materials, training of HEW and allowances[50]. The benefits associated with SRHE are complex and multidimensional and most of them are difficult to measure. For example, it may take an average of 20 years for lives of infants saved to enter labour force. In this analysis the benefits included are statistical value of years of lives saved (YLL) due to deaths averted, cost-savings from pregnancy and birth-related complications and value of caretaker's time saved. This study indicates that provision of SRHE in rural Ethiopia has a BCR of 10.2. Other studies with different interventions but targeting adolescents have reported comparable BCRs. For example, interventions to reduce child marriage in sub-Saharan African countries found the BCR of 9 or more [13].

Costs	Value (USD$)
Salaries of providers of SRHE	250,000
Cost of training materials per year	23,000
Training of Trainers (TOT)	36,000
Training of SRHE providers	3,300,000

Benefits	Value (USD$)
519 avoided maternal deaths (26,980 Years of Life Lost averted)	27,708,460
978 avoided infant deaths (59,640 Years of Life Lost averted)	61,249,972
Reduced healthcare costs	23,067,177
342 years saved for taking care of patients	90,243

Discussion

Adolescent pregnancy significantly contributes on infant and maternal morbidity and mortality rates and reduced future earning for women in LMIC countries. However, efforts to address

[49] This is based on the DHS 2017 data, which indicated that 6.3% of 15-year old girls had initiated sex

[50] Rahima S, Cost-effectiveness of sexual and reproductive health education and access to modern contraceptives to prevent unintended adolescent pregnancy in rural Ethiopia: an economic evaluation. Master thesis, 2019, University of Bergen.

this problem must consider the complex relationship between early pregnancy, marriage and school drop-out that varies between settings [14]. Early pregnancy and marriage are both the cause and consequence of school drop-out. So, while in Ethiopia about 83% of early pregnancy are estimated to occur within marriage[51], it is unknown whether the girls dropped out of school before they got married or they never attended school. Evidence shows that girls who are out of school are more likely to engage in sexual relationships, marry or get pregnant compared to those in school [15, 16]. Besides longstanding and deep-rooted traditions in Ethiopia [17, 18], poverty plays an important role for early sex, pregnancy, school drop-out and child marriage in LMIC [8, 19]. This complexity and interrelation of factors underscores the importance of empowering girls with SRHE.

It is estimated that by reducing adolescent pregnancy by 10% would reduce maternal mortality in a country by about 70% [20]. While saved earning loss was not included in our analysis, evidence shows that child marriage and childbearing reduce future earnings of a woman by 9% due to lower economic productivity [21]. Welfare benefits of reduced population growth by ending early childbearing for 106 countries was estimated to reach USD 566 billion [22] while economic benefits due to reduced under-five mortality rates and malnutrition is estimated at USD 100 billion by 2030 [23]. Therefore, scale-up of SRHE could be of great benefit in LMIC [52]. However, provision of comprehensive SRHE in schools is controversial in some places because of religious, social and cultural value embedded in it [24-26]. Thus, more research is needed on the acceptability of SRHE, cost and more efficient approach of delivering it in schools. In Ethiopia we considered the use of Health Extension Workers, but a more affordable and cost-effective approach will be to use the teachers.

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[51] https://www.rutgers.international/sites/rutgersorg/files/PDF/RHRN-HLPF_A4leaflet_Ethiopia.pdf

[52] Countries with highest annual incidence of adolescent livebirths above 150 per 1000 adolescent population include Central African Republic (229), Niger (210), Chad (203), Angola (191), Mali (178), Mozambique (166), South Sudan (158) and Guinea (154) have more potential to benefit from SRHE. These are closely followed with Madagascar (147), DR Congo (135), Zambia (145), Malawi (143), Burkina Faso (136), Tanzania (128), Somalia (123) and Sierra Leone (121): Sources: Most recent estimates for each country taken from 2015 Update for the MDG Database: Adolescent Birth Rate (UNFPA/UN Population Division)

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Expansion of Marine Protected Areas

Luke Brander

Identification of problem, scope

Marine ecosystems and the services they provide such as provisioning of nutrition, coastal protection, recreational opportunities and climate regulation are becoming degraded around Africa. Threats include coastal development, runoff of sediments, sewage, plastic waste, climate change, overfishing, ocean acidification and the use of destructive fishing practices. For example, 20-30% of the mangroves in west and central Africa have been lost in the past 25 years (UNEP, 2007); and in 2017 most of the fish caught in that region were classed as threatened and near threatened species (IUCN, 2017). According to the World Bank, fisheries and aquaculture provide employment to over 12 million people in Africa and directly contribute $24 billion to its economy (The World Bank, 2019). Fish is also an important source of essential proteins and nutrients to over 400 million people.

Proposed solution

In response to increasing degradation of the marine environment and declining provision of ecosystem services, several national and international initiatives have called for the development of Marine Protected Areas (MPAs)(CBD, 2010). An MPA is a clearly defined geographical space, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IUCN, 2008). MPAs can improve the condition of marine ecosystems through diverse ecological pathways and, although challenging to quantify (Fox et al. 2014), result in improved biological parameters such as habitat complexity, survival rates of juvenile fish, species diversity, fish biomass, density and size (Lester et al., 2009). Improved ecosystem condition may translate into improved provision of ecosystem services, particularly in terms of tourism and recreation (Badalamenti et al., 2000; Potts et al. 2014), fisheries in adjacent areas through spillover effects (Roberts et al., 2001; Gell and Roberts, 2003) and cultural values associated with the conservation of marine biodiversity and mega-fauna (Cañadas et al., 2005).

The intervention addressed in this policy brief is the expansion of MPAs to 10% and 30% of the Exclusive Economic Zones (EEZ) of each of the 38 coastal countries of Africa. All MPAs are assumed to be no-take areas within which no extractive activities are allowed. The projected location of new MPAs is mapped by targeting areas characterised by high biodiversity (Kaschner et al. 2013) and low exposure to human impacts (Halpern et al., 2008), which therefore provides protection to intact ecosystems from potential future human impact. Increasing MPA coverage to 10% of each national EEZ results in 561 MPAs covering just over 3 million km^2; and 30% coverage results in 381 MPAs covering just over 9 million km^2. Note that increasing the coverage of MPAs results in fewer but larger MPAs. The time duration to set up the MPAs is assumed to be 5 years and the full benefits are assumed to accrue over a further 30 years giving a total time horizon for the evaluation of 35 years.

Principal costs of intervention

Two broad categories of cost associated with the creation and management of MPAs are included in the analysis:

- Costs incurred by the implementing agency in establishing and operating the MPA. Establishment costs include all costs incurred up to and including the designation of the MPA and the initiation of its management, whereas all costs incurred subsequently are classified as recurrent operating costs. Studies that have examined MPA establishment costs indicate that these costs are spatially heterogeneous at a fine scale (Richardson et al., 2006). Establishment and management costs for each MPA are estimated using cost functions published in the literature (Balmford et al., 2004; McCrea-Strub et al., 2011).

- Costs incurred by industry and coastal communities in the form of compliance and opportunity costs (the value of foregone activities that are restricted by the MPA). The opportunity costs to fisheries are estimated using FAO data on the value of marine capture fisheries production and the area closed to fishing, accounting for potential spillovers from MPAs to fisheries. We are unable to quantify and value other opportunity costs resulting from MPA expansion, including to shipping; oil, gas and mineral extraction; off-shore wind power generation; and subsistence fishing. Shipping costs are not expected to be greatly affected by MPA expansion because MPAs may continue to allow shipping and route distance is only a partial determinant of total shipping costs. The short-term opportunity costs incurred by small-scale and subsistence fisher communities are likely to constitute a substantial loss in livelihood given the level dependence on small-scale fisheries for income and food. While it is apparent that the communities whose livelihoods depend on fisheries may benefit in the long-term, it is important that mechanisms are put in place to offset short-term costs.

Benefits

The economic benefits of expanding MPA coverage are the maintained or enhanced flows of ecosystem services that are provided by protected marine ecosystems (Sala et al., 2013; Potts et al., 2014; Pascal et al., 2018). The marine ecosystems included in our assessment are coral reefs, coastal wetlands and mangroves. The marine ecosystem services assessed are the provision of food and other materials for subsistence or commercial use; tourism and recreation; coastal protection; biodiversity; and carbon sequestration. The monetary values of benefits are estimated using meta-analytic value functions published in the literature to account for site level variation in the bio-physical and socio-economic characteristics of each MPA (Hussain et al., 2011; Brander et al., 2012; Brander, 2014).

The BCR of expanding MPAs is 9.2. and 1.16 for coverage of 10% and 30% of each national EEZ respectively.

The assessment of benefits is partial in the sense that it has not been possible quantify the impacts to all marine ecosystems (e.g. pelagic, seamounts and seagrass) and all ecosystem services (e.g. existence values associated with marine biodiversity) that are potentially positively impacted by MPAs. The marine ecosystems for which we are able to model the benefits of MPA coverage are predominantly coastal (i.e. coral reefs, mangroves and coastal wetlands) and it has proved harder to model the effects of MPAs on open ocean.

Discussion of the implications of scale-up of the intervention

The scale of the intervention is generally implemented at the level of individual MPAs or networks of MPAs; most often at the national level but also at multi-national scales. The scale of the analysis is at the level of individual MPAs for estimating establishment and management costs; individual ecosystems for the assessment of benefits; and at the national scale for the estimation of fisheries opportunity costs. The analysis necessarily involves large generalisations and the results are aggregated to the African regional scale to provide a general indication of the economic performance of investments in MPAs.

In this analysis, the spatial targeting of new MPAs is defined by a small set of simple rules in order to explore a broad strategy for MPA expansion to target areas with high biodiversity and low human impact. The spatial allocation of MPAs does not therefore reflect the wide range factors that would ideally be considered in the actual siting and design of MPAs. In particular, the siting of MPAs, and subsequent assessment of costs and benefits, does not account for network or connectivity effects (Pujolar et al., 2013) or for institutional factors of MPA expansion (Mora et al., 2009). The process of siting MPAs would need to consider the oceanographic, cultural and ecological connectivity in the maritime space to assess a

coastal state's and communities' interests and priorities for protection.

Further research that could be undertaken either to lower the costs of the intervention or to introduce a more efficient technology

The estimated costs of MPA management are a relatively small proportion of total costs (approximately 7%) but still represent one of the biggest challenges facing marine resources managers in many developing countries. Essentially, resource managers do not have sufficient funding to ensure compliance through monitoring, policing and enforcement; and hence many MPAs are not effective in delivering socioeconomic and ecological benefits. It may be possible to reduce monitoring costs through research into advanced technological approaches for tracking activities in MPAs (McCauley et al., 2016). The main costs of expanding MPAs, however, are the estimated fisheries opportunity cost (approximately 90% of total costs). As fisheries are important to the economy and to nutrition in many African countries, research into alternative livelihoods and sources of protein could be undertaken to reduce this cost.

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Scaling up improved access to clean water in Africa

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Introduction

In September 2015, heads of state from all around the world adopted the 2030 Agenda for Sustainable Development, an ambitious plan of action for "people, planet and prosperity", with 17 Sustainable Development Goals (SDGs) and 169 targets. Drinking-water, sanitation and hygiene are covered in SDG6 targets 6.1 and 6.2, as well as in other SDGs covering disaster risk reduction, education, health, nutrition, poverty and gender. Recognizing the basis of drinking-water for human survival as well as all its many health and socio-economic benefits (Hutton, 2012), target 6.1 for drinking-water states "By 2030, achieve universal and equitable access to safe and affordable drinking water for all".

In transitioning from the Millennium Development Goals to the SDGs, different rungs on the water service ladder should be noted. First, the new term 'basic' drinking-water refers to an improved water source (as per MDG water indicator), provided collection time is not more than 30 minutes for a round trip, including queuing. Hence, especially in Africa where 17% of rural households source their water from greater than 30 minutes roundtrip (a much higher proportion than other regions), the achievement of the 'basic' water service level already represents a challenge for the African continent. Note also that the 'basic' water service level is monitored as part of the poverty SDG, indicator 1.4.1, as well as the target service level for schools (indicator 4.a.1) and healthcare facilities. Second, the indicator for Target 6.1 is the "Proportion of population using safely managed drinking water services". 'Safely managed drinking water' is defined as "From an improved water source that is located on premises, available when needed and free from faecal and priority chemical contamination". Hence, this service level for water is significantly higher than the 'basic' water service level, and an even greater challenge for the African continent.

The latest report of the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene (2019) shows Africa to be trailing other regions in terms of access to safely managed water supply (27%) and basic water (61%). The report also notes the very significant inequalities, with rural areas (45%) having roughly half the coverage of urban areas (84%) for basic water supply, and other sub-national inequalities by region or by province. Recent JMP reports for schools (2018) and healthcare facilities (2019) show that major challenges remain in institutional access to water in sub-Saharan Africa, with only 51% of healthcare facilities with at least basic water and 47% of schools without basic water access.

The aim of this paper is to present updated cost-benefit numbers for achieving universal access drinking-water supply to African households from 2018 to 2030, to enable comparison of drinking-water with other development interventions included in the Copenhagen Consensus Center's Africa initiative. Access is defined as what water source is actually used by households. The analysis focuses on basic drinking-water as defined by WHO/UNICEF in the Joint Monitoring Programme's latest biennial report (WHO/UNICEF 2019). This is partly due to the lack of coverage data on the 'safely managed' service level, but also, from an equity perspective, the presentation of cost and cost-benefit results for 'basic' access brings greater attention to those being left behind and focuses policy makers' and financiers' attention on achieving basic access for all.

Methods

Global costing and cost-benefit studies have previously estimated the costs of achieving the SDG targets 6.1 and 6.2 (Hutton and Varughese

[53] The previous reports (Hutton 2015, 2018, Hutton and Varughese, 2016) this study draws on were based on work done while the author was employed by the World Bank.

2016) and the economic returns of water supply (Hutton and Haller 2004, Hutton 2012, 2015, 2018, Whittington et al 2008). This current study draws on the same methodology as these past studies, in particular the previous Copenhagen Consensus Center study (Hutton 2015) with figures updated to 2018 values. The costing methodology is described fully in Hutton and Varughese (2016).

In the model are included 53 African countries, with results presented for sub-regional as well as regional levels (see Appendix[54]). Cost-benefit ratios for Africa and its sub-regions are weighted by country population size receiving the interventions.

Given that coverage estimates of 'safely managed' drinking-water were not available for 46 out of the 53 African countries in the latest JMP report (WHO and UNICEF, 2019), only 'basic' drinking-water access was modelled in this current cost-benefit study. Households are considered to have a 'basic' drinking water service when they use water from a household piped water supply, collected rainwater, or a protected community source such as a well, spring and borehole within 30 minutes roundtrip, including queuing [55]. The intervention in this study assumes only protected wells are provided at the community level.[56] 'Basic' access is an important step in the service ladder towards 'safely managed water supply', where further health benefits, convenience and time savings are possible.

Key input variables were updated, including unit costs of water services and GDP per capita (to 2018 prices), while drinking-water coverage was updated to the latest numbers for 2017 (WHO and UNICEF, 2019). All results are presented by rural and urban areas, and nationally. Incremental costs were estimated as the full costs of providing access to a basic source within a 30-minute roundtrip to households currently without access. Capital costs, programme costs, capital maintenance and annual operations costs were included, modelled for a 12-year period from 2018 to 2030. Future costs and financial benefits were discounted to the present period at 5% per annum.

A large range of economic and social benefits can result from improved drinking-water services. The benefits included in this study relate to both health benefits[57] and time savings of reduced time spent collecting water, as previously described (Hutton 2015, 2018). A reduction of 34% in diarrheal cases and deaths is assumed, when moving from unimproved to improved community water sources, taken from a meta-analysis (Wolf, Prüss-Üstun et al, 2014). Due to lack of credible Africa-wide data, many previously documented benefits were excluded (water reuse value, property value, non-use values and other educational benefits beyond those estimated under health and time savings).

Results

Figure 1 shows the benefit-cost ratios (BCRs). It indicates an overall BCR of 6.4 for Africa for basic drinking-water, varying between 5.0 and 7.7 across sub-regions. Rural water supply has a higher BCR of 9.1, varying from 7.1 to 10.8 across sub-regions. Urban water supply has an overall BCR of 4.5, varying from 3.9 to 6.6 across sub-regions.

[54] http://www.amcow-online.org/index.php?option=com_content&view=article&id=117&Itemid=57&lang=en

[55] In terms of water source type, the previous definition of 'improved' water is the same as 'basic' water, except that the latter requires that the total collection time is 30 minutes or less for a roundtrip. This definition varies from the MDG definition in that the latter did not include criteria for collection time.

[56] 50% of unserved population receives a protected community borehole/tubewell and 50% of unserved population receives a protected dug well.

[57] Including financial savings related to seeking less health care, savings related to productive time losses from disease, and savings related to reductions in premature mortality (valued at 1.3 times the GDP per capita for each avoided year of life lost).

FIG 1. BENEFIT-COST RATIOS OF PROVIDING BASIC DRINKING WATER IN AFRICA, BY SUB-REGION

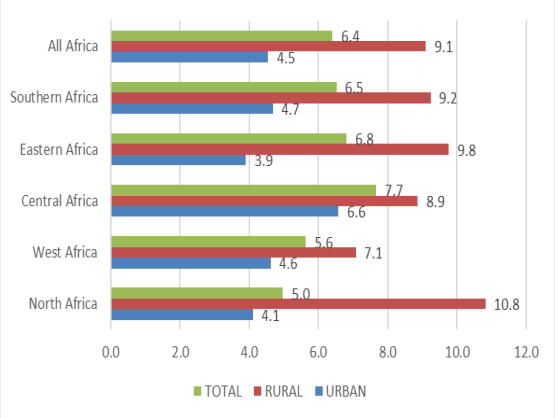


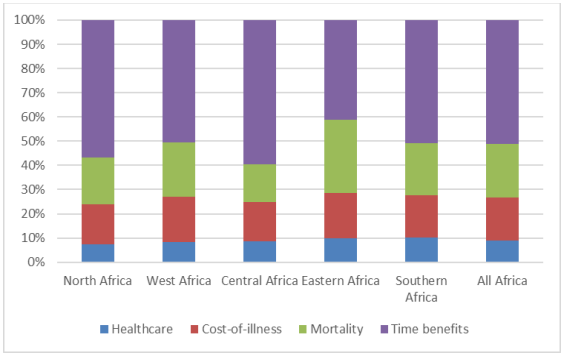
Table 1 provides the total costs and benefits for Africa and by sub-region. The total costs for Africa are US$ 65 billion, or roughly US$ 6 billion per annum. Given all costs need to be included in the calculation of the BCR, these numbers all cost categories, with an approximate split of 50/50 across capital/capital maintenance and annual operations costs over the 12-year period. However, these different costs are likely to be financed in different ways, with different financing mixes (between public sector, charities and communities or households) by country and by local context.

TABLE 1. COSTS AND BENEFITS FOR PROVIDING BASIC DRINKING WATER IN AFRICA, BY SUB-REGION, FROM 2018 TO 2030 (USD BILLION)

Costs			
Sub-region	Urban	Rural	Total
North Africa	7	1	8
West Africa	6.4	4.4	10.8
Central Africa	3.9	3.6	7.5
Eastern Africa	10.8	10.7	21.5
Southern Africa	10.3	7	17.3
All Africa	38.4	26.7	65.1
Benefits			
Sub-region	Urban	Rural	Total
North Africa	28.7	11.3	40
West Africa	29.4	31.4	60.8
Central Africa	26	31.7	57.6
Eastern Africa	42.2	104.1	146.3
Southern Africa	48.4	64.3	112.7
All Africa	174.6	242.7	417.3

The total benefits for Africa are US$ 417 billion, or roughly US$ 35 billion per annum, for basic drinking-water. These values could be a significant underestimate of the true benefits of basic drinking-water supply, due to many benefits being omitted. Time benefits account for roughly half of total valued benefits, varying 40% to 60% between sub-regions. The financial savings from avoided healthcare account for approximately 10% of the included benefits, with the remaining 40% from monetized value of economic benefits (22% from valued lives and 18% from valued time from less morbidity).

FIG 2. (%) BREAKDOWN OF BENEFITS BETWEEN TIME SAVING AND DIFFERENT HEALTH ECONOMIC CATEGORIES



Discussion

This study has confirmed that drinking water supply and sanitation both generate high economic returns to society, with returns exceeding costs by at least 4 times across all areas and sub-regions, and averaging 6.4 across the African continent. The study showed that economic returns varied between different sub-regions of the world. This variation is partly expected due to different relative price levels of water services, and different capacity to benefit (such as existing disease rates). The variation is also likely to be due to weak data for some regions and countries (e.g. unit costs of services, time savings from closer water source).

Several aspects could not be easily modeled in such a large area study of the African continent, and need to be considered in interpreting the results. First, there are many practices around management of water which affects its safety when used for drinking, food preparation and other hygiene purposes. The seasonal availability and access cost will lead to various compensating behaviors which affect the potential health benefits, both negatively (e.g. recontamination related to poor storage

practices) and positively (e.g. household water treatment, when sensitized to health risks). Second, in household self-supply and in programme implementation, different service levels will be chosen than 'basic'. In urban areas especially, expectations and needs for higher service levels will mean that municipalities will encourage water utilities to expand their networks, such as through regulation or subsidies. Where piped water does not yet reach household or is unreliable or poor quality, households might be willing to pay for vendor-supplied water and in many cases bottled water, often faced with little other choice. Hence, the eventual costs are likely to be higher than those included here. On the other hand, many of these solutions also have higher health benefits, time savings and other benefits compared with basic water supply. Third, the costs and benefits included reflect a part of the picture, but in reality there will be additional costs such as interest costs for capital costs financed by borrowing, additional programme costs in hard-to-reach communities and additional capital costs in water scarce regions (needing deeper wells). However, the benefits included are likely to underestimate the full social, economic and peace benefits of populations having at least a basic access to water supply.

There remain many challenges to scaling up drinking-water supply in Africa, among them water scarcity (both seasonal and all-year-round) and further changes in rainfall patterns induced by climate change. Also, competition for water among its competing uses, in particular agriculture, and pollution of both underground and surface water sources from human activities reduces the supply of clean water. Also, the costs even of basic water supply is challenging for many communities to cover, and the lack of public funds allocated to water supply, in particular rural water. Also, as has proven, there are many logistical and behavioural challenges in maintaining and sustaining water services.

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Appendix: Sub-regions of Africa

North Africa: Algeria, Egypt, Libya, Morocco, Tunisia

West Arica: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Liberia, Mali, Niger, Sao Tome and Principe, Sierra Leone, Togo

Central Africa: Cameroon, Central African Republic, Chad, Congo, DR Congo, Equatorial Guinea, Gabon

Eastern Africa: Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Uganda, United Republic of Tanzania

Southern Africa: Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Zambia, Zimbabwe

Community Health Workers for tuberculosis control

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Summary

A modelled strengthened CHW platform to support CHW-led TB case detection and adherence support translates in South-Africa to a high net benefit to cost ratio of 4.8. The largest contributor to the benefits stems from the value of the DALYs that have been averted through reduced deaths and reduced morbidity due to increased case-finding and cure rate. This analysis adopts a provider perspective and does not consider the broader savings to potential patients through averted infections. A crucial element in the success of CHW supported services is the standardization and adequacy of renumeration, as well as the strengthening of training and crucially supervision/support to ensure a high quality of service provision.

The problem

The deployment of CHWs has been demonstrated to be an important and cost-effective strategy in a range of low-and-middle income and underserved contexts where chronic shortages of nurses and doctors and large distances to health facilities have resulted in limited access to essential health services for vulnerable populations.(Vaughan et al., 2015) South Africa has a long history of using CHWs, spanning close to 5 decades. At present, CHWs are polyvalent paid workers and their roles have expanded to support the delivery of a range of high priority interventions. While CHWs have played an important role in amplifying the success of many of these programmes over the years, there has been significant inconsistency in the resourcing, management and functioning of the programme across South Africa (Schneider H, 2018). The absence of a developed CHW policy has meant that there has been no guidance on their qualification requirements, training, employment conditions, or scope of practice (Doherty et al., 2016). In addition, the lack of proper resourcing, estimated to comprise under 5% of PHC level expenditure in South Africa (Besada D, 2019), has led to inadequate coverage of CHWs, uneven training, limited provision of equipment and very importantly a poorly staffed supervision structure to support their work. The lack of detail on the CHW scope of practice has somewhat been addressed in the South African Department of Health's formalized Policy Framework and Strategy for WBOTs introduced in 2018, however financial commitments to resource this programme remain elusive. In order to advocate for increased resourcing of the CHW platform, the question arises*, what would the impact of an adequately resourced CHW platform? And would these additional benefits outweigh the input costs required?* This brief presents part of the analysis for TB.

South Africa ranks among the top 10 high TB burden countries. With 567 new cases per 100 000 population, South Africa has the second highest rate of TB incidence after Lesotho; collectively these two countries account for 31% of the world's burden of TB, and 37% of TB deaths. (Padayatchi et al., 2019). Furthermore, while multidrug-resistant tuberculosis (MDR-TB) prevalence rates have remained stable, at 2.9%, in the 2001–2002 South African survey, compared with 2.8% in 2012–2014, the rate of rifampicin resistance (RIF-R) has increased, from 3.4% to 4.6% (Diseases., 2016). The TB epidemic in South Africa is primarily driven by its concurrent HIV epidemic. SA reported the highest number of HIV-associated TB cases worldwide in 2017, with 60% of incident TB cases coinfected with HIV and HIV-positive TB mortality accounting for 71.8% of deaths among patients with TB. (WHO, 2018). While traditional cohort analysis reports a 75% treatment success rate, a detailed cascade of care analysis on 2013 programmatic data (Naidoo et al., 2017) found that just 53% of the estimated TB cases resulted in successful treatment completion. The study revealed a series of stepwise losses along the treatment pathway, from care seeking to treatment completion

The analysed solution

While estimated tuberculosis incidence rates and mortality appear to be decreasing in South Africa as a result of the expansion of the large roll-out of ARV treatment, the current rate of decline is too slow to meet the 2030 Sustainable Development Goals or 2035 End TB Strategy targets (Strategy, 2015)]. Pren Naidoo et al.(Naidoo et al., 2017) have indicated that by 2030 and 2035, tuberculosis incidence rates for South Africa would need to decrease to 167 and 83 cases per 100 000 population, respectively, and mortality would need to decrease to 9800 and 4900 cases, in order to reach global and local TB targets. Achieving these ambitious targets therefore requires a more invigorated response, shifting away from the historical focus on treatment success rates, which fails to reflect upstream losses contributed by individuals who do not access health services and by those for whom tuberculosis is not diagnosed, notified, and treated.

Global evidence has revealed that a well-resourced and supported CHW platform has the potential to increase both case finding and treatment success rate by supporting person-centered care, including raising TB awareness (and) providing TB information in local languages to communities, in addition to following up on defaulters. CHWs were demonstrated to increase case detection by a range between 16% (Ospina et al., 2012) and 55%(Miller et al., 2010) while treatment success through household visits by a nurse or lay counselor led to a 55% reduction in TB transmission over 3 years and a 12% reduction in TB prevalence (Ayles et al., 2013)

The modelled intervention consists of a four-fold increase in funding for the CHW platform to secure additional CHWs, alignment of their stipend to the national minimum wage, systematic ongoing training, dedicated supervision, 1 laptop per team to improve planning of coverage, patient monitoring and data analysis by team supervisors, mobile phones for both supervisors and the CHWs and the adequate refilling of job kits and airtime. Given the polyvalent nature of CHWs, an analysis of the 2017 burden of disease and demographic structure of the population in South Africa shows that CHWs would spend approximately 8% of their time on TB-related activities; 8% of the increased funding was thus allocated to TB services in the model. The analysis considers HIV positive and HIV negative populations separately as life expectancy and case fatality rates between these two populations varies significantly. This modeled intervention drew on conservative estimates of a 10 percentage point improvement (68%-78% for TB and 73% to 83% for MDR-TB) in case detection and a 5 percentage point improvement in treatment success for both TB(82%-87%) and MDR-TB treatment (55%-60% for MDR) and in turn estimates the resulting deaths averted, DALYs averted, and the benefit/cost ratio of the modelled intervention. The analysis summarizes the cumulative costs and impact over 10 years of a scaled-up CHW platform on TB outcomes and the multiplier effect of additional salaries for CHWs and supervisors spent back into the local economy. A sensitivity analysis was run on the scenario estimates for case detection and treatment success by applying both a 20% reduction and 20% increase for each.

The costs and benefits

10 years additional cost of the CHW intervention for TB	Within cost category	Value
Capital/set-up costs (4% of total cost)	100%	$12,689,639
Training	31%	$3,922,204
Equipment	69%	$8767434
Recurrent (96% of total cost of platform)	100%	$288,083,673
Overheads	9%	$26189425
Equipment	10%	$28272557
CHW & supervisor salaries	81%	$233,621,690
Additional treatments due to intervention		**Cost of Treatment**
Additional TB & MDR-TB treatment		$77427289
Total Additional Cost		**$378,200,600**

*The costs are reported in 2018 dollars and have been discounted at 5%.

Benefit	Within benefit category	Value
44,641 avoided deaths		incorporated in DALYS below
1,163,818 avoided disability adjusted life years Combines DALYS averted due to reduced mortality and morbidity	99.2%	$8,044,397,969
Savings due to **171,845** avoided TB & MDR treatments as a result of reduced transmission	0.5%	$40,237,945
Multiplier effect of additional salaries	0.3	$26,389,580
Total benefits		**$8,111,025,495**

BCR (HIV + and HIV -)	4.8 (4 – 5.2)
BCR (HIV+)	6.1(5.1 – 7)
BCR (HIV -)	2.8 (2-3- 4.4)

With a benefit to cost ratio of 4.8, this CHW led intervention represents a high net benefit relative to input costs. The BCRs have also been calculated independently for HIV + and HIV – populations, although the different costs are not presented. It is important to note that the HIV+ BCR is both for those on ARVs and those not on ARVs but the analysis demonstrates that the BCR for HIV+ populations is double that of HIV- populations. The intervention does not however provide immediate savings to the health sector, since the cost of additional treatments is higher than the savings incurred through avoided treatments. The largest contributor to the benefits stems from the value of the DALYs that have been averted through reduced deaths and reduced morbidity. The benefits incurred through avoided TB treatments due to reduced transmission and incidence represents a far smaller proportion of the total benefits. However, reduced transmission provides a broader societal benefit beyond the health sector through the DALYs averted and their impact on the economy due to the improved health status of the population. The analysis does not account for a reduction in the time to diagnosis through increased case-finding, and therefore could be an underestimate of transmissions averted. This analysis, however, adopts a provider perspective (ie cost to the health system) and does not consider the broader savings to potential patients directly stemming from reduced infections and successful treatments. While treatment for TB is provided free of charge, there still remains a cost burden on patients related to transport to facilities and a loss of income both to themselves and their care-takers.

Discussion

The PHC re-engineering strategy currently being implemented in South Africa envisions that CHW programmes will be transformed away from being employed and trained in vertical programmes into a system where they have a common role, serve more than one programme and have a core set of competences.(Heunis et al., 2013) While this analysis and policy brief focused on the TB related services, the comorbid nature of conditions, with the growing quadruple burden of disease in South Africa has necessitated an integrated response to service delivery. The broader investment case conducted by the South African Medical Research Council demonstrated that the strengthening of the CHW platform was also highly cost-effective for CHW supported interventions for Maternal and Child Health, HIV, and diabetes. Furthermore, palliative care provided by CHWs in the home translates into significant savings to the health sector.

However, scaling-up CHW programmes runs a high risk of overburdening CHWs and neglecting the necessary quality criteria, (Hermann et al., 2009) with the insufficient training of existing cadres as further reason for concern (Languza N, 2012). As noted earlier, a crucial element in the success of CHW supported services is the standardization and adequacy of remuneration, as well as the strengthening of training and supervision support to ensure a high quality of service provision. CHWs that are effectively supervised are motivated and perform a greater range of tasks. (Tseng et al., 2019). Furthermore, the acceptability of CHWs within communities is key to ensure higher case finding and adherence support.

This analysis has demonstrated that strengthening the CHW platform has the potential to significantly improve TB and MDR-TB outcomes. Given the highly contagious nature of un-managed TB, increasing case detection and resulting treatment coverage, in addition to improving treatment success through CHW led adherence support and defaulter tracing, results in both transmissions and deaths averted, as well as a reduction in TB incidence. The monetized value of benefits far outweighs the investment. This approach would be relevant for any resource constrained setting with inadequate human resource coverage to address their infectious disease epidemics and the growing burden of non-communicable diseases. This analysis demonstrates that this intervention would result in significant gains in settings with high TB incidence, inadequate case finding and poor access to PHC facilities, both with and without a concurrent HIV epidemic.

The 2018 WHO TB report highlight 14 countries in the world with a high burden of each of the 3 diseases. Of the 14, 8 were in Sub-Saharan Africa: Angola, DR Congo, Ethiopia, Kenya, Mozambique, Nigeria, South-Africa and Zimbabwe. With many countries reporting far lower coverage and success rates than South Africa, the magnitude of improvement of the suggested intervention is likely to be much higher. This analysis is also of relevance for countries which are still in the process of exploring a formalized CHW platform. In South-Africa the additional cost of strengthening the CHW platform may be higher than in other settings, particularly in Sub-Saharan Africa, on account of higher CHW stipends and salaries of supervisors. Despite this, the value of the additional benefits far outweighed the costs.

Further implementation research to assess the effect of different supervision interventions on CHWs' perceptions of support and resulting motivation and health related outcomes could be explored in settings with limited nurse personnel available to provide that role. In addition, effective community health information systems are critical in settings that are increasingly relying on CHWs to ensure that the health information generated by them is linked to the facilities for the continuity of patient care. Yet, in most countries, this vital information on health services provided by CHWs is not routinely captured and there is a need to increasingly explore the role of mHealth technologies to improve data capturing and monitoring.

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Improvements in Child Cancer Diagnostics and Treatment in Africa

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Summary

In Africa, more than 50% of cases of childhood cancer go undiagnosed. Africa accounts for 146,000 of the projected 397,000 new cases globally per year (including both diagnosed and undiagnosed cases) (Ward et al, 2019a). Of the diagnosed cases, only 11.6% of children in Africa survive (Ward et al, 2019b). Based on the above modeling exercise, we estimate that only about one-third of those who are diagnosed actually receive treatment; no hard data are available. Increasing access to treatment will increase survival, although to reach survival rates comparable to high income countries, investments will also be needed to decrease treatment abandonment and improve quality of treatment (Ward et al, 2019b).We recommend investing to expand treatment of five key cancers that are both treatable and affordable. These five cancers together account for 40% of the burden of childhood cancer in Africa. Studies of cost per child treated in sub-Saharan Africa for three of the conditions (Burkitt lymphoma, nephroblastoma and early-stage retinoblastoma) were $1248, $1976 and $2202 USD respectively in various low- and lower-middle income countries in Africa. More conservatively, costs of a comprehensive cancer centre in one African country which achieved a projected 5-year survival rate of 35% for a cohort of children with multiple cancer types, were around $10,000 per child in 2018 USD, or around 6.5 times per capita GNI (see text below for all study references).

Benefit:cost ratios were estimated as 9.1 to 19.3 for the three diseases for which studies were available, and a more conservative 5.2:1 for a comprehensive centre which treats not only the priority diseases, but also provides treatment for other less-treatable conditions and palliative care to children for whom cure is not possible. Ratios would be a little lower (4.6:1) but still very attractive if indirect costs to families were included in treatment costs, and higher if non-profit organizations took the lead in small investments to reduce treatment abandonment rates, as has been done successfully in a number of low- and middle-income country (LMIC) contexts.

Expanding care from the estimated one-third of those diagnosed to all those currently diagnosed would cost $407m using the comprehensive cancer centre model. This amount would double, if 90% coverage of were attained (i.e. if 80% of all undiagnosed children could be diagnosed and linked to treatment). The value of the benefits would however be an estimated 5.2 times the costs, or $2116m. There are other potential unquantifiable benefits, such as helping to show that cancer is indeed curable and helping reduce the stigma associated with cancer in Africa, potentially leading adults with cancer to seek care earlier and improve their survival. In addition, improving capabilities to treat childhood cancers has the potential to strengthen health systems more broadly, by developing radiologic and pathologic services, medicines procurement and supply management, surgical facilities, health human resource training and retention, and supportive care capacities.

Scope of the problem

Childhood cancer is a leading non-communicable cause of death in children aged 0-14 years worldwide (Global Burden of Disease Cancer Collaboration, 2017; Bonaventure et al, 2017). Diagnosed cases of cancer accounts for the death of 140,000 children globally annually, 1.8% of the global total number of child deaths (Global Burden of Disease estimates): given that more than 50% of cases of childhood cancer go undiagnosed, the true child cancer death rates are more than twice this large. These undiagnosed child cancer deaths are currently attributed to other or unknown causes.

Childhood cancer differs from adult cancer in that there are no known methods for

prevention. In adults it is possible to reduce cancer risks by avoiding exposure to hazardous substances such as tobacco, by changing diet, and by becoming vaccinated against certain conditions such as hepatitis B and human papillomavirus. No such options exist for childhood cancer at present, and treatment is the key option. Moreover, childhood cancers are sufficiently uncommon that screening is also not a viable strategy. Early diagnosis linked to treatment is the main, and perhaps only route to reducing mortality.

More than 80% of diagnosed cases of childhood cancer occur in LMIC (Magrath et al, 2013), where access to diagnostics and treatment are limited (Farmer et al, 2010). The substantial improvements in pediatric cancer survival in high-income countries (HIC), where greater than 80% of children are cured, have not been realized in LMIC (Allemani et al, 2018). This stark survival gap has provoked global calls to prioritize childhood cancer in efforts to expand universal health coverage (UHC) and meet Sustainable Development Goal 3 targets. The recent launch of a World Health Organization Global Initiative on Childhood Cancer reflects mounting international commitment to addressing this significant, and remediable, loss of young lives (WHO, 2018).

The African continent will become an epicenter of global childhood cancer mortality over the coming decade, as Africa currently accounts for 25% of the world's children, a share that will grow to 40% by 2050 (UNICEF, 2017). Indeed, modeling work by Ward et al. suggest that shortly after 2025, Africa will overtake Asia as the region with the highest number of childhood cancer cases (Ward et al. 2019a).The burden of childhood cancer is set to grow fastest in Africa: as national health systems expand their capability and reach, improved detection of childhood cancer will transform an epidemic of under-diagnosis into a signal health challenge for national governments. Presently, greater than 50% of childhood cancer cases throughout the continent remain undiagnosed. When accounting for under-diagnosis, estimates of age-standardized incidence rates of childhood cancer in western and sub-Saharan Africa are the highest of any in the world (Ward et al, 2019a).

Crucially, however, childhood cancer in Africa is a remediable problem, both in terms of scale and resources. Of the estimated 397,000 annual cases of childhood cancer globally (including both diagnosed and undiagnosed cases), roughly 146,000 occur in the African continent (Ward et al, 2019a). The majority of these cases are comprised of cancers that are highly treatable and for which treatment is very cost-effective. The five diseases that together account for 40% of childhood cancer incidence in Africa – acute lymphoblastic leukemia, non-Hodgkin lymphoma, nephroblastoma, Burkitt lymphoma, and retinoblastoma – are also the most curable, and at relatively low cost, representing a significant return on investment for health systems and societies.

Even when considering only those African children whose cancer is diagnosed, only a small proportion access treatment early enough to lead to a good outcome. Of those commencing treatment, a significant proportion abandon therapy, frequently due to health care costs and a lack of financial support for patients and their families (i.e. "financial toxicity"). Thus, though survival rates for all childhood cancers combined exceed 80% in North America, the survival rates for those diagnosed are only 8.1% and 8.5% in eastern and western Africa respectively, and only somewhat higher in southern and northern Africa (19.2% and 30.3% respectively: Ward et al, 2019b).

Proposed solution

We propose that for the first stage countries phase up treatment availability and financial support for the treatment of five highly curable childhood cancers, which represent relatively low cost and feasible interventions. These five cancers are: acute lymphoblastic leukemia (ALL), Burkitt lymphoma, nephroblastoma (also known as Wilms tumour), non-Hodgkin lymphoma, and early stage retinoblastoma.

These constitute five of the six WHO priority childhood cancers (WHO 2018); treatment of the sixth (low grade gliomas) is not as yet a widespread possibility in much of Africa. WHO's global goal is to achieve a 60% survival rate globally for childhood cancer by 2030, a

doubling of the current rate. To achieve this global goal, survival in Africa and South Asia (where cure rates are lowest) will need to increase significantly.

There are at least three important ways to improve survival. One is to expand availability of treatment, which includes specific treatment components (chemotherapy, radiotherapy, general surgery, and ophthalmic surgery); the second way is to reduce abandonment of therapy (which largely is a function of financial burden to the family); and the third way is to improve quality of care. Modelling by Ward et al (2019b) suggests that improving availability of treatment overall in Africa can increase survival from 11.6% (currently, across all four subregions) to 29.0%; decreasing abandonment can increase survival from 11.6% to 16.2% and increasing quality of care can increase survival from 11.6% to 21.0%. Ward et al (2019b) argue that there is "super-additivity" such that a combination of improvements in all three areas could increase survival in Africa to 80.9%. In high income countries, survival for ALL and lymphoma exceed 90% in several countries (Allemani et al, 2019) and are similarly high for early-stage cases of retinoblastoma and nephroblastoma.

We focus on the benefit:cost ratios for increased availability of treatment, since this is where most quantification has been done. We will make some suggestions regarding the likely benefit:cost of reducing treatment abandonment. Data are too limited to estimate the benefit:cost of improving treatment quality. Investments in the latter two areas will make investments to improve availability even more cost-effective.

Our results are most applicable to low- and lower-middle income countries in Africa, of which we identify 31 priority countries. The excluded countries are upper-middle income and high-income countries (10), small countries (5) and countries with life expectancy below 60 where advances in childhood cancer may be difficult to achieve due to conflict, infectious disease and other issues (9). The 31 priority countries account for more than 80% of the population of the continent and 82.1% of the incidences of childhood cancer (including both diagnosed and undiagnosed cases). We recommend that the upper-middle income countries continue to strengthen their treatment of childhood cancer, that the very small countries focus on diagnosing cases and linking children to treatment outside the country, and that the countries with lowest life expectancy start at least to educate healthcare providers about cancer. However we do not cost out interventions in the 24 countries excluded.

Principal investment costs

Previous important work, such as that conducted by the Disease Control Priorities Project, has concluded that childhood cancer treatment is cost-effective and recommended that the treatment of select childhood cancers be included in any "best buy" package of cancer interventions in low- and middle-income countries (Gelband et al. 2016). These conclusions were however based mainly on theoretical reasoning, albeit strong. In this proposal, we attempt to use recent data to further support this assertion.

The estimated benefit:cost ratios for increased access to treatment are derived from African countries as much as possible. There are, however, cases where African data and not available. In addition, there is a bias in the costing literature for individual childhood cancers to omit key cost components, as demonstrated in a recent systematic review conducted by our group (Fung et al., 2019). Whenever possible, we have cited studies with "comprehensive" coverage of costs or have used adjusted data from other regions if necessary. We have focused on cost studies in low- and lower-middle income countries since these constitute the large majority of African countries.

Expanding treatment availability involves providing more of the essential inputs: training staff in pediatric oncology; funding chemotherapy and supportive care; training more surgeons in the more specialized care required for pediatric oncology. The most "lumpy" investment is in increasing access to radiotherapy (Atun et al, 2015); however the five priority cancers rely less on radiotherapy

precisely because availability is so poor in Africa. Building capacity (particularly human capacity and specialized healthcare resources such as radiotherapy equipment) takes time. For this reason, we assume a 12-year horizon to 2030 (the end-date for the WHO survival targets).

We use estimates from our group's work that cost per child treated in a comprehensive cancer centre is about 6.5 times per capita GNI (based on studies in Ghana and El Salvador). To treat the two thirds of children currently diagnosed in the 31 priority countries, we estimate the costs as $407m per year (Appendix 1: costs).

Benefits

The benefits of the investment are primarily in child survival. The cost-effectiveness of treatment of individual highly-treatable cancers is already comparable to that of the investments being made at the margin against childhood infections in Africa (such as rotavirus and pneumococcus).

Studies for Rwanda, Cote d'Ivoire, Democratic Republic of Congo and Uganda suggest that the benefit:cost of investments in treatment of nephroblastoma, retinoblastoma and Burkitt lymphoma range from 9.1:1 to 19.3:1 (Appendix 1). A study of a comprehensive cancer centre in Ghana found not surprisingly that benefit:cost ratios of a centre treating not only selected highly curable diseases at early stages, but providing care to a broader range of cancers (including palliative care for cases which are not amenable to cure) has a somewhat lower benefit:cost ratio of 5.2:1 (Appendix 1).

Our results are sensitive to assumptions made. The estimates of how costs vary across countries are based on two published studies for lower-middle income countries. We have other cost and survival estimates for four other African countries not yet published (including one low-income and three lower-middle income African countries) which suggest that these estimates are reasonable and generalizable.

Benefit:cost ratios would be slightly lower if indirect costs to families were included (travel, accommodation costs associated with seeking treatment; and lost work time of the parents). Quantitative data on this are scarce, but an older study for the US (Bloom et al, 1981) suggested that these costs could be as much as 70% of per capita income (no comparable data including lost income are available for Africa). If the 70% figure were applied in Africa, the benefit:cost ratio for the comprehensive cancer centre would reduce from 5.2:1 to 4.4:1.

Relatively small investments in reducing treatment abandonment could increase the benefit:cost ratio. The Hospital Nacional de Niños Benjamin Blum in El Salvador has a charitable foundation which pays for chemotherapy and supportive care for childhood cancer. The hospital also employs two social workers to track patients who do not attend scheduled appointments, operates a hostel which provides accommodation for families, and offers a per diem for those families of low means. The cost of the social workers plus hostel plus per diem costs amount to $773 per patient or 2.2% of overall costs and is paid for by the non-profit foundation. Undoubtedly the fact that the non-profit foundation covers the significant costs of chemotherapy, diagnostics and supportive care (and that radiotherapy is provided at no cost to non-members by the public contributory healthcare scheme) reduces treatment abandonment. However, the modest support of parental costs plus follow-up by social workers have also been cited as crucial factors in reducing treatment abandonment rates (Rossell et al, 2018). As governments in Africa move to include pediatric cancer treatment among the benefits provided by universal health coverage, there is also a role for national non-profit organizations to support parents and in doing so increase the benefit:cost of investments in the health sector.

Implications

Extrapolating from the few studies for low- and lower-middle income countries in Africa with reasonable data, we have calculated benefit:cost ratios for the treatment of several common childhood cancers as well as for a

comprehensive cancer centre as a combined intervention. These ratios vary from 5.2 (for the comprehensive centre) and from 9.2 to 19.3 for three selected high-priority conditions, showing that treatment of select childhood cancers in Africa represents a highly attractive investment. It is also important to note that these ratios likely represent conservative estimates, as most of the studies were conducted in inadequately resourced treatment centres. Low cost complementary interventions such as a social worker or provision of food to caregivers have been shown to dramatically decrease rates of treatment abandonment and increase rates of overall survival. Thus, adequately equipping new or existing childhood cancer centres in Africa with the appropriate interventions is likely to result in benefit:cost ratios even higher than those calculated above.

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Appendix 1: Cost and Benefit:cost calculations

Costs

We assume that costs of a comprehensive cancer centre are 6.5 times per capita GNI, consistent with data for lower-middle income countries Ghana (Renner et al, 2018) and El Salvador (Fuentes-Alabi et al, 2017). Current survival rates are 11.6% in Africa overall. Even in a lower-middle income country in Africa survival rates are projected at 35%. We therefore hypothesize that only one-third of those diagnosed, access appropriate treatment on average (hard data were not available).

The number of diagnosed cases in the 31 priority countries for our analysis is 126,671 (see Appendix 2). We estimate that currently one-third of these children are treated, and the untreated gap is two-thirds. To calculate cost of treating these cases, we multiply number of cases per country by 6.5 times per capita GNI, and estimate cost as $407m. By investing double this amount (plus an unspecified amount for educating healthcare workers and families to improve diagnosis) 80% of all cases (both those currently diagnosed, and those currently undiagnosed) could be treated.

Benefit-cost ratios

In all cases, we assume that the costs of treatment increase in proportion with per capita GNP, such that the benefit:cost estimates below apply across low- and lower-middle income countries in Africa. It is important to note however that although labour costs increase with per capita GNP, the cost of traded inputs (particularly chemotherapy, diagnostics and supportive care costs) may increase more slowly, making estimates from low-income countries such as Rwanda and Uganda conservative estimates of benefit:cost ratios in lower-middle income countries.

1. Burkitt lymphoma:

Cost per patient treated (health system perspective, i.e. excluding most indirect costs incurred by the family apart from travel, e.g. accommodation and lost income): $1241 USD of 2018, for Uganda (Denburg et al, 2019).

Of those treated, 97% completed treatment, and survival after 2 years was 55%. It is important to note that the treatment included significant interventions aimed at reducing treatment abandonment; the costs of these interventions were also included in this study. The average age at the conclusion of treatment was 10 years, yielding 50 life-years of benefits for children who were cured.

Estimated benefit:cost = (1.3 x per capita GNP X 50) x 0.55 x 0.97/1248 = 17.9.

2. Nephroblastoma:

Cost per patient in Rwanda was $1796 (early stage) and $2372 (advanced stage) (2018 USD) (Neal et al, 2018), where life expectancy is 67 years. Survival rate from an 8-country collaborative study (Paintsil et al, 2015) was 0.25. This rate assumed that all patients who abandoned treatment ultimately died due to their disease. The average age of diagnosis was 2.5 years and a treatment duration of 1 year was assumed. (Costs for another study for Rwanda by Kanyamuhunga et al, 2015, are similar but a little higher).

Estimated benefit:cost: (1.3 x 773 X 63.5) x 0.25/1796 = 9.1: 1

3. Retinoblastoma

No detailed cost-effectiveness estimates were available for Africa although studies have been conducted in China and South Africa. A study conducted in Cote d'Ivoire (11 patients) and Congo DRC (27 patients) (Lukamba et al, 2018). The treatment cost per patient was $1954 in 2013-2014, adjusted to $2202 in 2018 USD using US CPI); estimated survival was 0.47, average onset was at age 3 years. Life expectancy is 54 in Cote d'Ivoire and 60 in DRC, giving a weighted average of 53.2; and GNI per capita in 2018 was $1715 in Cote d'Ivoire and $561 in DRC, giving a weighted average of $1382 (weighted by share of patients).

Estimated benefit:cost: (1.3 x 1382 x 50.2 x .47)/2202 = 19.3: 1

4. ALL/non-Hodgkin Lymphoma

No studies for low- or lower-middle income Africa countries were located, other than for

Burkitt lymphoma which is less costly to treat than other non-Hodgkin Lymphoma. In high income countries ALL and non-Hodgkin lymphoma are among the more expensive childhood cancers to treat.

5. Comprehensive cancer centre

A recent study conducted by our group conceptualized the maintenance of a childhood cancer treatment unit in Accra, Ghana as a single intervention and costed both direct and indirect costs (Renner et al, 2018). The population receiving the intervention therefore consisted of all children with cancer (regardless of type) that presented to the centre. The cost per child diagnosed with cancer was calculated to be $10,540. The average age at diagnosis was 5 years, life expectancy in Ghana was 63 years, and survival for the overall cohort was estimated to be 0.35.

Estimated benefit:cost: (1.3 x 57 x 2130 x 0.35)/10,540 = 5.2: 1

Sensitivity analysis.

If indirect costs to the family amounted to 0.7 times per capita GNI, then the benefit:cost ratio would fall to (1.3 x 57 x 0.7 x 2130 x 0.35)/(10,540+1491) = 4.6:1

Appendix 2: Applicability by country

Country	Category	No. incident cases 2015
Algeria	UMI	2417
Angola		1472
Benin		1998
Botswana	UMI	78
Burkina Faso		3596
Burundi	Low life expect	1329
Cabo Verde	Small	58
Cameroon		4135
Cantral Af Rep	Low life expect	824
Chad		2934
Comoros	Small	74
Congo		831
Cote d'Ivoire		4227
Dem Rp Congo	Low life expect	9495
Djibouti	Small	67
Egypt		6628
Eq. Guinea	UMI	136
Eritrea		586
Ethiopia		11192
Gabon	UMI	268
Gambia		389
Ghana		4720
Guinea		2337
Guinea Bissau	Low life expect	315
Kenya		4821
Lesotho		85
Liberia		810
Libya	UMI	392
Madagascar		2712
Malawi		949
Mali	Low life expect	3254
Mauritania		706
Mauritius	UMI	52
Morocco		1995
Mozambique	Low life expect	1589
Namibia	UMI	102
Niger		4387
Nigeria		34854
Rwanda		1268
Sao Tome & Pr	Small	26
Senegal		2804
Seychelles	High income	2
Sierra Leone	Low life expect	1186
Somalia	Low life expect	1345
South Africa	UMI	1733
South Sudan	Low life expect	1385
Sudan		3554
Swaziland	UMI	49
Togo		1336
Tunisia		556
Uganda		4911
UR Tanzania		6513
Zambia		2002
Zimbabwe		802

Note: Saharwi Arab Republic is not listed above (no cancer incidence data) – also small size.

Shading indicates priority countries (31). There is 1 high income and 9 upper-middle income countries where coverage of treatment of the more treatable conditions is likely better; there are 5 countries below 1 million in size where scale economies mean that it may be appropriate to identify children with cancer but send out of the country for treatment (including Sahrawi Arab Republic); and 9 countries with life expectancy below 60, where conflict/low income/infectious disease priorities may make childhood cancer a lower priority.

These data are Wade et al's (2019a) modelled estimates of childhood cancer incidence which include undiagnosed cases. IARC's GLOBOCAN data (Ferlay et al, 2019) are generally

considered as the authoritative source. However, GLOBOCAN data of course rely on cancer registry data that in turn capture only those children who are properly diagnosed and registered. Children who do not access healthcare, access healthcare but are are undiagnosed, or are diagnosed but not registered, will not be included in GLOBOCAN estimates. To overcome this issue, Ward and colleagues employed microsimulation modeling to estimate the total burden of childhood cancer across LMICs, taking into account health system barriers to access and referral. The model was calibrated to publicly available cancer registry data using a Bayesian approach with multiple model parameters as random variables.

The country specific estimates are what are illustrated in Appendix 2. Importantly, posterior predictive checks of the calibrated model comparing the model predictions of diagnosed incidence of specific malignancies to registry-reported incidence found that the prediction intervals of the former overlapped with the confidence intervals of the latter 99.3% of the time.

The priority countries account for 126,671 incident cases of pediatric cancer (age 0-14) in 2015 (87% of the cases for all African Union countries: calculated from Ward et al, 2019a).

Economics of resilience to drought

Courtenay Cabot Venton

Summary

The humanitarian system is stretched very thin, with funding struggling to keep up with needs. While humanitarian aid can save lives, it has historically arrived late, well into the peak of a crisis. There is increasing recognition that responding to these chronic and protracted crises with ongoing emergency aid is costly and unsustainable. Investing in people's resilience – their ability to manage shocks and stresses without compromising their future well-being – is critical for reducing humanitarian assistance needs in complex and protracted crises. The study findings demonstrate that billions of dollars in humanitarian assistance can be saved by investing in a proactive approach to protracted crises, with investments in resilience building activities combined with safety net transfer and an early humanitarian response yielding returns of $3.6:1. When the wider benefits of disaster risk reduction are incorporated, returns could rise to as much as $19:1.

Identification of the problem

The Horn of Africa is dominated by arid and semi-arid lands (ASALs) - areas that are characterized by low and irregular rainfall as well as periodic droughts. Between 1900 and 2011, more than 18 famine periods were registered in the region's history.[58] Food insecurity is driven by a combination of weather, price shocks, and conflict. Aid organizations have come to play a significant role in providing humanitarian response to fill the deficit in household needs during times of shock or stress. While humanitarian aid can save lives, it has historically arrived late, well into the peak of a crisis.

There is increasing recognition that responding to these chronic and protracted crises with ongoing emergency aid is costly and unsustainable. Investing in people's resilience – their ability to manage shocks and stresses without compromising their future well-being – is critical for reducing humanitarian assistance needs in complex and protracted crises.

The aim of this study is to investigate and quantify the impact of an early humanitarian response and resilience building on humanitarian outcomes, both in terms of cost savings, as well as the avoided losses that can result from a more proactive response.

The proposed solution

The counterfactual is a late humanitarian response.

The proposed solution is a layered approach combining:

- An early humanitarian response. Providing early humanitarian assistance to populations affected by crisis – in other words before assets have been depleted and negative coping strategies have been employed – can save lives and livelihoods and reduce the amount of humanitarian assistance required to protect those affected.
- A safety net transfer to all poor and very poor households. Regular and predictable safety net transfers have become a core component of government strategies to cope with and mitigate the effects of crises for those who are most vulnerable. The safety net transfer occurs in all 15 years of the model.
- Investment in resilience building that increases household incomes. Resilience is defined as the ability of a person or household to cope with a shock or stress without external assistance. A wide range of types of interventions can contribute to resilience building, and there is no one size fits all approach. For this analysis, it is

[58] http://www.globalhumanitarianassistance.org/wp-content/uploads/2011/07/gha-food-security-horn-africa-july-20111.pdf

assumed that households receive an (unspecified) package of interventions that raise income by a certain amount. Note that the analysis does not measure the cost to graduate households to a resilient status; this is not possible because resilience is fluid, depending on the conditions in each year. Rather it estimates the impact that a more proactive response would have on the ability of a household to cope with a shock or stress without external assistance, and the effect that would have on the overall humanitarian budget to fill those needs.

An economic model estimates costs and avoided losses/benefits over a 15-year period (2000-2015) at a discount rate of 5%[59], for a population of 15 million people across Kenya, Ethiopia and Somalia. The model specifically investigates the impact of changes in crop and livestock production, as well as local prices, on a household economy and hence the ability of that household to meet their food needs. This data on changes to production and prices is taken from actual data for the last 15 years, and mostly reflects repeated drought cycles, alongside any other drivers of change to production and prices such as global price trends and conflict.

The model is further broken down by livelihood zone (pastoral, agro-pastoral and urban) and wealth group (very poor, poor, middle, better off).[60]

Identification of the costs and benefits

Costs: The cost of the scenario is the cost of providing early humanitarian assistance over a 15-year period to all households in the modelled areas; the cost of providing a safety net program to all poor and very poor households; and, the cost of investing in a resilience building measure.

Benefits: The benefits are represented as the avoided losses in income (including the transfer amount that is surplus to filling the food deficit) and livestock as a result of an earlier and more proactive response, as well as cost reductions in providing late humanitarian assistance over a 15-year period to modelled households.

All model inputs are adjusted for inflation, to 2016 USD. All prices for valuation are based on actual data for each country (localized within the country where possible).

Costs and Benefits

Costs	Per year	Over 15 years
Transfer program - only very poor/ poor households	$258 million	$3.9 billion
Resilience investment	$8.8 million	$0.1 billion
TOTAL	$267 million	$4.0 billion
TOTAL Discounted		***$2.9 billion***
Benefits		
Avoided cost of food aid	$347-$650 million	$7.1 billion
Surplus income from transfer	$74-$200 million	$2.3 billion
Avoided income loss	$172-$444 million	$4.2 billion
Avoided livestock loss	$23m-$64 million	$0.7 billion
Multiplier effects[61]	$13 million	$0.2 billion
TOTAL	$850-$1,090 million	$14.5 billion
TOTAL Discounted		***$10.3 billion***
BCR		**3.6**

Summary of Analysis (discounted figures):

- An early humanitarian response saves US$2.1 billion in humanitarian aid costs over 15 years in comparison to a late

[59] Note that the original published study used a discount rate of 10% and therefore the figures presented here represent a sensitivity analysis adjusting the rate to 5%.

[60] The wealth breakdown is a division of the livelihood zone population into 4 locally defined wealth groups, based primarily upon the ownership of/access to productive assets (land, livestock, household labor, etc.).

[61] Note that the multiplier was only included for the Kenya analysis where evidence on the multiplier effect of cash transfers in the local economy was available.

humanitarian response. When avoided losses are incorporated, **an early humanitarian response saves US$3.3 billion, or an average of US$220 million per year.**

- Safety net programming (combined with an early response) saves an estimated US$2.8 billion in humanitarian aid costs over 15 years over the cost of a late response. When avoided losses are incorporated, **a safety net transfer scenario saves US$4.7 billion, or an average of US$310 million per year.**
- A resilience-building scenario (that combines an early humanitarian response with a safety net as well as resilience building measures that improve household income) reduces the net cost of humanitarian response by US$3.8 billion over 15 years over the cost of a late response. When avoided losses are incorporated, **a resilience building scenario could save US$5.8 billion, or an average of US$384 million per year.**

When intervention costs are offset against the avoided humanitarian aid costs and the avoided losses (benefits), **every US$1 spent on resilience programming results in net benefits of US$3.6.**

It is important to note that these BCRs account for the benefits that arise as a result of mitigating the effects of a production or price shock. Investment in disaster risk reduction can also yield numerous benefits outside of a drought or price shock, that would be additional to the estimates provided here. The World Bank estimates these benefits as ranging between US$3:1 and US$15:1.[62] **Thus the additive return would equate to a BCR of between US$6.6 and US$18.6.**

Implications for scale up

Across each of the three countries analyzed, the modelled population represents approximately one-half to one-third of the total population considered to be chronically food insecure, and therefore the savings articulated in this study could increase by a magnitude of two to three if extrapolated to all of the food insecure population.

The findings would be highly replicable for any country that faces recurrent food insecurity due to price or production shocks, with a large population of agricultural, agro-pastoral and pastoral households.

The humanitarian system is stretched very thin, with funding struggling to keep up with needs (UN coordinated appeals in 2017 saw a 41% shortfall in funding as compared with the amount required[63]). The study findings demonstrate that billions of dollars in humanitarian assistance can be saved by investing in a proactive approach to protracted crises – which accounted for 86% of humanitarian assistance globally in 2016[64]. By way of example, if we were to extrapolate these findings to the US Government (USG), as the largest donor to humanitarian assistance in Africa, the USG could have saved US$1.7 billion over the last 15 years on its humanitarian aid spend in these three countries, a savings of 31 percent. Incorporating the avoided losses to households, the model estimates net savings based on USG spend of US$4.4 billion.

[62] UNISDR (2015). "Making Development Sustainable: The Future of Disaster Risk Management." Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland, UNISDR.

[63] Development Initiatives (2018). "Global Humanitarian Assistance Report 2018."

[64] Ibid.

SME training on agro-processing equipment fabrication from scrap metal

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Summary

The industrial base of African countries is largely weak and fraught with a large number of micro and small enterprises with low productivity and weak growth prospects. This brief discusses the benefit cost ratio of training and provision of credit to one micro or small enterprise in scrap and metal fabricators as an intervention to increase the capacity and productivity base as a way of further boosting their long term growth and survival prospects. The estimates show that the intervention yields a benefit cost ratio (BCR) of 2.04 over a 2 year period using Ghana as a case. This is comprised of a cost estimate of USD 841 as cost of competency based certificate training in electrical/automotive engineering, a USD 50.5 sensitization cost and the opportunity cost to the participants (USD 641.89). It also has a USD 400 credit, with an operation cost of USD 140, a financing cost of USD 16 and default cost of USD 2.8. The benefits from this intervention amount to USD 2612 arising mainly from a 10% increase in sales and returns in credit (3%). There is the potential to scale-up this intervention by increasing the coverage of training and credit access. The potential for scaling across Africa is also possible albeit with some variation in terms of BCR-Kenya (BCR of 2.11) and Malawi (BCR of 1.48). Overall the benefits are substantially higher and the intervention costs are spread thin when one estimates with a 5 year horizon.

The problem

Most African countries have low levels of industrial activity. A large proportion of firm tissue in these countries is made up of MSMEs (micro, small and medium scale enterprises) with very weak industrial and technical capacity base (African Development Bank 2019). This comes with the often cited case of "large missing middle" in industrial activity, where a chunk of the firm tissue is made up of small and micro enterprises with some few large firms and almost an absence of medium sized firms. The implication is that growth prospects for micro or small sized firms is rather low or almost non-existent. As a result the quantum as well as value add of economic output from manufacturing base is low. A number of challenges have been raised as being the key cause of such low level of industrial base. Two critical and oft cited challenges associated with the low productivity of SMEs are that of technical/human capacity/capability and credit access (World Bank Enterprise Surveys). Indeed the hub of entrepreneurship is also the MSME sector which comprises of both formal and informal enterprises with a substantial proportion of manufacturing firms in this sector[65]. This manufacturing sub sector consists of enterprises in scrap and metal fabrication and manufacturing of cooking utensils, bolts and nuts, automobile spare parts and small processing equipment like millers. These small and micro enterprises can with adequate training and access to credit manufacture these small agro processing equipment. The low manufacturing base in Africa can therefore be increased via increasing the technical skill and easing the access to finance of micro and small enterprise industries in metal and scrap fabrication. Training and access to credit will help boost their productivity and small business in scrap and metal fabricators hubs on design and manufacturing of small processing equipment like millers, threshers, ploughs, canning, steel and metal processing, light industrial semiconductors for agro manufacturing.

The analysed solution

The intervention consists of training of small business in scrap and metal fabricators hubs on design and manufacture of small agro processing equipment millers, threshers, ploughs, canning, steel and metal processing, and light industrial semiconductors for agro

[65] See studies by Hope (2014) World Bank (2016)

manufacturing. The training will be offered by the existing accredited technical and vocational educational institutions in the respective countries. These are Council for Technical and Vocational Education and Training (COTVET) approved institutions in Ghana, the Technical and Vocational Education and Training Authority (TVETA) colleges in Kenya and Technical, Entrepreneurial and Vocational Education and Training (TEVET) institutes in Malawi[66]. This will be coupled with an access to credit programme post training. The low capacity and productivity state of SME activity in Africa is likely to remain or worsen in the absence of technical capacity building and credit based interventions like the proposed one. SME activity in African countries is large but mainly tiny and fragmented. For this reason the intervention is applicable to all African countries. However for the purpose of this brief the test is done on the cost and benefit of training one micro or small enterprise manufacturer in Ghana, Kenya and Malawi. These countries represent the main income groups (low income and lower middle income groups) and also help to gauge the sensitivity of estimates to the various country contexts.

The costs and benefits

The training intervention is estimated to cost USD 841 as fees for competency based training via Technical Vocational Education Training (TVET), a USD 50.5 sensitization cost, USD 641.89[67] as opportunity cost of participants time and USD 400 in credit to trained SME participants. Additional costs include the operational cost of credit (USD 140), the financing cost of credit and the default cost of USD 2.8. There is also an added cost of formalizing informal enterprises after training. The cost calculations as indicated are based on the costs of intervention. The scrap industry already exists in these countries hence the cost of collection and processing is not added as an intervention cost. The intervention will yield a benefit of USD 2612 additional sales made up of a 10% increase in sales (USD 2,600) and a 3% return on credit (USD 12).

TABLE 4 COSTS

Costs	Value (USD$)
Total training cost (based on TVET)	841
Sensitization cost	50.5
Cost of formalizing business	26
Opportunity cost of participants' time	641.89
Credit microloan	400
Operational cost of credit	140
Financing cost of credit	16
Default	2.8

TABLE 5 BENEFITS

Benefits	Value (USD$)
Increase in sales	2600
Return on credit	12

Sales estimates are based on an estimate of annual turnover of MSMEs from respective publications on SME activity (International Trade Centre, 2016; Kenya National Bureau of Statistics, 2017). The benefits of the project are that the metal and fabrication industry which consists of micro and small businesses will grow as a result of skill enhancement and credit access, equally the agricultural sector which consists mostly of smallholder farmers will benefit from the availability of small agricultural equipment to enhance processing and value addition. In addition the MSME sector is a substantial employer of low skilled people and is where entrepreneurship activities thrive. Their growth will therefore also increase the employment level across the economy. The benefit estimates exclude the potential employment effect that could arise from increased sales and growth. They also

[66] For instance Tema Technical Institute of Ghana established in 1968, Nairobi Technical Training Institute of Kenya established in 1964 and Kaiboi Technical Training Institute of Malawi established in 1962

[67] This is based on a foregone income of participants (USD 641.89) to be absent from their business for a 5 days training programme. The income is calculated as the loss of manufacturing sector income = GNI*manufacturing value add-contribution to GDP (9%)*labour force rate (66.9%). This is rather high given that manufacturing income of USD 128 is not on a daily basis. Nonetheless it is taken to show a fairly conservative estimate of opportunity cost.

exclude enhanced environmental benefits from a cleaner and environmentally friendly processing and production that will be acquired under the training. The estimates do not include the production and or operational cost of new equipment as a result of the skills acquired.

The estimated BCR for a period of 2 years for Ghana is 2.04. On the short term end of a 1 year period the BCR is lower at 1.28. Indeed a 5 year horizon has a much higher BCR of 3.16. To have an idea of the possibility sensitivity of these BCR estimates to country contexts, results for Kenya and Malawi are also provide below. From a 2 year horizon, Malawi has the lowest BCR of 1.48 and Kenya the highest at 2.11. The BCR across countries is higher for a 5 year horizon. It does show some sensitivity to BCR estimates across countries. The latter section of the table shows BCR estimates with an assumption of a one time loss of income of USD 128.

TABLE 6 BENEFIT COST RATIOS

	Ghana	Kenya	Malawi
BCR (5 Years)	3.16	3.20	2.18
BCR (1 Year)	1.28	1.35	0.96
BCR (2 Years)	2.04	2.11	1.48
Lower opportunity cost-one-time loss			
BCR (5 Years)	3.53	3.38	2.27
BCR (1 Year)	1.68	1.55	1.07
BCR (2 Years)	2.50	2.34	1.60

Discussion

There is potential for scaling up this intervention across many African countries. It is likely to increase the value add potential of SMEs and lead to a gradual but high impact increase in the productivity and growth of SMEs in Africa. This has a high potential to strengthen the industrial base of African countries. The intervention can be replicated in most African countries, given the importance and density of SME activity on most African countries. A potential risk in scaling up across Africa may lie in the cost of TVET based training in countries where TVETs are not well established or well equipped. In such instances the cost of training may escalate or training may be substandard. The issue of smuggling of scrap metal across borders as well as vandalizing and theft of public infrastructure could be a potential challenge and appropriate regulation is needed. Regulation in the case of smuggling should also have a regional dimension where there is uniformity and information exchange across regional borders to ensure smuggling is adequately and uniformly curbed across borders. Regulation also has to be carefully structured so that it promotes the industry to develop and not become counterproductive. As a matter of fact Kenya and Ghana realised that a previous outright ban on scrap and metal dealers caused more harm in terms of lost economic and social benefits from the downstream production chain and thus rescinded the ban. Although it is estimated that female representation in the informal economy (which hosts a large segment of this sector) is high not much exists in terms of specific percentage of women in the scarp and metal fabrication industry. Indeed in the scale up of the intervention, there should be a target at encouraging women and in particular young females.

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Solar energy for unreliable urban grids

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Abstract

Africa is plentiful in renewable energy resources, especially solar. These resources are well spread across the continent and could contribute to secure and affordable supplies of energy where they are in high demand such as urban areas. A long-term vision to support effective investment in renewable energy is paramount to safeguard the effective use of available regional resources by both countries as well as regional groups. A hybrid energy system such as LPG and solar can be applied successfully in urban areas where grid connections are unreliable, not available or considered uneconomical. This research article aims to conduct cost-benefit analysis of interventions targeting low urban electrification rates in Africa through regional energy parks with the hybrid system. The intervention focuses on improving energy access in urban areas. Nairobi and Accra are used as a case study. The city of Nairobi, Kenya, and City of Accra, Ghana were chosen due to their geographic and climate characteristics which create optimal conditions for the development of PV and LPG gas reticulation, and therefore of a system that allow for the full integration of RES hybrid via Feed-in Tariff or net metering in the distribution grid. The shared energy park project's innovation components may be summarised as follows: 1 MW Solar plant smart monitoring & metering system, solar water Pumping, treatment and smart refilling, Shared Solar Cooling & Refrigeration at the park, 10 Ton LPG ATM integration and smart gas distribution cylinders, storage based on Li-Ion battery technology, EV charging infrastructure, and home energy consumption monitoring equipment. The analysis of the system indicates that regional energy park will have a net benefit of US$6,662,608 at a 5% discounted rate with a benefit-cost ratio of 3.256 an indication that the proposed intervention is economically feasible.

The problem

Africa is facing energy poverty, it poses great threats to the economies, environment and regional security despite being home to roughly 13% of the global population. Africa's energy sector is crucial to its future development [1]. Approximately 625 million sub-Saharan Africans lack electricity access and the average on-grid energy generation capacity of Africa is approximately 90 Gigawatts (GW) in 2012, with roughly half being in South Africa (SA), 45% of the generated capacity is coal (highest percentage from SA), 14% gas (mostly Nigeria), 17% oil and 22% hydro (more evenly spread)[68-69]. The inaccessible, unreliable and insufficient power supply has led to large scale individual ownership of expensive oil-fuelled generators across Africa and more focus shifted on developing off-grid mini power generation systems. The demand for energy is only set to increase with increasing population, economic productivity as well as urbanization[70]. For those without access to electricity in SSA, mean residential electricity consumption/capita is 317 kWh/year (225 kWh excluding SA). Consumption per capita is undoubtedly lower in rural and urban areas in Africa, normally in the range of 50-100 kWh/year for rural areas.

Green energy is usually preferred due to its win-win nature for SSA. Green energy has a major role to perform in energy sector decarbonisation and mitigation of the climate

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change effects. Solar, which is currently not fully utilized for electrification could jointly address the severe deficit of electricity access in the region, tackle energy security and also mitigates climate change[71]. Green energy capacity is increasing rapidly though from a very low base (except hydropower). The huge amount of green energy remains untapped; especially the attractive solar energy across Africa, hydro (Congo and other countries), wind (countries along the coast) and geothermal (East Africa (EA) rift valley). Countries having low electrification rates commonly have lower GDP/capita and less developed. For that reason, there is a dire need to improve electricity access to the urban populace. The intervention aims at widest possible applicability. The basic logic is that most urban areas are densely populated and the increasing energy access leads to greater benefits including, healthcare, security, education, environment, economic and life expectancy improvements

The intervention: Regional energy parks in Africa.

The energy parks form the backbone of the green energy supply chain just like the petrol stations are to the fossil fuel (oil & gas) industry improving market access, saving cost and uplifting millions out of environmental and energy poverty while taking back ownership to the end-users which includes both residential and small-commercial enterprises within the estate or energy catchment zone. The Shared Energy Park infrastructure of renewable distributed energy generation integrated with smart communication and intelligent protection systems for maintaining high quality standards of managing generation, loads and faults in an efficient, targeted and timely manner. This intervention will provide end-users with more electricity when it is fed to the main grid but can also be used as a stand-alone hence providing energy when the national grid is offline.

The Shared Energy Park will enable a new approach to distributed generation, by monitoring it through the active involvement of distributors and clients. For the first time, customers will be involved in an experimental programme on consumer awareness. Participants in this programme will receive the Smart Monitoring Kits providing energy consumption data in real time. The customers will receive phone alerts and advice every time energy employment exceeded predefined levels, so to foster more rational energy employment patterns. The above innovative distributed renewable energy grid solution can be implemented as a Green Energy Station or Shared Community Parks within estates. The system can function as a stand-alone energy park given that the energy storage component is included in the design.

In estates energy communes, these can operate as coops by the residents thus ensuring a win-win in ownership governance as well as plough back revenues in the hands of the users/market in form of dividends for every energy share held, with regards to the potential sustainability of the investment if a collection of investors is needed to scale-up, then Pay-As-You-Use by the end users will be more applicable. The region, community or estate residents agree to collectively lease to the coop/agency their rooftops to be used to generate PV energy, or have a common central location (for all the renewable energy sources identified) for the whole region or community this reduces issues of right of way and reduces the cost/capex associated with individual implementation of the same.

Costs and benefits

For discounted cost calculations, the project has considered capital cost and operation, maintenance (O&M) cost, environmental cost et. cetera. The auxiliary facilities will exist within the park and end-user's premises, they include smart meters, charging ports, batteries for energy storage, water dispensing facilities, productive elements within the energy parks,

[71] Pueyo, A., S. Bawakyillenuo, and H. Osiolo, Cost and returns of renewable energy in Sub-Saharan Africa: A comparison of Kenya and Ghana. 2016, IDS.

customers support centers, charging points, solar coolers, solar pumps, etc. Capital cost for the system in this analysis comes to a total cost of US$ $2,953,550. All values are discounted at 5%. The benefits are involving both direct and indirect benefits, the direct benefits include the energy and carbon emission savings. Indirect benefits entail long term employment generation. The direct benefits will result to reduced power outages in days, improved security (street lighting), mitigation of climate change, reduced oil and charcoal consumption, minimized emissions with improved health benefits.

TABLE 1. COSTS

Parameter	Value (US$)
Initial Investment Cost (Feasibility, Design & EPC)	2,042,500
O&M (Administrative Operations & Variable for Grid-Connected Mode)	265,525
Auxiliary Facilities	612,750
Fuel (Grid-Connected Mode)	28,500
Emission Control	1,900
Emissions Allowances	1,425
Emissions Damages (Grid-Connected Mode)	950
Total	**2,953,550**

TABLE 2. BENEFITS

Benefits	Value (US$)
Economic benefits	8,690,929
Security benefits	748,718
Environmental benefits	176,511
Total	**9,616,929**
Total Benefits	**9,616,929**
Net Benefits	**6,662,608**
BCR	**3.3**

Source: Author's Calculation; Notes: Assuming a 5% discount rate.

Implications of scaling-up shared energy parks in Africa

The various foreseeable impediments and barriers in Africa energy space include insufficient policies and not providing the needed support, lack of information and awareness, high cost of production unless scaled-up, and limited institutional capacity to promote green energy up-take[72]. In the scaling-up effort of shared energy parks, this will require financing from either donors, governments et. cetera which may result in additional costs. According to Hellen[73] there is positive willingness to pay for improved energy sources in Kenya. Analysis conducted by Daniel[74] indicated that, households in Ghana are prepared to pay on the average about ¢0.2734 for a kilowatt-hour which is about one and a half times more than what they were paying. The Kenyan and Ghanaian regulatory frameworks used as case study in this analysis are all friendly to Shared Energy Parks. The energy Kenyan regulatory frameworks are provided in appendix 5. In the case of Ghana, there is no specific mention of mini grids in the 2010 policy statement, but there is scope to consider mini grids as one of the options for achieving universal access by 2020[75]. The purchasing and installation costs in this article are specific to the two countries considered although other countries and solar companies costing may slightly vary. This intervention can be replicated in All Africa countries.

Conclusions

The shared regional energy parks in Africa are a feasible solution to the low electrification rates in Urban areas in African cities. With a BCR of 3.3, this system will be viable for 39% of the population in SSA that live in urban areas and already have an existing but unreliable grid connection. It can also be adaptable for off-grid use since the storage component is catered for

[72] George, A., et al., Review of solar energy development in Kenya: Opportunities and challenges. 2019. **29**: p. 123-140

[73] Helen Hoka Osiolo, Willingness to pay for improved energy: Evidence from Kenya, 2017. 112: P. 104-112

[74] Daniel Kwabena Twerefou, Willingness to Pay for Improved Electricity Supply in Ghana, 2014. **5**, P. 489-498

[75] The World Bank, MINI GRIDS FOR TIMELY AND LOW-COST ELECTRIFICATION IN GHANA, 2017. Technical Report.

in the auxiliary facilities. Meaning, it can function as a stand-alone system, in both cases, BCR will still remain higher than 1. The system is also very much ideal for rural setup since it can function as standalone given that land and way-leave is not an issue, especially in rural market centers. It can be applied to all African countries. Further research should therefore be undertaken for system implementation with increased number of DER in rural areas in Africa.

References supporting the benefit-to-cost ratio

APPENDIX 1. FINANCIAL AND ECONOMIC ASSUMPTIONS FOR NAIROBI, KENYA

Parameters	Unit	Reference value	Ref.
Time horizon	Years	20	Author's value
No. of people served		8,000	Author's calculation
Solar insolation hours	hours	6	[5]
Unit investment cost	US$/Kw	2150	[4]
O &M costs	US$/kW	21.5	[4]
Average electricity energy tariff-off grid	US$/kWh	0.52	[76]
Average electricity energy tariff-on grid	US$/kWh	0.158	[77]
Economic avoided costs	US$/W	5.1	[78]
Inflation rate	%	4.4	[79]
Fuel/Oil price	US$/litres	1.0281	[80]
Average CO_2 price	US$/$tCO_2$	13.3	[81]
Reduced pollutants			
NO_x	US$/kg	3.15	[11]
SO_x	US$/kg	0.7	[11]
PM_{10}	US$/kg	0.2	[11]
LPG cost	US$/kg	1.6	[82]

Exchange rate 1 US$=102.192 Kenya Shillings (https://www.centralbank.go.ke)

[76] Safdar, T.J.S.V., Business models for mini-grids. 2017

[77] KPLC, Approval of the schedule of tariffs set by the energy regulation commission for supply of electrical energy by Kenya Power & Lighting Company Limited, pursuant to Section 45 of the Energy Act, 2006. 2018

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[79] IMF. Inflation rate, average consumer prices. 2019 [cited 2019 June 26]; Available from: https://www.imf.org/external/datamapper/PCPIPCH@WEO/GHA.

[80] ERC, Petroleum prices. 2019.

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[82] KNBS. Economic survey 2019, Kenya 2019

APPENDIX 2. FINANCIAL AND ECONOMIC ASSUMPTIONS FOR ACCRA, GHANA

Parameters	Unit	Reference value	Source
Time horizon	Years	20	[83]
No. of people served		8,000	Author's calculation
Solar insolation hours	hours	5	[84]
Unit investment cost	US$/Kw	2014.52	[4]
O &M costs	US$/kW	20.83	[4]
Average electricity energy tariff-off grid	US$/kWh	0.22	[85]
Average electricity energy tariff-on grid	US$/kWh	0.164	[86]
Economic avoided costs	US$/W	5.1	[8]
Inflation rate	%	9.1	[9]
Fuel/Oil price	US$/litres	0.99	[87]
Average CO_2 price	US$/$tCO_2$	50	[11]
Reduced pollutants			
NO_x	US$/kg	3.15	[11]
SO_x	US$/kg	0.7	[11]
PM_{10}	US$/kg	0.2	[11]
LPG cost	US$/kg	0.86	[88]

Exchange rate 1 US$=5.46 Ghana Cedi (https://www.bog.gov.gh/markets/us-dollar-daily-forex-interbank-rates)

APPENDIX 3. FINANCIAL AND ECONOMIC ASSUMPTIONS FOR BOTH NAIROBI, KENYA AND ACCRA, GHANA

Parameters	Unit	Reference value
Time horizon	Years	20
No. of people served		8,000
Solar insolation hours	hours	5.5
Unit investment cost	US$/Kw	2082.26
O &M costs	US$/kW	20.15
Average electricity energy tariff-off grid	US$/kWh	0.33
Average electricity energy tariff-on grid	US$/kWh	0.134
Economic avoided costs	US$/W	5.1
Inflation rate	%	6.75
Fuel/Oil price	US$/litres	1.01
Average CO_2 price	US$/$tCO_2$	31.65
Reduced pollutants		
NO_x	US$/kg	3.15
SO_x	US$/kg	0.7
PM_{10}	US$/kg	0.2
LPG cost	US$/kg	1.23

[83] Adaramola, M.S., et al., Multipurpose renewable energy resources based hybrid energy system for remote community in northern Ghana. 2017. **22**: p. 161-170

[84] Asumadu-Sarkodie, S. and P.A.J.A.E. Owusu, A review of Ghana's solar energy potential. 2016. **4**(5): p. 675-696.

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[86] http://purc.com.gh/purc/node/7771

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APPENDIX 4. STAKEHOLDERS BENEFITS AND COSTS IN SCALING UP EFFORT.

Stakeholders	Benefits	Costs
Donors	Climate change associated Sustainable funding's Social impact	Feasibility cost Capacity building cost Financing/Corporate Service Investment cost
National government	Security enhancement Social impact Economic growth	Tax benefits/ tax incentives
Local government	Security enhancement Social impact Economic growth	Tax benefits/ tax incentives Land and way-leave
Commercial enterprises	Reliable energy Improved security Affordable energy Reliable utilities e.g. water	Forgone costs of existing back up system e.g. generators
Private investors	Economic benefits	Financing costs
Utilities	Reduced expansion costs More reliable More grid stability	Reduced customer base Loss of revenue Maintenance costs
Energy providers	Improved customer engagement Increased customer base Reliable energy data	Operation and management costs CAPEX costs

APPENDIX 5. REQUIRED AUTHORIZATION FOR MINI GRIDS IN KENYA

	Undertaking or activity	Required authorization	Applicable regulation
1	Generation of electricity not exceeding 1MW for own use	None	-
2.	Generation and supply of electrical energy not exceeding 3MW	Permit	Energy (Electricity Licensing) Regulations 2012
3.	Generation, transmission, distribution, and supply of electrical energy exceeding 3MW	License	
4.	Electrical installation work at the premises of a customer	Electrician's license and Certificate of Registration as an electrical contractor	Electrical Power (Electrical Installation Work) Rules 2006

Source: http://www.erc.go.ke

Community Health Workers for hypertension control:

Anastase Dzudie, Douala General Hospital

Summary

Hypertension ranks among the main causes of mortality in sub-Saharan Africa (SSA). A principal contributor to cardiovascular disease, a costly and debilitating occurrence, in which many African households find themselves undertaking significant expenditures, in some cases considered catastrophic vis a vis their disposable income. The Pan-African Society of Cardiology (PASCAR) has identified the screening and treatment of hypertension as the first priority to reduce the burden of cardiovascular diseases in sub-Saharan Africa (SSA). Hypertension detection in Africa currently relies on opportunistic screening at health facilities. With the non-existence of health facilities in remote/rural areas and the shortage of staff willing to go to those areas, task-shifting or task-delegation has been positioned as a practical solution for improving hypertension control. Thus, the benefits and costs associated with the scaling-up of the screening and treatment of hypertension using community health workers as active case-finders have been analyzed. Screening everyone, that is potentially hypertensive, reveals itself to be an expensive proposition, as prevalence rates in SSA average 46%. The model analyzed is active case detection by professional community health workers, which results in modest benefit-cost ratios of 4.3, 2.1, 2.3 in South Africa, Nigeria, and Kenya.

Scope and identification of the problem

Hypertension is a major contributor to cardiovascular diseases (CVDs) and related mortality in sub-Saharan Africa (SSA). With an estimated prevalence of 46% among adults in 2013 (WHO, 2015), and a projected 216.8 million cases by 2030 (Adeloye and Basquill, 2014), hypertension is a major health crisis in SSA (Dzudie et al., 2017).

Mozaffarian et al (2014) found that, globally, 1.65 million annual deaths from cardiovascular causes (95%; 1.10 million to 2.22 million) were attributed to sodium intake above the reference level; that these deaths accounted for nearly 1 of every 10 deaths from cardiovascular causes, and that four of every 5 deaths (84.3%) occurred in low- and middle-income countries. One of the risk factors for hypertension and cardiovascular disease is salt consumption exceeding 2g of sodium/5g of salt) per day. Africans consume on average 7 to 10 grams of salt per day, of which 40% is considered discretionary (Wentzel-Viljoen et al. 2017). Sodium reduction significantly lowers blood pressure, which consequently reduces the probability of occurrence of heart disease and stroke.

This high prevalence of hypertension in SSA is against a background of huge detection, treatment and control gaps (Ataklte et al., 2015), a picture that reflects the ineffectiveness of the existing health systems across Africa, to capture and efficiently treat people with hypertension and its related risk factors like salt intake and tobacco use. Hypertension detection in Africa currently relies on opportunistic screening at health facilities. With the low contact of the population with the health systems across Africa, only a small proportion of the population get exposed to health systems. Of those who eventually have contact with the health system, a large number of those eligible for hypertension screening do not benefit from such screening. Reasons include the shortage of adequately trained health personnel to screen for hypertension and initiate appropriate management, the lack of functioning equipment, the lack of- or unaffordability of medications. With the lowest doctor-to-population ratios globally, SSA cannot afford to rely on the traditional doctor-delivered model of care to improve the detection and control of hypertension.

Description of the proposed solution

The intervention modelled is a patient-focused hypertension screening activity and subsequent antihypertensive treatment, using community health workers (CHW) for active

case finding. The intervention consists of the following activities:

- Training of the requisite number of CHW for screening, detection, treatment and ongoing management of hypertension at health care facility
- The door-to-door screening for identification of patients unaware of their hypertensive status and subsequent referral to a health care facility
- Follow-up visit to assure medication adherence

The countries of South Africa, Nigeria, and Kenya were selected because of the availability of data and the existence of previous studies evaluating the training and deployment of community health workers. According to the Southern African Hypertension Society, only half of South Africans are aware of the blood pressure status. The intervention for South Africa was therefore defined as the use of CHW to increase the number of persons screened and treated for hypertension, currently at 50%, to 75%. In Nigeria, since it has been estimated that as much as 78% of people are unaware of their status, the intervention was specified as the use of CHW to increase the number of persons screened and treated for hypertension, currently at 22%, to 50% (Raji et al, 2017). In Kenya, as 56% are unaware of their status, the intervention was specified to use CHW to increase the number of persons screened and treated for hypertension, currently at 44%, to 75% (Achoki et al (2019).

The countries have comparable mortality rates due to cardiovascular disease (CVD), and death occurs at approximately 64 years of age.

	South Africa	Nigeria	Kenya
Population	57.7M	206.1M	49.7M
Prevalence rate, hypertension	0.4	0.37	0.24
Mortality rate, CVD	0.14	0.11	0.13
Expectation of life at age 50, years	23.4	21	26.3
Weighted average age of death from CVD, years	63.8	64.2	63.3

Calculations were therefore undertaken based on a hypothetical person, screened at age 50, in order to avert a potentially fatal (and costly) CVD event.

Costs

The costs of the CHW intervention include (1) the training, screening and salary costs for CHW and (2) the costs of antihypertensive treatment. The combined costs associated with the deployment of CHW per person screened was US$6.09 (Gaziano et al., 2015), $5.82 (Rosendaal et al., 2016), and $17.73 (Oji Oti et al. 2016) for South Africa, Nigeria, and Kenya, respectively. In all three countries, the screening costs constituted the principal cost component: 52% in South Africa; 85%, Nigeria, and 95% in Kenya. Training costs in all three countries were negligible, compared to screening costs. With reference to screening, CHW undertake door-to-door household visits to raise awareness about the burden of cardiovascular diseases in the community and provide information about opportunities for screening, to conduct the screening and to provide brief counselling among the eligible population. The costs of screening includes equipment and screening kits and transportation.

Though most CHW in sub-Saharan Africa are volunteers, remunerated with a stipend, the assumption was made here that they would be fully integrated into the medical architecture as front-line service providers and therefore offered a salary.

The costs of hypertension management include the cost of medication, biology test, and consultations. It is assumed that patients undertake quarterly screenings and monthly medication pick-up for the remaining years of expected life. It is also assumed that everyone diagnosed with hypertension attempts to control it with medication. Because of the intensity of care required to treat hypertension, this component makes up 99% of total costs of the intervention. The costs of antihypertensive treatment were standardized across the countries, using the median estimate of a systematic review of studies in low and middle-income countries, of US$22/month (Gheorghe

et al,2018). Its magnitude depends entirely on the life expectancy of the 50-year old patient. Consequently, Kenya had the highest present value (discount rate of 5%) of treatment costs, $3933.11; the costs for South Africa and Nigeria were $3721 and $3560, respectively.

Cost components, USD	South Africa	Nigeria	Kenya
CHW costs (training, screening)/patient	$6	$6	$18
Hypertension treatment costs/patient	$3,721	$3,591	$3,933
Total costs/patient, discounted	$3,727	$3,567	$3,951

The social costs are dependent on the size of the population, the prevalence of hypertension and the effectiveness of case detection. The annual social cost of antihypertensive treatment of approximately a quarter of the people, who have been diagnosed as hypertensive in South Africa, is potentially $671.7 million. In Nigeria, the corresponding cost is $1.65 billion; in Kenya, $279 million.

These costs are incurred to society as a consequence of being screened and positively diagnosed as hypertensive.

Benefits

The benefits include the averted death and disability (DALY) arising from uncontrolled hypertension. The DALYs for the CHW intervention are presented below, as well as the valuation proxy.

	South Africa	Nigeria	Kenya
DALYs/capita	0.637	0.374	0.886
GNI/capita	$5,720	$1,960	$1,620
PV, DALYs averted	$10,771	$2,578	$3,927

Evidently, the magnitude of the value of DALYs depends entirely on the income factor used, and the GNI/capita estimates vary widely among the three cases.

It is assumed that controlled hypertension significantly reduces CVD risk. Therefore, another benefit included is the averted acute care costs of a CVD event. These costs reflect the median direct costs at a public institution across a selection of low- and middle-income countries. Indirect costs (i.e. transportation, food, and productivity losses) have not been included due to high variation in the literature both between countries and between public and private service providers. The median direct cost to society of a CVD event (stroke) is $5000 (Gheorghe et al., 2018).

	South Africa	Nigeria	Kenya
Averted death/ disability/patient	$10,771	$2,578	$,3927
Averted medical expenses /patient, CVD	$5,250	$5,250	$5,250
Total benefits/ patient, discounted	$16,021	$7,828	$9,177

Conclusion

For the CHW intervention, the benefit-cost ratios (BCR), discounted at 5%, are as follows:

	Benefits	Costs	BCR
South Africa	$16,021	$3,727	4.3
Nigeria	$7,828	$3,567	2.2
Kenya	$9,177	$3,951	2.3

Even though hypertension management is a lifetime treatment, it is still by far cheaper than a CVD episode. In Nigeria, direct medical costs/patient, up to 12 months post-stroke, have been reported to be as high as $62,217 (2012); in South Africa, the average in-patient treatment for a CVD episode has been reported at $11,093.74 (2012) and the cost of in-patient visit for stroke care at $16, 992 (Brouwer et al, 2015). Stroke admissions in Kenya have been costed at $16,711 (Subramaniam et al, 2018).

And even though using CHWs for active screening and treatment follow-up could be considered cost effective, compared to setting up clinics and the provision of incentives to retain medical personnel in remote/rural areas, the more beneficial intervention is prevention, which, given the level of absorption of mobile technology and radio communications, should be the intervention of choice.

Though not modelled this way in the analysis, in practice, CHWs are polyvalent; that is, their

time in the field is spread over other health objectives such as active TB case finding, the promotion of antenatal and postnatal care, including the promotion of good nutrition, HIV testing, among others. Therefore, the screening for hypertension would carry a slightly lower cost burden, increasing the BCR.

Gheorghe et al (2018) calculate the ratio of the total costs of CVD care to health expenditures per capita. The median ratios for coronary heart disease and stroke are 10.02 and 12.7 respectively. The incidence of catastrophic payments, which is defined as an expenditure of more than 10% of disposable income on health costs, due to hypertension in Kenya, has been estimated to be 43%, 59% when transport costs are factored in (Oyando et al, 2019). This implies that there is an element of poverty alleviation associated with the early detection of hypertension, as well as the need to both curtail medical costs and expand access.

According to the evidence available on the societal impact of the scale up of community health worker programmes and health-related communications in Africa, it is expected that the interventions will increase productivity from a healthier population: person with cardiovascular disease like stroke or heart failure is prematurely removed from the labour market due to disability/death. They will also Increase access to the health system, particularly in remote areas. They will also raise awareness among poor communities of the dangers of high salt intake and uncontrolled hypertension. Lastly, the interventions will promote the generation of more (and needed) evidence regarding lifestyle and hypertension management, as well as lead to a substantial reduction of CVDs complications and deaths on the African continent.

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Graduation from ultra-poverty

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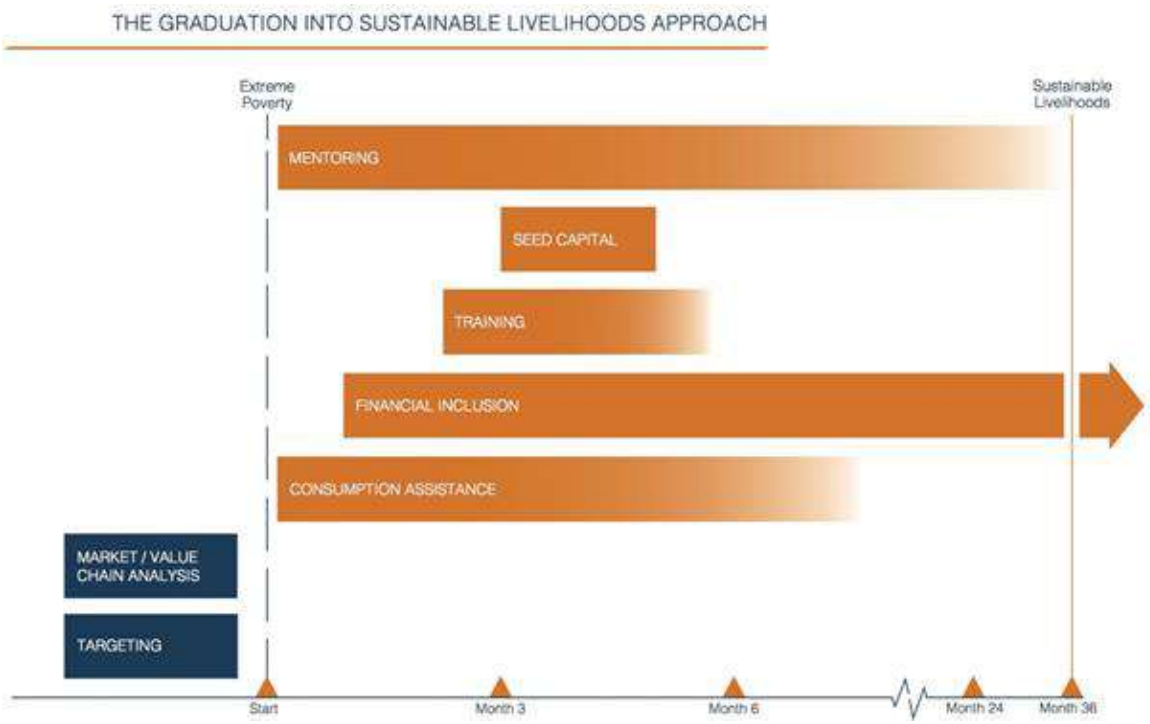
"End poverty in all its forms everywhere", the first of the United Nation's Sustainable Development Goals (SDG), has direct and indirect links with many of the other SDG targets. While the world has seen unprecedented decline in extreme poverty in the first decade of this millennium, the recent statistics indicate this goal will be challenging to achieve. According to World Bank (2018) estimates, decline in extreme poverty is slowing down. The proportion of people living below 1.9 dollars a day has declined from 11.2% to 10% between 2013 and 2015. As of 2015, there are about 736 million people living in extreme poverty, of whom more than half (413 million) are living in Sub-Saharan Africa. In their projections, in all but the most optimistic scenarios, the rate will remain in double digit. Economic growth alone is clearly not enough to reach the targets. Increasing the depth and coverage of social protection, which is an SDG target on its own, is going to play an important role for us to achieve the SDG of endling poverty.

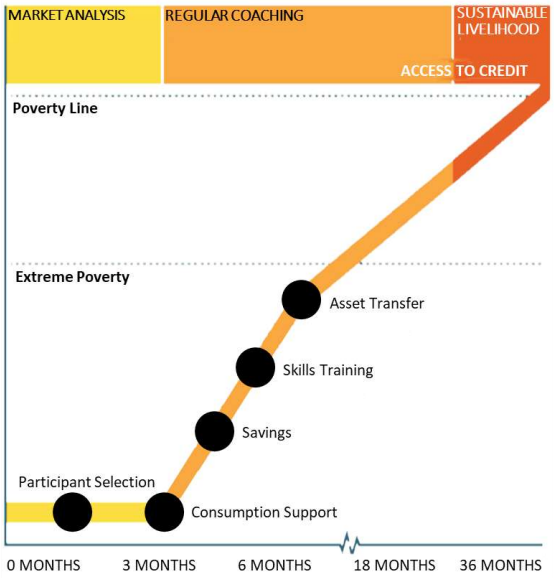
Graduation model for the ultra-poor: A social protection tool

The Graduation Model, developed by BRAC in Bangladesh in early 2000 and piloted in a number of countries by various agencies, has emerged as one of the potential tools for addressing extreme poverty in a sustainable manner. This model combines a set of targeted interventions to create pathways out of ultra-poverty.

The package of the model includes creating self-employment through seed capital, a transfer of asset (usually livestock). The other key components – consumption support, financial inclusion, training and coaching – are designed to protect their asset and to maximize profitability of their micro-enterprise. The three key features of the model are – careful sequencing of the interventions, rigorous targeting to reach the ultra-poor and a time-bound exit strategy.



Source: Graduation 101, CGAP



The interventions are delivered in sequence over 18–24 months per household, following a local market assessment to identify potential livelihood activities that extremely poor households could engage in. Beneficiaries were selected through a rigorous targeting process to identify the poorest: generally, a participatory wealth ranking in which the community identified the poorest households, along with a set of selection criteria to reduce inclusion error. Although most graduation initiatives predominantly target rural ultra-poor, there have also been urban adaptations of this model. The intervention starts with cash stipends to support subsistence while beneficiaries develop new livelihoods. Through a consultative process with the household members, appropriate enterprises are determined for each household. Following initial training on the selected enterprise, the assets required to start the livelihood activity are transferred. The assets or enterprises supported in various projects so far were primarily livestock and small nonfarm businesses. This asset transfer is followed by regular coaching to provide technical assistance on enterprise management as well as to assist beneficiary households in coping with shocks and various social pressures. Depending on the service availability, the beneficiaries are provided with bank accounts as a secure place to save their income or are mobilized to form savings groups.

Evidence of effectiveness

Motivated by the initial success of the model in Bangladesh, CGAP and the Ford Foundation launched a major initiative to pilot the model at 10 sites between 2006 and 2014 to learn how well it could be adapted outside Bangladesh. Under these initiatives, impact of the model has been evaluated using randomized control trial (RCT) method in seven countries, including two countries in Africa – Ethiopia and Ghana. The results of these RCTs demonstrate that the model not only reduce poverty (in terms of household income and consumption) during the intervention phase but also the impacts increase in the years after the interventions are completed. Subsequently, there have been two more RCTs (in South Sudan and Uganda) that confirm the impact of this model as well as its higher effectiveness compared to unconditional cash transfers.

Benefit and cost analysis

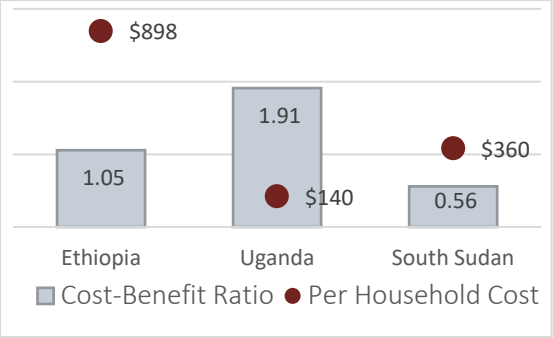
The benefits included in calculating benefit-cost ratio (BCRs) are – impact on annual consumption, and impact on asset and net savings one year after the end of intervention. Although there is evidence of graduation model causing changes in other non-economic indicators (such as reduction in children's stunting in Bangladesh), those are not included in benefit calculation since the evidence does not come from Africa. For the overall BCR estimates, the meta average from the four impact studies to compare benefits with average cost using the same weights. The main determinant of the BCR is the sustainability of the impact on household consumption after the interventions are completed. If impacts vanish after 1 year from the end of interventions, the BCR is lower than one. The investments are worthwhile, in terms of the social benefit, only if the consumption gains persist at least for 5 years. However, the evidence from pilots outside Africa show that the impacts not only sustain after the end of interventions but also keep increasing even after 14 years. The four pilots in Africa also indicate such trend whereby the impacts at the end of intervention is lower than the impact after 1 year later.

TABLE. OVERALL BENEFIT-COST RATIOS

Duration of consumption gain after the end of interventions	Discount rate		
	3%	5%	8%
Continue for 15 years	2.15	1.89	1.59
Continue for 10 years	1.70	1.55	1.37
Continue for 5 years	1.06	1.02	0.96

The country specific BCR shows that the graduation model in Uganda and Ethiopia are cost effective even if the impact on consumption does not sustain at all after two years from the end of intervention.

FIGURE. COST AND BCR FROM THE THREE PILOTS



Note: The BCR estimates are based on impact sustaining for 2 years after end of intervention at 5% discount rate. Ghana is not shown in the graph since the study did not collect monetary value of assets.

Considerations for investment in Graduation Model in Africa

Local market opportunities: Since the model utilizes existing market opportunities for creating self-employment for the ultra-poor, the stability of local market is a critical factor. Although the study in South Sudan find higher impact of graduation model than unconditional cash transfer, the BCR is lower than one. Therefore, the model can be prioritized in countries that are not conflict affected. In other contexts, it is conceivable to combine this model with market development initiatives, which would require longer time for implementation.

Lowering cost of interventions: There are a few ongoing projects that are reducing per household cost of the model by creating an enterprise for a group of 3 to 5 eligible households – such as Village Enterprise in Uganda or Boma in Kenya. It is possible to achieve higher BCR and reach larger number of ultra-poor households through such cost reduction approaches. A second promising way of improving BCR is by reducing the cost of coaching component by utilizing information technology-based tools.

Prioritizing countries: If all the extreme poor household in 20 countries with the highest concentration of ultra-poverty and are not conflict affected, this model can reach 218 million or over half of the extreme poor in the continent. At an average cost of USD 600, this would require an investment of about USD 5 billion. Incidentally, several of these 20 countries are already have projects run by different agencies following the Graduation Model.

Utilize existing social protection programmes: Scaling up graduation can be done faster and with lower additional investments by leveraging on existing social protection schemes. For example, the pilot in Ethiopia used the Productive Safety Net Programme (PSNP) to implement graduation by adding a few additional components. It is conceivable that several of the components of Graduation model are already being implemented under difference schemes that can be aligned to create the effectiveness of this model.

Community-Led Total Sanitation

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Summary

We analyze the economic costs and benefits of "Community-Led Total Sanitation" (CLTS), a sanitation intervention that relies on community-level behavioral change. We estimate the benefits and costs of implementing a CLTS program in a hypothetical rural district or administrative region of a country in Sub-Saharan Africa. This region is assumed to include 200 villages, and each village has 100 households with five members (two adults, two children between five and fourteen, and one child under five), for a total population of 100,000 people. The CLTS campaign is assumed to affect villages in the region differently. In some villages a large proportion of households will build and use latrines as a result of the CLTS intervention (high-uptake villages). In other villages a medium proportion of households will build and use latrines (medium-uptake villages). And in some villages only a small proportion of households in a village will build and use latrines (low-uptake villages). We make assumptions about the distribution of these three village types in the region based on recent research. Benefits and costs are calculated at the household level for each of these three village types, and then aggregated to the village and regional levels. We find that CLTS interventions would pass a benefit-cost test in many situations, but that outcomes are not as favorable as many previous studies suggest. If all villages in the region are considered, the benefit-cost ratio is 1.6[89].

Problem Description

One of the most important development challenges in Sub-Saharan Africa is how to end the practice of open defecation. While there is universal agreement that open defecation is a serious public health problem, governments have limited policy options for addressing it. The most common approach has been to subsidize construction of improved pit latrines, but having a latrine does not ensure that a household will use it. The economist's standard prescription of a tax or fine on the negative externality resulting from poor disposal of feces is common throughout high-income countries, but is typically judged to be politically infeasible in low-income countries. Health education interventions have met with limited success.

Proposed Intervention: Community-led Total Sanitation (CLTS)

At the beginning of the 21st century a new and promising approach – "Community-Led Total Sanitation" (CLTS) – was added to the arsenal of policy instruments to end open defecation. This community-level behavioral change technique was developed by Dr. Kamal Kar and rolled out in Bangladesh beginning two decades ago. CLTS has since been promoted by most major donors working in the water and sanitation sector, including the World Bank, UNICEF, and the Water Supply and Sanitation Collaborative Council's Global Sanitation Fund. CLTS interventions have now been implemented in approximately sixty countries, and today the approach is mentioned in the official rural sanitation policies of about thirty countries.

CLTS takes a very approach from other health education interventions. Instead of teaching people about the health benefits that households can obtain from improved sanitation, CLTS facilitators conduct community participatory exercises that aim to "trigger" behavioral change by engendering a sense of

[89] A more in-depth discussion of the benefit-cost model and results is available in Radin, Jeuland, Wang, and Whittington (2019).

shame and disgust among village residents who engage in open defecation, leading to a community rather than just an individual or household response. The CLTS approach has offered WASH practitioners hope that there is a practical, low-cost way to end open defecation practices in situations where other policy instruments have failed.

Costs (CLTS)

The costs of a CLTS intervention include the following three components: 1) program delivery, 2) latrine construction, and 3) the time households spend participating in CLTS activities. Program implementation costs are assumed to be independent of whether or not a household constructs a latrine after the CLTS intervention since these are costs incurred by external agencies attempting to mobilize communities to change their sanitation behaviors. Household time costs for participation in CLTS activities vary according to the level of latrine uptake in a village. We assume that not every household in a village attends the initial or follow-up CLTS meetings. Households that attend these meetings and build latrines have higher time costs on average than households that do not attend the meetings or do not build latrines. Villages where fewer latrines are built thus incur lower time costs.

The total costs of building latrines in a village vary depending on the level of latrine uptake. In villages where more people decide to construct latrines, costs will be higher. Operation and maintenance costs depend on the extent to which members of households with latrines actually use them, which evidence suggests declines over time. Our analysis assumes that all households that build a latrine use and maintain it for five years, and that a fixed percentage of households abandon their latrine in each of the subsequent five years.

Benefits (CLTS)

In our benefit-cost analysis we include three types of benefits. First, we estimate the number of lives saved (mortality reduction) and value these lives saved using a statistical value of life (VSL) approach. Second, we estimate the number of cases of non-fatal diarrhea and value these diarrhea episodes using a cost-of-illness approach. Third, we include the time savings from not having to walk to an open defecation site, which we value as a proportion of the wage rate for unskilled labor in the rural area.

The time stream of benefits to households in a village depends on how many households construct and use latrines. The estimated diarrhea reduction for households in a village targeted by a CLTS intervention assumes there is a positive health externality, but this positive externality only “kicks in” once village coverage with improved latrines exceeds a sufficient threshold. The magnitude of the diarrhea risk reduction is assumed to be different for households that i) adopt latrines due to the CLTS intervention, ii) do not adopt latrines, and iii) already had latrines before the intervention.

We do not include estimates of the benefits from reduced risks of assault, enhanced dignity, and increased privacy, which are especially relevant for women and may result from households switching from open defecation practices to the use of latrines at their homes. Nor do we include estimates of any disamenities associated with the use of improved latrines, such as the unpleasantness of defecating in foul-smelling latrines or increased exposure to flies and mosquitoes.

Benefit-Cost Ratio (BCR)

Because many of the more than 50 parameters in the benefit-cost model are uncertain, we conduct a Monte Carlo Analysis varying the key model parameters over a specified range of what we judge to be reasonable values, assuming a uniform probability distribution. We model 10,000 realized benefit-cost outcomes. Table 1 presents the mean benefit-cost results of this Monte Carlo Analysis for three benefit-cost metrics (Present Value of Net Benefits, Economic Internal Rate of Return, and Benefit/Cost Ratio) for all villages in the region, as well as for a single low-uptake village, a medium uptake village, a high-uptake village.

The results suggest that for many combinations of plausible parameter values in the benefit-cost model, a CLTS intervention would pass an economic test. If we consider all villages in the

region, all three metrics are positive. The benefit-cost ratio is 1.6. The model results are sensitive to baseline conditions, including the income level used to calculate the VSL, the discount rate, the value of time, and the case fatality rate, the diarrhea incidence, and the time spent traveling to defecation sites. We conclude that many communities likely have economic investment opportunities that are more attractive than CLTS, and recommend careful economic analysis of CLTS in specific locations.

Concluding Remarks

Our analysis assumes that the CLTS intervention is rolled out in a rural region with a population of 100,000 people. Scaling up the CLTS intervention to additional regions of similar size could stretch the government's ability to effectively administer multiple CLTS programs. On the other hand, lessons may be learned from early roll outs that can be deployed to increase effectiveness in subsequent regions.

The parameter values assumed in the analysis are believed to be typical of many rural regions in Sub-Saharan Africa, but cultural and social differences may well affect how communities respond to the CLTS intervention. This is thus a risk that the program may not be as effective in some regions and in some villages as assumed in our analysis. It is also possible that the CLTS intervention could be more effective than we have assumed. Further research is needed on the magnitude of the positive public health externality.

TABLE 1: MEAN BENEFIT-COST RESULTS FOR THREE BENEFIT-COST METRICS (PRESENT VALUE OF NET BENEFITS, ECONOMIC INTERNAL RATE OF RETURN, AND BENEFIT/COST RATIO)

	Low-Uptake Village	Medium-Uptake Village	High-Uptake Village	All Villages (n = 200)
Benefits	$3,415	$9,350	$28,380	$2,156,275
Mortality Benefits	$1,430	$4,290	$13,335	$991,090
Morbidity Benefits	$900	$2,695	$8,485	$626,870
Time Savings	$1,085	$2,365	$6,560	$538,315
Costs	$5,810	$6,580	$8,365	$1,325,790
Program Costs	$4,900	$4,900	$4,900	$980,000
Time Costs	$535	$535	$535	$107,265
Capital Costs	$270	$805	$1,880	$161,175
O&M Costs	$100	$340	$1,050	$77,350
Net Benefits	($2,395)	$2,770	$19,750	$830,485
ERR	-7%	11%	49%	16%
BC ratio	0.6	1.4	3.4	1.6

References

Radin, M., M. Jeuland, H. Wang, and D. Whittington (2019). Benefit-Cost Analysis of Community-Led Total Sanitation: Incorporating Results from Recent Evaluations. Harvard T.C. Chan School of Public Health. Guidelines for Benefit-Cost Analysis. Working Paper. https://sites.sph.harvard.edu/bcaguidelines/methods-and-cases/

High Speed Train Network

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Summary

In 2014, the African Union approved the plan for an African Integrated High-Speed Rail Network (AIHSRN). High speed trains of over 250 km/h are expected to be constructed but there is on-going debate on whether the costs will outweigh the benefits. In this study, a cost benefit analysis is undertaken where: all direct and indirect cost and benefits are outlined, monetized, future values discounted to present values and combined. A minimum and maximum BCR of 0.91 and 1.52 respectively are computed which signifies the importance of the project.

The problem and scope

Africa's economic growth is envisioned to have more potential growth more than the developed countries in the future. Hence, reduction of trade costs through investment in transport is viewed as a way of boosting economic growth, linking cities, accelerating urbanization and strengthening regional integration. The demand for transport services in Africa is growing, however poor quality combined with high cost transport services, distorted model split, deficiencies in policy and institutional frameworks, lack of funding and high land fragmentation frustrates the growth of the sector including related sectors. With Africa land total area of about 30.37 million km², the vast distance between North and South as well East and West, makes movement of cargo and passenger even more difficult. For example, travelling from North to South of Africa requires, not only to an itinerary for the travel days but it also requires additional days to get boundary approvals. A High-Speed Rail can offer solution to Africa's transportation challenge.

The AIHSRN is part of the African Union's Agenda 2063. The Agenda is a fifty-year plan that has s additional implications on African integration overall, beyond economic and social gains. High Speed Rail (HSR) is designed for at least 250km/h speed with dedicated rolling stocks and tracks that are of complex technology. HSR in the modern society is considered fast, safe, comfortable, efficient in both time and cost, sustainable with increased economic growth, reduced environmental impacts, and reduce delays and congestion in roads and air transport, (Angoiti, 2018; Campos et al. 2007; and Almujbah and Preston, 2019). Despite the aforementioned benefits, HSR has its own drawbacks. HSR operates at very high speed, curved tracks are avoided to enhance speed and avoid accidents, this therefore requires huge land from residential areas, agricultural land and forest land among others (Almujbah and Preston, 2019). HSR embodies a sophisticated technology that allows construction of tracks underground, on land and overpass to reduce the negative impacts on economy, social and environment. With such massive investments required, careful analysis of the benefits as well as cost is demanded. In this brief, cost benefit analysis of the HSR in selected African countries is undertaken. The objective of this study is to analyze whether investment costs in AIHSRN is surpassed by its benefits during the project lifespan using the Benefit Cost Ration (BCR).

The brief is organized as follows; computes the potential benefits of investing in high speed rail and the factors that influences the potential benefits. The factors explaining the potential cost of HSR investment are analyzed. The Benefit Cost Ration (BCR) approach is used to appraise the HSR project. The BCR results are complemented by sensitivity analysis that helps to inform decision making for investing in BCR projects.

Description of the intervention

The AIHSRN intervention aims to interconnect African capitals with each other, thus promotes trade and development of major industries in manufacturing, agriculture, forestry, fishing, mining, manufacturing, energy, tourism and financial services among others. The AIHSRN is expected to connect 54 countries, the study only provides the case for only 10 countries where 44 links estimated at 42,657 km are

identified and are projected to meet a freight demand of between 156,325 - 225,637 million tonnes per year between 2020 and 2063. The project is expected to be constructed between 2020- 2024 and has a lifespan of 50 years.

To make a case for the massive investments of the AIHSRN, 10 countries selected for analysis are based on six regions/ geographical distribution of projects in Africa. Algeria is selected from Northwestern and North Central Region; Ghana and Nigeria for Western Region; Ethiopia for North Eastern Region; Kenya, Tanzania and Uganda for Eastern Region; Central Republic of Congo for Central Region; and Mozambique and South Africa for Southern Region.

Cost analysis

The infrastructure cost/initial capital outlay captures two key components; planning and land costs; infrastructure building costs and superstructure costs which constitutes about 10%-19% and 81% -90% respectively (De Rues, 2012). Infrastructure costs vary depending on land prices, amount of tunneling involved, and costs of entering large cities (Nash, 2010) and also by source of fuel required for operation and by different policies and approval processes. Literature shows that construction cost per kilometer ranging from $4 million to $74 million (Ardui and Ni, 2005). With the exception of China, construction costs were generally higher in Asia than in Europe as reported by Gourvish[90]. CPCS (2019) estimates that the initial capital outlay is estimated at $25 million per track km, however Lao estimates this cost as $20 million which this study adopts. The estimated cost of capital for links/tracks identified in the selected countries is $853,140,000,000 for 42,657km of track

The cost of rolling stock differs based on the type (i.e.: locomotive, wagons, and passenger trains) and number of units defined by the traffic volumes of specific tracks. The costs of freight locomotive, wagon and 10 car passenger train set was established to be $3,500,000, $125,000 and $40,000,000 respectively (CPCs,2019). While the rolling stock units required were specified by 0.0000000123 per net-tonne-km for freight locomotives; 0.00000061445 per net-tonne-km for wagons and 0.00000000174 per passenger-km for passenger trains. The total cost of rolling stock was estimated at $18,934,192,656 and & 27,315,022,624 depending on freight and passenger traffic.

Operation and maintenance costs captures the cost of operation for both freight and passengers, as well as for infrastructure maintenance. These costs include train crews; electricity and consumables; rail traffic control, station masters, and operations management; passenger station employee cost, rolling stock maintenance and administrative; infrastructure maintenance and administrative costs. Tao et al. (2011) estimates HSR operations cost to be a product of operating cost ($679.04 million) and 10,00 seats on service annually. While the maintenance cost of infrastructure and the rolling stock is estimated at $40,742.64 per km per year and $5,432.35 per seat per year. The CPCS estimates of $0.0187 per ton-km, $0.0183 per passenger-km and $55,458 per track-km are applied for freight operation costs, passenger operation costs and infrastructure maintenance respectively. Based on the minimum and maximum traffic estimates by link in 2018, the freight operation cost are estimated at minimum of $2,043,199 and maximum of $76,931,796 while that of passenger operation is at minimum of $39,977 and $54,981. The cost of Infrastructure maintenance is estimated at $2,365,671,906.

Literature proposes computation of residual values when appraisal period is shorter than the useful lifetime of some of the assets. Though this is different in France where, where the appraisal period is set at a fixed 20 years. Casares and Coto-Millán (2011) estimates the residual value at 10% of the value of the investment. Using a 50-year lifespan where re-invested is expected at 25 years for both locomotive and passenger trains, and at 20 years for wagons for the selected AIHSR

[90] Gourvish, T(n.d). The High Speed Rail Revolution: History and Prospects Report

project, the minimum and maximum estimated residual cost is $1,829,876,959 and $2,610,704,612 respectively.

External costs capture the negative impacts of investing on HSR projects, such as: land resumption, barrier effects, visual interruptions, noise, air pollution and contribution to global warming (Tao et al. 2011). Of the total external environmental costs, 53% of the cost is attributed to average accident cost, while average climate change cost, average air pollution cost, and average noise pollution cost is represented by 32%, 14% and 1% respectively (Almujbah and Preston, 2019). De Rus (2012) established that the external cost of 1000 passengers per kilometer is equal to $14.13 per year. The external costs for this project are estimated at a minimum of $30,807,356 and $42,369,723 depending on traffic levels.

Total cost is calculated at a minimum of $ 876,366,174,361 and maximum of $ 885,656,135,981 while the cumulative PV of total cost is about at a minimum of $917,755,589,02 and a maximum of $928,271,560,959 as shown in table 1.

TABLE 1: COST BENEFIT RATIO ESTIMATES

Benefits	**Annual (US$)**		**PV over 50 years**	
	Min	**Max**	**Min**	**Max**
Passenger time savings	41,332,500	55,845,833	754,563,039	1,019,517,371
Reliability	5,662,553	7,650,879	103,375,136	139,673,880
GDP from HSR industry	13,286,766,501	19,930,149,751	242,562,218,845	363,843,328,268
Increased GDP from trade	31,424,635,079	55,307,357,739	573,685,795,632	1,009,687,000,312
Road traffic injury reduction	1,081,966,125	2,163,932,251	19,752,292,937	39,504,585,874
Total Benefits	**45,840,362,758**	**77,464,936,454**	**836,858,245,590**	**1,414,194,105,705**
Annual recurrent cost	**Annual (US$)**		**PV over 50 years**	
	Min	**Max**	**Min**	**Max**
Freight operation cost	2,043,199	61,514,484	37,300,494	1,123,003,844
Passenger operation cost	39,977	54,981	729,824	1,003,736
Infrastructure maintenance	2,365,671,906	2,365,671,906	43,187,529,980	43,187,529,980
External cost	30,807,356	42,369,723	562,416,802	773,498,513
Total	**2,398,562,439**	**2,469,611,095**	**43,787,977,100**	**45,085,036,073**
Capital cost				
	Min	**Max**	**Min**	**Max**
Initial CAPEX	853,140,000,000	853,140,000,000	853,140,000,000	853,140,000,000
Rolling stock	18,934,192,656	27,315,022,624	18,934,192,656	27,315,022,624
Residual value	1,893,419,266	2,731,502,262	1,893,419,266	2,731,502,262
Total	**873,967,611,922**	**883,186,524,886**	**873,967,611,922**	**883,186,524,886**
Total cost	**876,366,174,361**	**885,656,135,981**	**917,755,589,022**	**928,271,560,959**
BCR			**0.91**	**1.52**

Benefit analysis

The main drivers of revenue estimates are the traffic levels and tariffs for both freight and passenger operations. The estimated tariff rates for both freight and passengers were assumed to be the same for all links. In addition, the average rail transport charges for freight and passenger along all the links is estimated at USD $0.080 per ton-km and $ 0.024 per passenger-km. respectively. Tao et al. (2011) uses $17.99 as average ticket price for Hong Kong which almost similar to the ticket price in Africa. Freight and passenger ticket revenue estimates are between $12,506,000,000 - $18,050,160,000 and $51,180,000 - $69,360,000 respectively. To avoid double counting, this benefit, is not incorporated in the computation of the HSR total benefits but it is captured as HSR industry contribution to GDP.

The user travel time in transportation studies is involved into many categories such as the access/egress time, waiting time, and the in-vehicle travel time. The value of time (VOT) is identified as one component in the total equation of user cost and it can be calculated by multiplying an hourly wage rate by an average ridership component (Tao et al. 2011). VOT values varies depending on as trip purpose, socioeconomic and demographic characteristics, the total duration of the trip, among others. Tao et al. (2011) observes that HSR saves about 40 minutes compared to other convectional rail and that the average value of travel time (VTTS) is estimated at $17.11 per person per hour. Dijkman et al. (2000) indicates that the time saving estimates lies between $80million-$210million and its expected to rise to $160 million to $300,000 million. This study assumes time saving of 2 minutes per km per passenger, valued at 50% of average wage rate which is calculated based on GNI per capita. This gives total time savings benefits of $41,332,50 and $55,845,833 annually. According to Tao et al. (2011) unreliability in travel time is a major concern in transportation and captures both congestion and delays. Transport for London reports of 2008 that the value of reliability improvement is estimated based on the ratio of VTTS, which is about 13.7%. Based on this, the estimated reliability improvements range between $5,662,553 and $7,650,879.

HSR is expected to enhance accessibility with critical linkages established that widens markets and increases both competitiveness and productivity in the new developed regions. However, the level and the significant of this contribution is anticipated to be low[91]. Nevertheless, literature indicates GDP growth contribution from HSRs to be about 1-3 % (Preston and Wall, 2006) and captures wider economic impacts of HSRs as an industry. The economic contribution of HSR considers direct impacts through industry operations where returns to capital and labour are critical. At the same time, it also considers indirect impacts that extends to the wider economy through demand created in upstream industries as they produce inputs to the industry (Deloitte, 2017). Recent research from china indicates that High speed rail seems to provide a 1.0% to 1.5% annual GDP boost to regional economies. Based on the recent estimates from China[92], the minimum projected potential economic growth is estimated at a minimum of $13,286,766,501 and a maximum of $ 19,930,149,751.

Transport improvements impact on labour market and consequently on labour costs. According to Ministry of Transport New Zealand (2014) improvement in transport can develop labour market catchments, increase job matching and enable business interactions. Improved transport is also associated with reduced trading costs. When transport costs fall, both domestic and international trade increases. Fall in transport costs in the UK was associated with an increase in international trade by 10%—17.5% and also GDP by about 2.5% - 4.4% (Ministry of Transport New Zealand, 2014). Using this estimate, the

[91] According to Gourvish report

[92] Retrieved from https://www.nextbigfuture.com/2010/09/chinas-building-high-speed-rail-economy.html

increased GDP from trade in this study is between $1,081,966,125 and $2,163,932,251.

Investments in HSR is anticipated to reduce road accidents. This study calculates road traffic injury reduction by summing years of life lost (YLL) with years lived with disability (YLDs) and multiplying the value by 1.3* GNI per capita with the assumption that 10-20% of injuries will be averted by the rail network. The projected road traffic injury reduction is about $1,081,966,125 to $2,163,932,251.

Total benefit estimation ranges between $45,840,362,758 and $77,464,936,454. Cumulative PV of total benefit is about at a minimum of $836,858,245,590 and a maximum $1,414,194,105,705 as presented in table 1.

Sensitivity analysis

Several factors may influence the projected CBR values estimated; risks (such as capital costs, construction costs, and operating costs), population level, economic growth level, value of time and discount rates. Literature review establishes two views about risks. One is that risk is usually embedded in the total project costs, and second, risks is considered as a contingency, estimated at 5-10 percent risk margin. Gleave (2004) observed that actual high-speed rail projects have in recent times experienced significant budget overruns, a fact which has generally not yet been fully reflected in the risk margins adopted in the appraisal frameworks. Three key risk aspects are examined in the study according to Gleave (2004): an increase capital costs by 66%, increased construction time by 2 years with construction overruns of 25% and increased operating costs by 15% which should be allowed for in line with Green Book Guidance. These risks lower the level of CBR as shown in Table 2. The CBR is insignificant to minimal risk levels of between 10%-15%. The minimum value CBR is incentive to passenger time levels when value of time increases by 50%, while when capital costs increases by 66%, the CBR falls by 38.6% to between 1.42 and 2.21 respectively. CBR is established to be more sensitive to project capital cost than annual recurrent costs. For instance, a 10% increase in capital costs leads to about 8.5% to 38.6% drop in CBR, at the same time a 10% increase in annual recurrent costs is estimated to a fall in CBR by 0.5% to 0.7%.

TABLE 2: CHANGE IN BASE BENEFIT-COST RATIO FROM ADJUSTMENTS IN DIFFERENT SENSITIVITY INDICATORS

	Minimum BCR		Maximum BCR	
Base-BCR				
	0.91		1.52	
increase in capital costs				
10%	0.83	-9%	1.39	-9%
66%	0.56	-39%	0.94	-39%
construction delays and cost overruns				
10%	0.83	-9%	1.4	-8%
25%	0.74	-19%	1.24	-19%
increase in operating cost				
10%	0.91	-0.5%	1.52	-0.5%
15%	0.91	-0.7%	1.52	0
Increase in passenger revenue				
10%	0.91	0%	1.52	0%
25%	0.91	0%	1.52	0%
increase in value of time				
10%	0.91	0.01%	1.52	0.01%
50%	0.91	0.05%	1.69	11%

Discussion

The CBR computed was based on both minimum (0.91) and maximum (1.52) projected traffics for both freight and passengers. For policy decisions, it is important to take considerations of the country specific CBRs and also the link/track specific CBRs. For example, the maximum CBR above 1 was observed in most countries except for Kenya, Mozambique, Tanzania and Uganda, Ghana and Nigeria are countries with the highest maximum CBR values at 3.9 and 3.5 respectively.

Among the links/tracks with the highest CBR are in Nigeria and South Africa at 5.47 - 8.88 and 2.81 - 4.52 respectively. Subsequently several risks factors such as capital costs, construction costs, and operating costs, traffic demand, economic growth level, value of time and discount rates are critical for investment decisions. Mozambique is among the countries with links that have the lowest CBR of about 0.03 to 0.06.

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Annex

Assumptions applied to BCR

The analysis is based on a period of 50 years (2020-2050) that incorporates construction period of 5 years (2020-2024) and adopting a 5% discount rate

Links/Track, length (km) and Cost of investments, Freight and Passenger Traffic vary and are sourced from CPCS (2019)

Freight and passenger traffic vary by link and data is presented in minimum and maximum values, sourced from CPCS (2019)

Rolling stock units required were specified by 0.0000000123 per net-tonne-km for freight locomotives; 0.00000061445 per net-tonne-km for wagons and 0.00000000174 per passenger-km for passenger trains.

The costs of freight locomotive, wagon and 10 car passenger train set adopted was $3,500,000, $125,000 and $40,000,000 respectively.

Cost of operation and maintenance are: $0.0187 per ton-km, $0.0183 per passenger-km and $55,458 per track-km for freight operation costs, passenger operation costs and infrastructure maintenance respectively.

Residual value costs are estimated at 10% of the value of the investment (Casares and Coto-Millán, 2011).

External cost assumes $14.13 per year for 1000 passenger per kilometer, (De Rus, 2012)

Average rail transport charges for freight and passenger along all the links is estimated at USD $0.080 per ton-km and $ 0.024 per passenger-km, respectively.

Time saving estimates are based on 2 minutes per km per passenger, valued at 50% of average wage rate which is calculated based on GNI per capita.

Value of reliability improvement is estimated based on the ratio of VTTS, which is about 13.7%. (Transport for London report of 2008)

GDP growth contribution from HSRs to be about 1-1.5 %

HSR is expected to contribute an average of 1-3 % to GDP growth (Preston and Wall, 2006).

Increased GDP by about 2.5% - 4.4% (Ministry of Transport New Zealand, 2014).

Investments in HSR is anticipated to reduce road accidents by assuming 10-20% of injuries will be averted by the rail network.

Off-Grid Rural Electrification in Africa

Bahman Kashi, Limestone Analytics

Background & Motivation

"Off-grid rural electrification" reminds most of us about bringing solar lanterns to rural communities who otherwise use kerosene for lighting. The menu of technological options is, however, much broader than solar lanterns. 2019 Jaglin categorizes off-grid, or "autonomous," generation technologies as mini-grids, energy kiosks, and individual systems. Each of these systems can come with a range of technological options.

Similarly, the use of electricity is also not limited to household lighting and can include other appliances and productive use. For instance, in a recent study in Kenya (2017 Rom), 48% of rural households reported using cell phone light as their secondary source of lighting, after Kerosene (99%). The same population's use of solar lights and electricity-powered lights is at 6% and 2%, respectively. Mobile phones, in such a population, clearly dominate the electricity use.

More than ever before, donors and governments are concerned about rural electrification. In the pursuit of economic development and equitable access to electricity, significant amounts of funding have been driven towards rural electrification in recent years. Since 2000, the share of people with access to electricity in the least developed countries has more than doubled (sustainabledevelopment.un.org/sdg7). The experience with the impact of energy access on welfare, however, is mixed. As shown in the benefits section of this brief, many studies find no attributable impact in the short to medium term.

The nature demand for off-grid electricity solutions is also complex. For instance, off-grid solutions such as solar home system are popular in Haiti for on-grid applications as opposed to off-grid. The solar home system can perform a coping function and address the reliability issues of the grid. The rural population is also often reported to have negligible demand and low willingness to pay for electricity. 2015 Peters reports an average of 4.6 to 11 kWh of electricity consumption for off-grid households that are provided solar home systems or connected to a village grid per month in Rwanda, Senegal, and Burkina Faso, compared with 867 kWh in the US (www.eia.gov/tools/faqs/faq.php?id=97&t=3).

2019 Grimm suggests that off-grid solar is the most cost-effective technology for most of rural Africa. Other studies (2018 Leo, 2016 Baurzhan, and 2017 Robert) suggest mini-grids and grid extension are the solution and highlight the importance of understanding the use of electricity beyond lighting (industrial, air conditioning, etc.) when thinking about increasing access to electricity.

This brief uses principles of cost-benefit analysis to bring the readers' attention to the nuances and contextual parameters that can help in scaling up access to electricity. Furthermore, the paper provides a crude estimate of the benefit-cost ratio based on preliminary calculations.

Scale

According to the International Energy Agency (https://www.iea.org/sdg/electricity/), 600 million people lack access to electricity in Sub-Saharan Africa. Considering an average household size of 5 people, the energy access gap is **120 million households** in Sub-Saharan Africa alone. Based on a recent study (2017 Rom), 68% of all households and 83% of rural households in sub-Saharan Africa remain without access to electricity.

Benefits

Past studies have listed a range of benefits associated with electrification, these benefits include education, health, safety, income, economic development, and time-savings. Recent studies, however, provide conflicting evidence on the realized impacts. Studies in Kenya (2018 Lee and 2017 Rom) report no impact, while other studies report significant impact (2011 Dinkelman and 2018 GOGLA) in South Africa, Kenya, Mozambique, Rwanda, Tanzania, and Uganda. The internalized portion

of the benefits can be captured by Willingness to Pay (WTP) studies.

2019 Grimm and 2018 Lee estimate the WTP for electricity for off-grid and under-grid households respectively. 2019 Grimm considered 3 different solar home systems while 2018 Lee considered grid extension for serving households with electricity. Both studies found the costs of service is greater than the WTP. Furthermore, they both argued that the investment gap will not be closed even after the inclusion of external impacts. 2019 Grimm reports that the WTP for the three solar kits is between 38 and 55 percent of their respective market prices. The costs are 13, 37, and 180 USD for the three technologies. With an average life of 3, 6, and 4 years, and a discount rate of 10% the monthly **WTP comes to 0.72 to 1.05 USD per household per month**[93].

2015 Peters provides a summary of education outcomes reported by recent literature. Studies in Rwanda, Burkina Faso, and Indonesia show report that access to electricity has no impact on the total number of hours studied. A recent evaluation report in El Salvador (2017 MCC), however, reports the health impacts of electrification due to improved home air quality. This study uses the relative risk published by 2017 MCC for cardiovascular disease and lung cancer, along with the Disability-Adjusted Life Years estimated reported by 2018 Lancet and the value of statistical life reported by 2017 Viscuzi to calculate the value of health benefits. The value of DALYs averted per household per month in Sub-Saharan Africa is **2.05 USD**.

Costs

The investment costs for solar home systems included in the study by Grimm (2019 Grimm) range from 13 to 182 USD for 0.5 Watt, a 3.3 Watt, and a 20 Watt device. The study, however, finds the willingness to pay to be significantly lower and concludes that there is no economic justification for subsidizing electrification using solar home systems. 2019 Lee, arrives at a similar conclusion when looking at grid extension to areas that are close to the grid but not connected, "under-grid."

Micro-grids are a middle step between individual systems and grid connection. These systems are considered as the most cost-effective off-grid solution by a recent study (2018 Reber). The same study reports a Levelized Cost of Energy (LCOE) for micro-grids in Africa that ranges from 0.75 to 0.85 per kWh. To make this estimate comparable with the WTP reported earlier, monthly consumption of 4.6 to 11.1 kWh is borrowed from 2015 Peters. As a result, the **monthly cost of generation per household is 3.45 to 9.44 USD**.

Benefit-Cost Ratio

As explained under the Benefits and Costs sections. A crude estimate of the revealed benefits, based on willingness to pay reported by 2019 Grimm ranges from 0.72 to 1.05 USD per household per month. The cost of serving this demand using micro-grids is 3.45 to 9.44 USD per month. The resulting **Benefit-cost ratios by household per month, therefore, range from 0.08 to 0.30**. Adding the health benefits increases the range of benefit-cost ratio to **0.29 to 0.90**.

A Policy View & Recommendations

The calculations provided in this study are based on crude assumptions and must not inform decisions. Some of the key parameters in this study come from Rwandan data. Rwanda's electrification rate and income is considered average among Sub-Saharan African countries. The main goal of this brief is to bring attention to the complexities involved with the analysis and decision-making when it comes to off-grid rural electrification. There are many technologies to consider, and the demand must not be overestimated. Alternatively, one can consider a policy lens and focus on the least-cost approach to achieve universal access. 2019 Grimm finds the individual systems (such as solar home systems and solar lanterns) as a more cost-effective approach to achieve such a policy goal.

[93] Note that all three systems run on solar panels.

The parameters used to estimate the cost of generation relate to the technology selected, its useful life, and the consumption level of subscribers. Depending on the value of these parameters in each location, the right choice of technology can be different.

Another important policy concern raised in the literature is that market-based solutions, naturally, do not target the poor. The lack of incentive to serve the poor justifies direct subsidies or cross-subsidies to fund rural electrification programs.

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PART 2

BENEFIT AND COSTS OF R&D INVESTMENTS FOR DEVELOPMENT

COPENHAGEN CONSENSUS CENTER

Summary for policy makers on R&D priorities

Many problems in Africa have solutions that simply need more money to resolve, like lack of water, where access can be improved with more dollars spent on well-understood bore-well technology. This was the subject of the first part of this report, where we investigated about 30 ready to scale-up policy solutions.

This second part looks at possibilities to further improve yields from existing interventions, and also problems that have more expensive solutions or maybe no feasible solutions at all currently. Here, investment into research and development (R&D) could possibly help make future spending more effective.

The overview on the next page shows 35 areas where R&D might help future spending becoming more effective. It answers where more resources can be invested into R&D to produce most social good.

It should be emphasized that this analysis is very preliminary and estimated for the world. However, as Africa has a significant part of both the global challenges and will stand to gain much from cheaper ways to tackle these challenges, it is likely that much of the global estimates will be similarly applicable for Africa in specific.

The uncertainty of the benefit-cost ratio (BCR) is clear, spanning 1-4 orders of magnitude. This is simply a result of making educated guesses on what is essentially very difficult to predict — what extra R&D can develop of new knowledge and how much and how valuable that will be.

Here, we will summarize the top 6 solutions that have an expected return on investment above 100, but clearly many of the other areas also have very attractive BCRs.

Action research is carried out in cooperation with receptive government departments to support program implementation and might produce $**5000** of social good per dollar spent. It does so by helping to compress 100s of years of learning into 10 years. It essentially takes the best ideas from across the world and make specific projects better implemented.

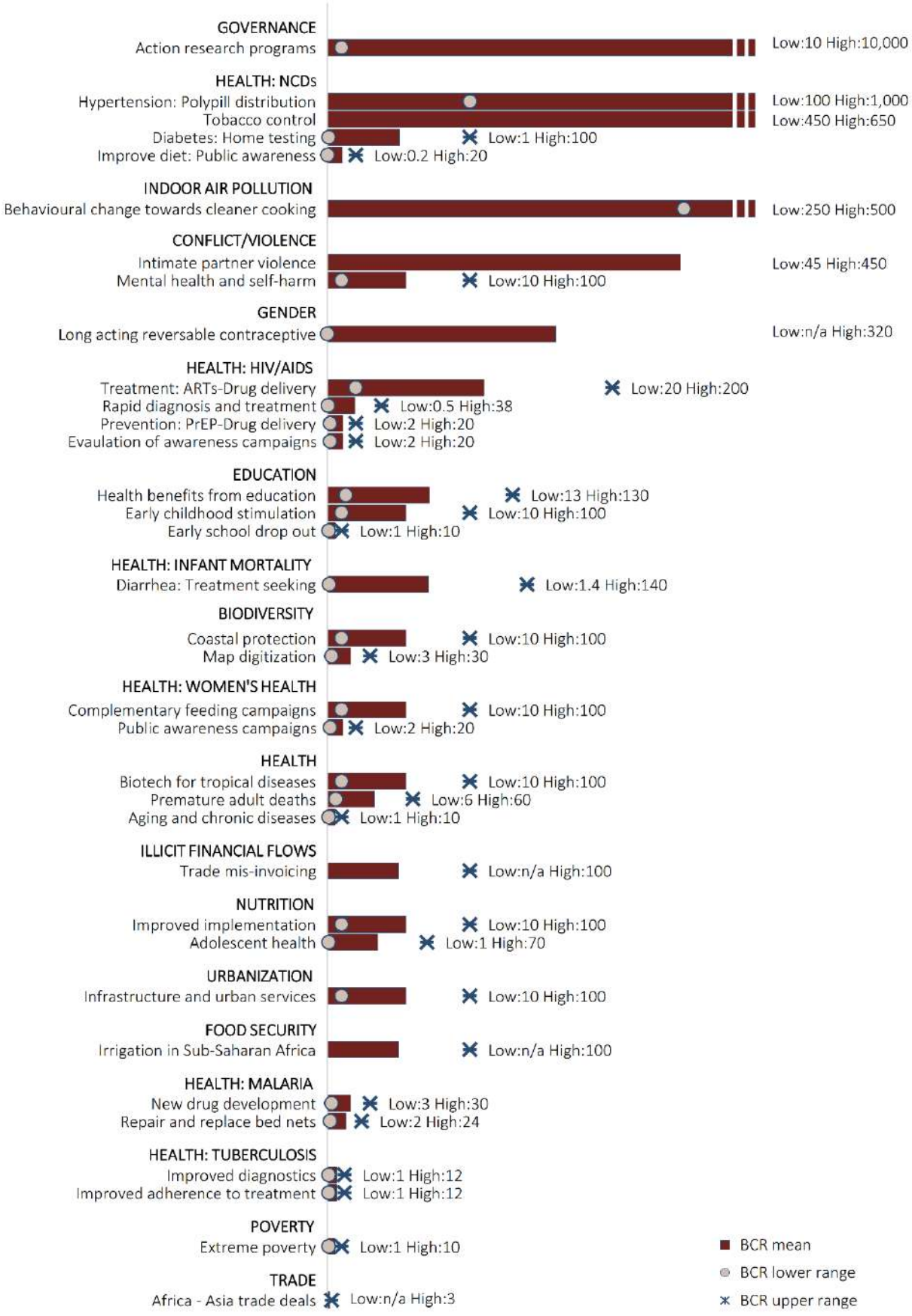
About one billion people will die from **tobacco** in this century, if current smoking patterns persist. R&D could help generate and implement politically feasible solutions, from estimating the most effective and least disruptive tobacco tax increases to creating packaging to reduce consumption. Each dollar spent could produce $**550** of social benefits.

Cardiovascular disease kills almost a million people in Sub-Saharan Africa each year. **Hypertension** can be treated with a combination of drugs, but a polypill (one pill which contains many) is cheaper and dramatically increase adherence. R&D to increase distribution, by studying different targeting and assessing existing and new distribution mechanisms for treatment could produce $**600** of social benefits.

Cooking with poor fuels kills 270,000 people in Sub-Saharan Africa every year, and if we could change cooking habits towards **cleaner cooking**, we could dramatically lower deaths. R&D would focus on household cooking habits, use of single or multiple burners, awareness and understanding of health effects, time spent cooking, how time is valued in the household, etc. Each dollar spent could produce $**425** of social benefits.

Intimate partner violence is an enormous and often underappreciated problem. Each year it costs $4.4 trillion or 5% of global GDP. Researching and developing better and cheaper ways to cut violence could have a massive impact — for instance, the American SAFE DATEs program has reduced domestic violence among teenagers by 56%. Each dollar could produce $**250** in social benefits.

If we could develop **long acting reversible contraceptive**, it could dramatically increase women's empowerment, their labor market participation and ensure improved health outcomes for the women and their babies. R&D to improve existing technologies and get them to market could generate $**160** for every dollar spent.


GOVERNANCE
Action research programs
Low:10 High:10,000
HEALTH: NCDs
Hypertension: Polypill distribution
Low:100 High:1,000
Tobacco control
Low:450 High:650
Diabetes: Home testing
Low:1 High:100
Improve diet: Public awareness
Low:0.2 High:20
INDOOR AIR POLLUTION
Behavioural change towards cleaner cooking
Low:250 High:500
CONFLICT/VIOLENCE
Intimate partner violence
Low:45 High:450
Mental health and self-harm
Low:10 High:100
GENDER
Long acting reversable contraceptive
Low:n/a High:320
HEALTH: HIV/AIDS
Treatment: ARTs-Drug delivery
Low:20 High:200
Rapid diagnosis and treatment
Low:0.5 High:38
Prevention: PrEP-Drug delivery
Low:2 High:20
Evaulation of awareness campaigns
Low:2 High:20
EDUCATION
Health benefits from education
Low:13 High:130
Early childhood stimulation
Low:10 High:100
Early school drop out
Low:1 High:10
HEALTH: INFANT MORTALITY
Diarrhea: Treatment seeking
Low:1.4 High:140
BIODIVERSITY
Coastal protection
Low:10 High:100
Map digitization
Low:3 High:30
HEALTH: WOMEN'S HEALTH
Complementary feeding campaigns
Low:10 High:100
Public awareness campaigns
Low:2 High:20
HEALTH
Biotech for tropical diseases
Low:10 High:100
Premature adult deaths
Low:6 High:60
Aging and chronic diseases
Low:1 High:10
ILLICIT FINANCIAL FLOWS
Trade mis-invoicing
Low:n/a High:100
NUTRITION
Improved implementation
Low:10 High:100
Adolescent health
Low:1 High:70
URBANIZATION
Infrastructure and urban services
Low:10 High:100
FOOD SECURITY
Irrigation in Sub-Saharan Africa
Low:n/a High:100
HEALTH: MALARIA
New drug development
Low:3 High:30
Repair and replace bed nets
Low:2 High:24
HEALTH: TUBERCULOSIS
Improved diagnostics
Low:1 High:12
Improved adherence to treatment
Low:1 High:12
POVERTY
Extreme poverty
Low:1 High:10
TRADE
Africa - Asia trade deals
Low:n/a High:3
BCR mean
BCR lower range
BCR upper range

R&D to make policies cheaper for the long run

Many problems in Africa and the world have clear and well-understood solutions that simply need more resources — mostly money — to move towards resolution. Lack of access to clean water has well-understood solutions based on existing technology, where extra dollars relatively straightforward can be converted into more people having access to clean water, helping resolve the problem. In the first part of this report, we discussed about 30 such policies that could be immediately scaled up with existing technology. The question there was simply: for each of these existing solutions, where can spend a shilling (or naira, rand or franc) to help produce the most social good.

But other problems have more expensive solutions or maybe no solutions at all. Here, it might be possible for investment into specific research and development (R&D) to help make these problems cheaper to solve and hence produce more value per dollar spent. Especially for problems we will be at least addressing partly anyway, investment in R&D could reap large benefits.

Clearly analyzing the possible future of knowledge creation is fraught with uncertainty. Moreover, this report had very limited time available, and we have focused most of our attention to the immediately unscalable solutions presented in part one.

Thus, we here presenting previous work we have done on global development R&D. Since Africa has a significant part of both the global challenges and will stand to gain much from cheaper ways to tackle these challenges, it is likely that much of the global estimates will be applicable for Africa in specific. We reconnected to the researchers that originally helped us put this overview together, but it was clear that in the time available, it was impossible to substantially improve these previous, back-of-the-envelope estimates.

With this in mind, let us look at a preliminary scoping of the R&D opportunities across a wide number of areas relevant for Africa. It presents a valuable starting point from which more detailed analysis could and should be undertaken.

The general argument for R&D

This part makes three main arguments concerning the priorities for development R&D

First, R&D investments in public challenges is often an extraordinarily good investment. It promises to deliver benefits many times its cost. However, it is crucial to focus on the right investments – if the spending is done poorly and without regards to the likely benefits, it is possible that the entire project could miss out on benefits worth more than $100 billion in total benefits. For Africa, it is worth investigating the possible range of R&D policies available.

Second, we will outline many of the most promising R&D areas along with their costs and benefits. Our most recent global research, the Post-2015 Consensus, focused on the UN's Global Goals (otherwise known as the Sustainable Development Goals for 2016-2030) and in it we covered all areas of development and worked with more than 80 of the world's top economists. You can see more of the project and its 1800+ pages of peer reviewed research at post2015consensus.com.

We returned to involve as many of the economists from our Post-2015 Consensus project, and asked each to identify the best R&D options within their area of expertise, which ensured that we covered all the major fields of international development. A broad understanding of R&D was used. Traditionally, R&D is more often associated with technology and product development, for example investing in new drug development, but for the purposes of this part, R&D also encompasses policy and implementation issues.

Between them, the economists identified around 70 concrete ideas which they considered worthy of R&D investment. For 35 of these ideas we present preliminary assessment on the costs and benefits that are relevant for Africa, and where it has been possible do a rough 'back of the envelope' calculation, which gives an order of magnitude for a benefit cost ratio.

In coming up with the cost benefit assessment we identified the first-order magnitude of the cost of the problem that the research and development could possibly address, the likely size of the cost of the R&D, and the likely size of the actual impact on reducing the cost of the problem. We used existing data and evidence to make these estimations, also drawing on the expertise of the economists we consulted with, as well as our own judgements and experience. While this has not provided detailed analysis of the costs and benefits, it is nevertheless a well-informed expert assessment, which provides us with an order of magnitude. Bringing these estimates together in a cost benefit calculation, this gave us a very back-of-the-envelope assessment of the cost of the R&D compared to the likely benefits. That means we can start to identify proposals as to their effectiveness, all the way from projects that are likely to only just cover their costs with similar benefits, to projects that will achieve amazing benefits for a small cost.

Third, these analyses make it possible to make a broad preliminary ranking for R&D spending, helping focus which areas Africa could produce the most social good in R&D first.

Development R&D is often very efficient

In previously research, we have looked in depth at three concrete development R&D proposals: agricultural R&D to achieve yield enhancement (also presented in section 1 since on can argue that improving practices and deployment of technology are an integral part of modern agriculture); the cost-benefit of extra spending on R&D into an HIV vaccine; and the costs and benefits from increased green energy R&D.

All three analyses showed two things. First, the benefit-cost ratio of R&D can be very high and thus very attractive: for agricultural R&D, for every dollar invested, a return of $34 was calculated; in the case of the HIV vaccine, the total benefit-cost ratio as a central estimate is likely to be $17 back on the dollar; and for green energy, it is likely the BCR of an ambitious green energy R&D policy is at least 11 and likely much higher. This is a clear indication that development R&D can be a very effective investment. Of course, it also means that if the best development R&D projects are *not* chosen, the potential loss can also be very great. This means that we need to choose carefully.

This work in estimating the benefit-cost ratio of an R&D project shows that it requires a very substantial amount of academic work, including many scenarios and large or even global models run across a variety of assumptions. So, for example, when assessing the impact and cost benefit of a vaccine on HIV/AIDS, three different scenarios were considered, which included one scenario where a cure was developed. The two other scenarios made differing assumptions on the political will and resource allocation to access treatment. The analysis then turned to what difference it would make within each scenario to bring forward the development of a vaccine by approximately 10 years. Experts identified that an additional investment of approximately $100 million annually on vaccine research, on top of existing investments which stood at around $900 million, as substantially accelerating progress. This figure was then used as the basis for further analysis. More assumptions were made on the elasticities of accelerated time-to-product with respect to R&D spending, using discount rates at 3% and 5%, to give an evaluation of the benefits of research into HIV vaccine.

All three of the analyses we conducted, into agricultural R&D and energy, as well as an HIV vaccine, show that they hinge on very specific assumptions on the effect of R&D. This is not surprising, since R&D is in essence about affecting *future* knowledge to increase productivity. It is thus intrinsically unknowable, because such information relies on knowledge that has not yet been created. Hence, all analyses use specific, expert-generated, literature-based estimates of crucial parameters. In R&D for agricultural yield increase, the fundamental assessment of the annual yield increase is based on a literature review but essentially an estimate. In the additional R&D for an AIDS vaccine, multiple assessments of future scenarios (Scenario I-III likelihoods) and of the elasticities of accelerated time-to-product are crucial for generating the results. In the green energy R&D

analysis, the choice of comparison along with estimates of early-vs-late R&D success generates a wide range of plausible BCRs.

This is why this current study will also have to liberally apply assumptions and expert assessment. Of course, it would be wonderful to *know* the real BCRs rather than these back-of-the-envelope estimates. But first, the limited time and resources sets a hard back-stop to what is possible. Secondly, even with much better and more sophisticated analyses we could peer further into the future, but still we would not know the unknowable. Thus, we can only ever know approximately what is a good and a less good R&D project.

Estimating BCRs for development R&D projects

Identifying R&D ideas and the size of the problem being addressed

In order to get a well-rounded sense of possible projects we took as our starting point the areas covered by the UN's Global Goals (the so-called Sustainable Development Goals for 2016-2030). Here, we reached out to all of our economists again. Of course, because of the tight time frame and the limited availability of researchers we have here been consulting with a subset of all researchers, outlined in Appendix A. Through telephone interviews we asked the researchers to identify what they would think the best and/or the most important development R&D opportunities in an African context within their area of expertise.

In some cases the ideas were clear and concrete, but in other cases, the ideas needed some additional work to clarify them. In all cases, the ideas are not presented as fully formed research proposals. Some areas of international aid have a stronger track record of applying cost benefit analysis to R&D, for example in health and agriculture, and overall this meant it was easier to make estimates than in a field such as education where R&D is not as well developed a concept.

Where the economists consulted were able and willing to provide us with figures, we used these, and in other cases we made estimates based on existing research and data, and confirmed these with the economists. There were five steps in our calculations, and these are set out for each of the R&D ideas listed in the main part of this report. First we estimated the cost of the R&D activities. The framework for doing this is outlined below, and depended on the nature of the problem and its heterogeneity. Second, we estimated the size of the problem being addressed by the particular R&D idea, whether that was in terms of number of people dying or disability adjusted life years (DALYs), which is so widely used in health research, or some other recognized measure. We made use of data from the Global Burden of Disease, from UN agencies, as well as from our own research and other peer reviewed research. This was then converted in the third step to an estimate of the cost, and therefore the potential benefit in coming up with a solution. For the purposes of this paper, we standardized the value of a global DALY which is estimated across all areas at $3,000. In addition, following Global Burden of Disease, all DALYs used in this report are not age weighted. For almost all the analyses in this report, we also standardized the costs and benefits calculated to a per year basis in order to simplify the calculations. Below we discuss how we set up the model so that a decision on discount rate becomes unnecessary.

The fourth step, which in this report is perhaps the most speculative and therefore dependent on expert judgment, was the potential impact of the R&D on the problem in question. This step depends on both the potential success of the research, and the potential impact of the research in practice. Because of the speculative nature of this step, we tended to be conservative in our assessment, and the potential impact of the research was framed in terms of a range of percentage. The fifth and final step was to take the first cost, the estimated R&D, and the final estimated benefit, to calculate a benefit cost ratio. This then gave a broad order of magnitude estimate for the BCR, and in almost all cases is presented as a range of possible values, and while these should not be considered definitive, they provide initial guidance on where R&D investments can do the most good.

A basic framework for assessing the R&D costs

Before we describe the research ideas, it is useful to outline the basic framework we have used for assessing the costs of each R&D effort. Experience shows that there can be large variance in how much money needs to be spent on R&D to yield results, and in this section we detail two key dimensions that influence this.

Two considerations were applied to each intervention and, although the approach is not wholly comprehensive, this was done to ensure some level of consistency between the analyses. The two dimensions are:

- Whether the intervention primarily addresses a **social problem**, or a **technology problem**
- Whether the intervention addresses a problem that has **low levels of heterogeneity** or **high levels of heterogeneity**

The first dimension is the extent to which the problem can be defined as ***a social or a technology problem***. Social problems are issues where the barrier to improved outcomes rests mainly in the human response to a particular situation. Why more households do not use clean cook stoves or why parents do not seek health treatment when their children have diarrhea are examples of social problems. The approach to solve these problems typically requires investigation of a social science nature, for example, randomized controlled trials exploring the cultural root causes of the issue and the efficacy of potential solutions.

Technology problems are issues where the barrier to improvement is that humanity currently does not have a robust, useable, scalable and / or affordable solution to the problem at hand. The approach required to solve these types of problems is what might be considered the 'traditional' method of R&D, mostly associated with hard science: design, proto-typing, piloting, trials of increasing size, iteration, refinement and rollout. Designing new medical drugs, new seed varieties or new diagnostic tools are examples of technology problems.

For a given level of problem heterogeneity, we assume that R&D addressing social problems has lower cost than R&D for technology problems. This is mainly because of the inherent nature of the two problems: problems of a social nature typically do not involve inventing new technologies[94]. Research can be as simple as measuring which of multiple approaches, *already used by individuals*, is more effective in addressing a certain problem in specific types of context. It can also involve understanding why certain cultures might not prefer to use or cannot readily adopt existing technology used elsewhere. It will also involve testing approaches that might improve the uptake of that technology. Assuming the research passes the necessary ethical clearances, there is a reasonable 'line of sight' between applying the research and finding a partial solution.

In contrast problems of technology, by definition, require innovation to solve. We assume this is more costly because the technology must be identified where it does not already exist, almost certainly at the technology frontier. Beyond that new technologies must undergo rigorous testing, especially where there are hazards to people and the corresponding ethical consideration, and this can be very costly.

This is not to say that social science research is 'easy'. Some social problems have been show to be just as intractable as technology problems, for example reducing corruption. We are merely noting that the expected costs of investigation for social problems tend to be lower than for technology problems. For example, a typical randomized control trial experiment (RCT) in economics might cost $1m-$3m. Additionally, many NGOs, government departments and multilateral actors at the forefront of development, alter their interventions in response to real-time

[94] In this case the word 'technology' is used quite liberally, and might represent for example different behaviors like better teaching practices or more vigilant attention to child health, not just physical goods like clean cook stoves.

feedback. In this way they engage in 'R&D' every day on much smaller budgets. In contrast, the full range of costs required to develop a new drug, engage in the required testing rounds, pass regulatory hurdles and bring it to market could foreseeably fall within the realm of $10m-$1bn.

The second dimension which we have applied is the level of ***problem heterogeneity***. In this category we are making an assessment of how individuals experience the problem in their day-to-day lives, and the extent to which it differs across contexts. We assume that more heterogeneous problems cost more to solve than less heterogeneous problems. For example, the reasons people use or do not use clean cook stoves appear to be culturally specific, and we can have little confidence a solution in one country will hold in another country. On the other hand, a disease such as malaria shows reasonable homogeneity across regions in terms of transmission, symptoms and response to treatment. To give one example, ninety-five percent of all malaria is transmitted by two parasites, P. falciparum and P. vivax. Therefore, we can have reasonably high confidence that a treatment regime for one person who has malaria will work in a similar fashion on a person in another part of the world with the same strain. Put differently, the same solution will be applicable to many people and in different contexts.

These two dimensions can be applied to form a two category options matrix – social/technology problem and low/high problem heterogeneity. We assign a cost range to each combination of type of problem and problem heterogeneity. Obviously in real life, problems fall on a spectrum and are not strictly dichotomous. Nevertheless for the purposes of estimating order of magnitude costs this framework is suitable for the task at hand. Figure 1 below outlines the costs for each and where each R&D suggestion falls within the framework.

FIGURE 1. R&D COST ESTIMATE MATRIX

R&D addresses	R&D addresses problem of **low heterogeneity**	R&D addresses problem of **high heterogeneity**
Social Problem	**COST = $1m-$10m p.a.** • Irrigation in sub-Saharan Africa • Better use of Insecticide impregnated bednets • Distribution of polypill for hypertension • Expanding early childhood stimulation programs • Opportunities for improved trade agreements between Asia and Africa	**COST = $10m-$100m p.a.** • Better promotion of clean cook stoves • Intimate partner violence • Identifying health gains from education • Early school drop out • Action research programs for governance • Public awareness campaign for HIV / AIDs • Treatment seeking behaviour for diarrhea • Public information campaign for pregnant women • Public information campaign on complementary feeding • Public awareness campaign to improve diet • Improving adherence to TB treatment • Mis-invoicing in trade transactions • Better implementation of nutrition interventions • Chronic disease in LMICs • Understanding needs and characteristics of the very poor • Urban infrastructure • Adolescent health and nutrition • Mental health and self-directed violence
Technology Problem	**COST = $10m-$100m p.a.** • Coastal protection and map digitization • Long lasting reversible contraceptive • Drug delivery for PrEp • Drug delivery for ARTs • Rapid diagnosis and treatment for HIV/AIDS • New drug development for artemisinin • Polypill for hypertension • Affordable home testing for diabetes • Improved diagnostics for TB	**COST = $100m-$250m p.a.** • Reducing premature adult mortality • Application of CRISPR technology to all 17 neglected tropical diseases

Estimating the effectiveness of the R&D proposal and its potential impact

As earlier exposition described, assessing the effectiveness of R&D in solving a given problem often requires sophisticated modelling and complex analysis. This was not possible in the time frame for this report. As such, the economists interviewed provided their order of magnitude estimate for how much each R&D might solve the problem at hand. This effectiveness estimate accounts for several factors:

- the likelihood of R&D being successful
- the tractability of the problem now and in the future
- how neglected the problem is, including the existence of competing solutions
- the likely efficacy of the intervention if R&D is successful
- the intensity of the R&D

A more detailed cost-benefit analysis of R&D in the future would make each of these components explicit.

The first concrete proposal

Our methodology is perhaps most easily described through an example.

Urbanization and infrastructure development was mentioned by several of the economists as one of the most pressing challenges facing the world, especially given the rapid rates of urbanization in many countries and particular developing countries. Research into city planning and infrastructure development associated with the rapid urbanization experienced in developing countries was identified as a critical issue. Current estimates are that 2.5bn more people than at present will live in urban environments. Cities in Africa and Asia in particular are growing faster than ever, and a lot of money is being spent on infrastructure and it is clear that even more is going to be spent in the future.

We worked to identify what would be the best way to have development R&D help urbanization and infrastructure. Currently, there are no relevant models of city development to inform current growth patterns. Research and development is needed to understand new forms of urban growth and to develop options for city planning and more specifically for effective infrastructure investment and maintenance. One specific issue is to research and assess ways to better manage and integrate private water and energy supplies implemented privately with improving public supply and ensuring reliable service. Many of the benefits will relate to the efficiency gains made on existing public investment into urbanization and urban infrastructure.

We then tried to find the best estimates of the size of the problem, which conversely would also be the maximal size of the benefit of the project (if it was possible to implement a project that made the costs entirely disappear).

What is the cost of lack of well-coordinated infrastructure with regards to urbanization and infrastructure? Well, the McKinsey Global Institute (2013)[95] has estimated that the total cost globally of badly needed major infrastructure investment for 15 years up to 2030 is $57 trillion, with two-thirds in developing countries. We assume that half of this goes to urban infrastructure. Thus, the total cost for developing countries is therefore about $19 trillion, or on a per-year basis about $1.27 trillion.

The cost of a development R&D project to help find better solutions to these infrastructure problems is in the order of $100 million per year.

The central question then becomes what does these $100 million per year produce in terms of benefit. With an in-depth literature review of

[95] Dobbs, R., Pohl, H., Lin, D.Y., Mischke, J., Garemo, N., Hexter, J., Matzinger, S., Palter, R., and Nanavatty, R. (2013). "Infrastructure productivity: How to save $1 trillion a year." *McKinsey Global Institute*. Available online: http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/infrastructure-productivity (Accessed on 07 April 2017).

urbanization and infrastructure development and a meta-study of the relevant R&D projects and their effectiveness, it could potentially be possible to estimate an interval for the R&D spending's likely annual benefit. However, this approach would for resource constraints alone fall outside the current project, and moreover it would have to be repeated across all 40 proposals to make possible a comparison. Even then, it is likely that many of the proposals would find few (or no) studies that could help link future R&D spending to very specific benefit outcomes.

Therefore, we have in the current study chosen to base our estimates on expert elicitation – essentially asking the relevant economic experts what are not-unreasonable estimates for the annual benefits. Here, our expert has accepted that a not-unreasonable estimate of the $100 million per year R&D project for urbanization and infrastructure development would tackle somewhere in the range of 0.1-1% of the full problem. This would both cover that the R&D project could reduce the cost of the problem, and that it could do so with a certain probability. For instance, both an assumption that developmental infrastructure R&D could reduce costs by 1% for certain (100%), and could reduce cost by 10% with a likelihood of 10% would result in the overall estimate of 1% reduction. It bears repeating that this range is obviously a very rough estimate, based on broad but not specific understandings of the challenge area.

The methodology uses estimates for both costs and benefits measured per year in perpetuity. This idealized model is chosen for several, and overlapping reasons. First, it is unlikely that a much more detailed specification would dramatically change the outcomes: in the real world it is likely that a specific R&D project would be run over a time period of, say, 10 years, with the likelihood of a break-through increasing throughout the period, and declining after the end of the project. However, we try to model the impact of a large number of R&D projects running in partially overlapping periods across the whole area of urbanization and infrastructure development. It is not unrealistic to expect the total cost runs to a near-permanent $100 million and the near-permanent effect is a constant probability of reducing the problem by 0.1-1%. Second, the annual costs and benefits approach is also the one on which the probabilistic estimates are based on, so in that sense, the estimates have the methodology baked-in. Third, all of the estimates below have been elicited on a similar methodology meaning all are comparable.

This methodological setup of estimating annual costs and benefits also means we can avoid the complications of setting a discount rate, since the time profile of the costs and expected benefits are entirely symmetric.

With these considerations we can finally estimate that a $100 million annual investment will be able to provide annual benefits of 0.1-1% of $1.27 trillion or about $1-10 billion per year. Each dollar spent will provide benefits that are about 10 to 100 times higher, as an order of magnitude. Iis important to emphasize that the total benefits for this effort are likely to be significantly higher, in particular to include improved quality of life (including health) and increased economic opportunities for the populations.

This proposal will be presented in the following way:

Urbanization and infrastructure

Research into city planning and infrastructure development associated with rapid urbanization experienced in developing countries. Current estimates are that 2.5bn more people than at present will live in urban environments. Cities in Africa and Asia in particular are growing faster than ever, and a lot of money is being spent on infrastructure and it is clear that even more is going to be spent in the future. There are no existing relevant models of city development to inform current growth patterns. Research and development is needed to understand new forms of urban growth and to develop options for city planning and more specifically for effective infrastructure investment and maintenance. One specific issue is to research and assess ways to better manage and integrate private water and energy supplies implemented privately with improving public supply and ensuring reliable service. Many of

the benefits will relate to the efficiency gains made on existing investments into urbanization.

Costs of R&D: US$100m per year

Cost of problem(i): US$57 trillion for 15 years up to 2030, two thirds of which is in developing countries. Assume that roughly half of that is for urban infrastructure, meaning approximately $1.27 trillion annually.

Estimated potential benefit of R&D: The benefit would be in reducing the costs of attaining a given set of services in the future. For the purposes of this calculation, we assume that there could be a savings of between 0.1% (US$1.3bn) to reducing 1% of the problem ($12.6bn) per year

Estimated BCR: order of magnitude, approximately 10 to 100

Additional benefits: While the benefits would occur in future years, they are likely to be significantly higher and in particular to include improved quality of life (including health) and increased economic opportunities for the populations as well as on-going accumulated benefits.

(i) *http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/infrastructure-productivity*

Agricultural R&D

Expanding the potential for irrigation in Sub-Saharan Africa

Sub-Saharan Africa currently lags behind in irrigation development. Currently 93% of SSA agriculture is rain-fed. The IFPRI team assessed the potential of several smallholder irrigation technologies:

Motor pumps	can profitably irrigate 30 million ha and full adoption of the technology can generate annual net revenues of $22 billion/yr for irrigated farmers. Potentially 185 million people could benefit.
Treadle pumps	24 million ha for treadle pumps, with annual net revenues of $19 billion/yr Potentially 243 million people could benefit.
Communal river diversions	20 million ha for communal river diversions, with net revenues of $14 billion/yr. Potentially 113 million people could benefit.
Small reservoirs	22 million ha for small reservoirs, with net revenues of $20 billion/yr. Potentially 369 million people could benefit.
Total potential benefits	***$75 billion/yr***

Additional investments in Irrigation and water use efficiency would increase crop yields, reduce prices, and thereby generate higher incomes. Enhanced rural infrastructure also reduces post-harvest losses and marketing margins, improving the profitability of farm production, and boosting supply to consumers for any given level of production.

Costs of R&D: The research costs are estimated at approximately US$10m per year

Potential benefits: US$75bn in increased farm revenues per year.

Estimated potential benefit of R&D: We assume that R&D of $10m per year could capture 1% of the potential benefit or US$750m per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 100

Air Pollution R&D

Promote behaviour modification for cleaner cooking technologies

The challenge is the limited adoption of existing cook stove solutions to tackling household air pollution. R&D is needed to identify how to best promote cleaner cooking solutions, adapt stoves to meet demand concerns and ensure that they are appealing, affordable and suited to people's needs and habits. Research should focus on factors such as: household cooking habits, use of single or multiple burners, awareness and understanding of health effects, time spent cooking, how time is valued in the household, household decision-making and power structures, peer and community perceptions, financial constraints and barriers, and marketing of cleaner cooking solutions in order to improve both the products and their promotion and adoption. Research should also address how to maximize community-wide adoption of cleaner cooking solutions, as this is the most effective way to reduce the effects on communities of individual households cooking with dirty fuels/stoves.

Costs of R&D: The research costs are estimated at approximately US$25m per year. The challenge of effective promotion / adoption is linked to each culture's unique cooking and diet preferences. Cook-stoves need to be promoted and modified in ways that will ensure greater uptake and acceptance, and each new approach is likely to be culturally specific. Research for every major country or region that uses solid fuels would be required to identify these parameters. Assuming $2m per country and 125 unique countries or regions, this is $250m in total or $25m per year, assuming the research is relevant for 10 years.

Size of problem: The Global Burden of Disease Project estimates that 2.9m people died prematurely from illnesses resulting from household air pollution from solid fuels in 2015 (Global Burden of Disease 2015). With respect to the Africa Region, the Global Health Estimates (2016) calculate that lower respiratory infections account for 9.8% of total DALYs.

Cost of problem: The costs of are estimated at approximately US$333bn per year[96].

Estimated potential benefit of R&D: It is possible that improved promotion would improve uptake of cook stoves by 10-20%. While research has noted resistance to cook stoves in India and Bangladesh[97] [98], promotion has been much more successful in China[99], suggesting that there is potential for enhanced adoption if the right conditions are implemented.

The effectiveness of improved cook stoves in reducing the health burden are typically around 20%, depending on the type of cook stove used, the surrounding environmental conditions and whether cooking occurs inside or outside the main living areas.[100] This implies a potential benefit of 2% to 4% of the problem or

[96] Larsen, B. (2014). "Benefits and Costs of the Air Pollution Targets for the Post 2015 Development Agenda." *Working Paper, Post-2015 Consensus*. Copenhagen Consensus Center. Available online: http://www.copenhagenconsensus.com/sites/default/files/air_pollution_assessment_-_larsen.pdf (Accessed on 07 April 2017).

[97] Rema Hanna, Esther Duflo and Michael Greenstone. "Up in Smoke: The Influence of Household Behavior on the Long-Run Impact of Improved Cooking Stoves," American Economic Journal: Economic Policy.
A. M. Mobarak, P. Dwivedi, R. Bailis, L. Hildemann and G. Miller. "The Low Demand for New Cookstove Technologies," Proceedings of the National Academy of Sciences, 109(27): 10815-20, July 2012

[98] G. Miller and A. M. Mobarak, "Learning about New Technologies through Social Networks: Experimental Evidence on Non-Traditional Stoves in Rural Bangladesh," Marketing Science, 34 (4): 480-499, July-August 2015

[99] Smith. K., Shuhua G., Kun H. and Daxiong Q., 1993, 100 million cookstoves in China: How was it done?, World Development, vol 21, p941-961

[100] Larsen, B. (2014). "Benefits and Costs of the Air Pollution Targets for the Post 2015 Development Agenda." *Working Paper, Post-2015 Consensus*. Copenhagen Consensus Center. Available online: http://www.copenhagenconsensus.com/sites/default/files/air_pollution_assessment_-_larsen.pdf (Accessed on 07 April 2017).

approximately 60,000 to 120,000 lives saved per year.

However, in order to achieve this health benefit, there would need to be additional expenditure on top of the proposed R&D investment. The households which adopt and use the new cook stoves would also need to spend on their maintenance and, for LPG based stoves, the would need to spend significant sums on the fuel. This could be partially offset by the time saved for cooking and fuel collection. These additional costs and benefits are not factored into the BCR reported below.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 250 to 500.

Biodiversity R&D

Coastal protection

Research is needed on several fronts: Research into the extent to which ecosystem adaptations such as mangroves provide enhanced coastal protection, and what if any additional protection is needed. This would be especially relevant in areas of large coastal populations where there are increasing risks of climate change and where there is not a full evaluation of what combinations of protective interventions offer worthwhile investment. Most notably, the crucial role of mangroves is well recognised as an important protection, but the need for additional protective measures is not so well acknowledged. This is especially the case in South Asia and South East Asia. The research would involve computer modelling which is most likely to be carried out by national governments (UN and NGOs do not have the funding structures to invest in this kind of research). This is an issue which is not adequately addressed or funded at either the international or national level at present. In order to reduce monitoring costs of protected areas, there is also need research into advanced technological approaches for tracking activities. Finally, coastal protection has a high opportunity cost, as fisheries are important to local African economies and a vital component to diets as a source of protein. Research is need to discover alternative livelihoods and sustainable sources of protein.

Costs of R&D: The research costs are estimated at approximately $10m per year.

Cost of problem: The projections[101] for present and future flood losses for major cities around the world are US$6bn in 2005, reaching an estimated US$61.5bn in 2050 (a conservative estimate, given that projections for losses could be $1 trillion per year in 2050).

Assuming that the increase between 2005 and 2050 is linear this adds approximately US$1.24bn per year, meaning that estimated losses in 2018 are US$22.1bn. The assumption

[101] Hallegatte, S. et al.(2013). "Future Flood losses in major coastal cities." *Nature Climate Change 3, 802-806*. 18 August. Available online: http://www.nature.com/nclimate/journal/v3/n9/full/nclimate1979.html (Accessed on 07 April 2017).

is that half of these losses take place in developing countries, which have the resources and protection in place to manage this. Furthermore, this R&D proposal is less likely to directly benefit richer countries, where coastal protection systems would likely take a different form. As a rough order of magnitude approximation, the value of losses for coastal cities in 2018 in developing countries is estimated at US$10bn.

Estimated potential benefit of R&D: The R&D could contribute approximately an additional 1% to 10% to coastal protection, averting US$100m to US$1bn in flood related losses per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 10 to 100.

Map Digitization

One of the biggest hurdles in designing better conservation interventions is the limited availability of good maps of current land use. Current maps used lack fine resolution. R&D is required to update high resolution maps for SSA: to help improve systems for collecting, collating, on-the-ground-checking, and digitizing land use and making it available to the right people in the right formats with a view to setting international standards to enable easy access and comparison. It would contribute to more accurate needs assessment and better targeting of resources currently spent on conservation interventions.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Cost of problem: A 2012 Nature study estimates the amount of money required to preserve global biodiversity is UD$76bn[102]. However, in reality much less is actually spent on biodiversity conservation. Waldron et al (2012)[103], drawing on multiple sources, create the largest database on global conservation expenditure. They estimate spending in 2001-2008 at $21.5bn p.a. in 2005 dollars, or roughly $27bn in 2017 dollars.

Estimated potential benefit of R&D: Better land use data could improve the effectiveness of existing spending on biodiversity by 0.1% to 1%, providing estimated efficiency benefits of $27m to $270m.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 3 to 30.

[102] Cressey, D. (2012). "Cost of Conserving Global Biodiversity Set at $76 Billion." *Scientific American*, *Nature*. Available online: https://www.scientificamerican.com/article/cost-conserving-global-biodiversity-set-76-billion/ (Accessed on 07 April 2017).

[103] Waldron, A. et al., 2012, Targeting global conservation funding to limit immediate biodiversity declines, Proceedings of the National Academy of Sciences , vol.110, no 29. http://www.pnas.org/content/110/29/12144.full

Conflict & Violence R&D

Intimate partner violence

There is growing recognition, as well as data, into the extent of interpersonal violence directed against women and children and which generally takes place within the household. Improving understanding of the nature of such violence and the possible interventions which would tackle it requires research into the relationship between social norms and cultural practices at the level of the household, and evaluation of specific programs in different cultural settings. In particular there is a need for a focus on African countries, where governments have the fewest resources or capacities to address this. **Additional research is also needed into the correlation between IPV and mental health.** It would also be productive to find meaningful ways of grouping countries which are dealing with similar issues or which have similar characteristics in order to identify scalable solutions.

Costs of R&D: The research costs are estimated at approximately $100m per year[104] given the complex and the country specific nature of the problem.

Cost of problem: The estimated global cost is US$4.4 trillion per year.

Estimated potential benefit of R&D: While the problem of domestic violence is significant and neglected, there is emerging evidence that some programs could be effective in reducing the burden. For example, education programs directed at teenagers could reduce violence in adulthood, for example the SAFE DATEs program has been shown to reduce incidence of domestic violence among teenagers in the United States by more than 56%[105]. Encouragingly there appears to be evidence that the program can be translated to a developing country setting. Another study piloted the same program in Haiti and found that it has had some success in increasing knowledge of dating violence[106]. More programs of this nature would need to be tested in countries around the world, particularly in sub-Saharan Africa, where the prevalence of domestic violence is the highest globally at 28%. It is reasonable to assume that the benefit could be somewhere between 0.1% of the problem (US$4.4bn) to 1% of the problem ($44bn) per year. This equates to a reduction in prevalence of domestic violence in sub-Saharan Africa alone of around 0.3 to 3.6 percentage points. Any benefits which were then experienced in the rest of the world would further increase the BCR, adding value to the proposed R&D.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 45 to 450

Mental health and self directed violence

Self directed violence kills more people than all other forms of violence put together, yet little is understood about the relationship between mental health and self directed violence. This is an area of growing concern both in developed as well as developing country contexts. The main challenges are to make progress on identifying the nature of the problem in different contexts and what interventions work in which contexts. Research should focus on both identifying a range of interventions and how these might vary depending on the particular setting, as well as developing their potential to scale-up.

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[104] Fearon, J. and Hoeffler, A. (2014). "Benefits and Costs of the Conflict and Violence Targets for the Post-2015 Development Agenda." *Working Paper, Post-2015 Consensus*. Copenhagen Consensus Center. Available online: http://www.copenhagenconsensus.com/publication/post-2015-consensus-conflict-and-violence-assessment-hoeffler-fearon (Accessed on 07 April 2017).

[105] Foshee, V. A., Reyes, H. L., Gottfredson, N. C., Chang, L. Y., & Ennett, S. T. (2013). A longitudinal examination of psychological, behavioral, academic, and relationship consequences of dating abuse victimization among a primarily rural sample of adolescents. Journal of Adolescent Health, 53(6), pp. 723-729.

[106] Gage, A.J., Honoré, J. G., and Deleon, J. 2016. Short-term effects of a violence prevention curriculum on knowledge of dating violence among high school students in Port-au-Prince, Haiti. Journal of Communication in Healthcare, 9(3): 178-189.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Size of problem: The number of people dying from self-harm is 830,000, or 34 million DALYs (Global Burden of Disease, 2015). According to the Global Health Estimates (2016), mental and substance abuse disorders account for 3.3% of total DALYs in the Africa Region.

Cost of problem: approximately US$102bn (34 million x $3,000).

Estimated potential benefit of R&D: The benefits are estimated at between 0.01% (US$10m) and 0.1% (US$102m), which equates to 83 to 830 fewer self-harm deaths per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1 to 10.

Education R&D

Identifying health gains from education (going beyond the economics)

Considerable progress has been made understanding the relationship between education and economic benefits, and there is growing evidence on a range of other externalities including significant health gains (such as improved life expectancy and reduced infant mortality) and higher levels of democratic engagement, especially in developed countries. Research into the relationship between education and health in developing countries, and the potential for increased investment in education as contributing to improved health outcomes. By taking account of a fuller range of benefits for each education intervention – health as well as productivity benefits – resources in education could be allocated more efficiently to produce more social good.

Costs of R&D: The research costs are estimated at approximately US$10m per year, most likely in a series of longitudinal studies to assess short and long term health impacts of education.

Cost of problem: UNESCO estimates that developing countries spend about 5% of GDP on education[107]. The World Bank estimates developing world GDP at 27 trillion USD, which suggests 1.3 trillion USD is spent on education every year.

Estimated potential benefit of R&D: While benefits could be very large from better resource allocation, public education investments tend to be 'sticky', changing only marginally from year to year. Health benefits would accrue mostly in the long term via intergenerational effects, which would also reduce discounted benefits. Benefits are therefore estimated at a modest 0.01% (US$130m) to 0.1% (US$1.3bn) per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 13 to 130

[107] UNESCO, 2012, Chapter 2 Financing Education for all, *Global Monitoring Report*, available online: http://www.unesco.org/fileadmin/MULTIMEDIA/HQ/ED/pdf/gmr2012-report-ch2.pdf accessed: 24 April 2017

Early school drop out

Research is needed into the causes of children dropping out of school early, in particular what is the relationship between poverty, cultural practices like child marriage, sexual and reproductive health, and child labor practices in the home, and what incentives or combination of incentives support children remaining in school in different settings. Completing schooling has a significant impact on potential labour market participation and earnings. While not attending school at all is clearly significant, it is considered that it may be easier to implement interventions which reach out to children who have attended school in the past and have subsequently dropped out, rather than children who have never attended, for example through incentive schemes aimed at parents as well as directly at children.

Costs of R&D: The research costs are estimated at approximately US$10m per year. The conditions that drive dropouts and the interventions to reduce them are likely to be context specific, though we already have robust evidence on incentives to improve school attendance such as conditional cash transfers and subsidies.

Size of problem: UNICEF (2015)[108] report 58 million primary age children are not in school, of which 23% had attended in the past, meaning approximately 13 million children have dropped out.

Cost of problem: Unesco (2014)[109] reports that the cost of 250 million children not learning the basics is equivalent to $129 billion. Therefore, the potential benefit of 13 million children not dropping out and 'learning the basics' is approximately US$7bn per year.

Estimated potential benefit of R&D: The benefits of research could mean 13,000 to 130,000 children stay in school. This equates to 0.1% (approximately $10m) and 1% (approximately $70m) in benefits. CHECK WITH BRAD

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1 to 10. THE FIGURES WE USE GIVES BCRS OF 10 TO 100

Expanding early childhood stimulation programmes

Studies in Jamaica have shown very high returns for early stimulation of young children who have experienced deprivation and poor nutrition, and there is growing evidence that interventions can be effective in a variety of settings[110]. More investigation is needed on how to structure and deliver quality programmes in different contexts and how to scale them up resource-constricted settings.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Size of problem: Unicef[111] estimate that globally 23% children under-5 are stunted, which is 156 million children. A single cohort is therefore 31 million children.

Estimated cost of problem: As mentioned previously (in the analysis on complementary feeding), the global cost of stunting is around $1 trillion per year in lower future productivity.

Estimated potential benefit of R&D: This intervention has shown to be as effective as averting stunting in the Jamaican context. However the absolute value of improvement in wages (35%) is lower than the improvement in avoiding stunting altogether (66%). We therefore estimate the benefits as between 0.01% (US$100m) and 0.1% (US$1bn) per year

[108] UNESCO Institute for Statistics (UIS) and UNICEF (2015). Fixing the Broken Promise of Education for All: Findings from the Global Initiative on Out-of-School Children. Montreal: UIS. http://dx.doi.org/10.15220/978-92-9189-161-0-en. Available online: https://www.unicef.org/publications/index_78718.html# (Accessed on 07 April 2017).

[109] UNESCO. (2014). Education for All Global Monitoring Report. Teaching and Learning: Achieving quality for all 2013/4. UNESCO.

[110] Gertler, Paul, et al. "Labor market returns to an early childhood stimulation intervention in Jamaica." *Science* 344, no. 6187 (2014): 998-1001.

[111] UNICEF Data: Monitoring the Situation of Children and Women. Available online: https://data.unicef.org/topic/nutrition/malnutrition/ (Accessed on 07 April 2017).

or mitigating the effects of stunting for 3,100 to 31,000 children per year.

BCR: An order of magnitude estimate gives a BCR of approximately 10 and 100.

Gender R&D

Long acting reversible contraceptive

Research into an affordable, reversible, easy to administer and long acting contraception for women. The direct impact is on enhanced control over child bearing, but additional benefits women's empowerment and all the benefits of potential labour market participation and improved health outcomes, as well as beneficial impacts on mitigating climate change. R&D would focus on improving existing technologies and providing options for the development world markets.

Costs of R&D: The research costs are estimated at approximately $10m per year

Size of problem: Potential DALYs saved by expanding family planning programs is[112]:

Women – 12,430,000/year

Newborns – 23,710,000/year

Total is approximately 36 million DALYs/year

Cost of problem: The estimated costs based on the size of the problem identified above: US$3,000 x 36 million DALYs = approximately US$110bn per year.

However, the Koehler and Berman analysis finds that DALYs constitute only one-third of the total potential benefit of contraception, with the other two-thirds coming from increased economic growth due to the demographic dividend. Thus, the total cost of the problem is likely about three times as big at $330bn per year.

Estimated potential benefit of R&D: increasing access and effectiveness of contraceptive could give a benefit of approximately 1% (US$3bn)

Estimated BCR: As an order of magnitude estimate, the BCR is approximately 320

[112] From Singh et al (2010), quoted in Koehler and Behrman (2014), table 4, p38. Copenhagen Consensus Center. Kohler, HP and Behrman, JR (2014). Benefits and Costs of the Population and Demography Targets for Post-2015 Development Agenda. *Working Paper, Post-2015 Consensus*. Copenhagen Consensus Center. Available online at: http://www.copenhagenconsensus.com/sites/default/files/population_assessment_-_kohler_behrman_0.pdf

Governance R&D

Action research programs

Action research is a particular approach and type of research, which, when carried out in cooperation or in partnership with receptive government departments, can support program implementation. Action research involves a high level of engagement between researchers and practitioners. Such an approach can help to compress 100s of years of learning which has taken place in rich countries, into 10 years in developing countries. Action research provides on-going iterative support to improve the implementation of projects across a wide range of issues (education, nutrition, health care, etc). Over 6 months, a dedicated research team works with government officials on the implementation of approximately 5 projects within a field, focusing research on how to improve performance and overcome specific problems. The process helps to institutionalize learning in the implementing teams, providing insight, increasing problem-solving capacities, as well as directly improving individual project efficiency and quality. The benefits of learning and improved performance are therefore likely to be sustained and to have a broader impact beyond the particular focus projects.

Costs of R&D: The research costs are estimated at approximately $500k over 6 months across 5 projects in one country. For 150 developing countries this would be approximately $75m, and would need to be updated every 4-5 years.

Possible example. This is a methodology which can be applied across a range of different issues, including education, social care, and health. The key factor is that there is government engagement. For the purposes of this report, health care India has been chosen as an example for which a quick estimate can be calculated.

Size of problem: All health problems across India result in an estimated loss of 500 million DALYs. Average per state (29 states) is approximately 17m DALYs.

Estimated cost of problem per state: US$3,000 x 17 million DALYs = approximately US$51bn.

Estimated potential benefit of R&D: Improving implementation could foreseeably result in a reduction in the health burden by 1,700 DALYs (0.01% or $5m) to 170,000 DALYs (1% of the problem or $0.5bn). To put this in perspective this is approximately 60 to 6000 additional lives saved per year in an 'average' Indian state of 35m people.

BCR: As an order of magnitude estimate, the BCR is approximately 10 to 1,000. This is a particularly wide range as the effectiveness of the research will depend very much on the exact context and the issue and programs being researched.

Health Systems R&D

Reducing premature adult mortality

Low to middle income countries have limited tools to reduce adult mortality at low cost. Furthermore they are not using the tools which are readily available, in particular in preventing and treating vascular, neoplastic and respiratory diseases, and controlling tobacco use and the consequences of obesity, including diabetes. Given the progress in recent years on child mortality and infectious disease, there is potential to successfully tackle premature adult mortality in a systematic way. In addition there are successful treatments available in developed countries which are therefore good bets for quick and cost effective results in terms of R&D investments, in particular for coronary illness, stroke, diabetes, and many common forms of cancer. The idea proposed here is to conduct a 5-year, three phase, multi-disciplinary research program, drawing on big data and focusing on both global trends and national contexts to address premature adult mortality in low and middle income countries.

Costs of R&D: The research costs are estimated at approximately US$250m per year for 5 years.

Size of problem: The number of adults dying prematurely, between the ages of 20 and 59, is approximately 14 million a year, equivalent to 1bn DALYs. (Global Burden of Disease 2015)

Estimated cost of problem: US$3,000 x 1bn = approximately US$3 trillion

Estimated potential benefit of R&D: 0.01% (US$300m) to 0.1% (US$3bn)

BCR: An order of magnitude estimate gives a BCR of approximately 1 to 12

Tobacco control: Triple the excise tax and adopt other effective tobacco control interventions

On current smoking patterns, with about 50% of young men and 10% of young women becoming smokers in early adult life and relatively few stopping, annual tobacco deaths will rise from about 5 million in 2010 to more than 10 million a few decades hence, as the young smokers of today reach middle and old age. This is due partly to population growth and partly to generations where few smoked substantial numbers of cigarettes throughout adult life being succeeded by generations where many did so. There were about 100 million deaths from tobacco in the 20th century, most in developed countries. If current smoking patterns persist, tobacco will kill about 1 billion people this century, most in low or middle income countries (LMICs). About half of these deaths will be before age 70 years.

Worldwide, a reduction of about a third could be achieved by doubling the real price of cigarettes, which in many low and middle-income countries could be achieved by tripling the real excise tax on tobacco. Smart taxation involves large increases (above the rate of inflation), plus focus on narrowing the gap between cheap and more expensive cigarettes (which leads to downward substitution). Other interventions recommended by the Framework Convention on Tobacco Control could also help reduce consumption and could help make substantial increases in real excise tax politically acceptable. Without large price increases, a one-third reduction in smoking would be difficult to achieve.

Costs of R&D: The research costs are estimated at approximately US$25m per year. The main area of research involves substantial efforts on taxation (local estimates of price elasticity, impact on poor/non poor smokers), industry tracking research and research on newer interventions, such as plain packaging (adopted successfully in Australia). Such R&D would need to be paired with active dissemination to Ministries of Finance and to global agencies to spur uptake of tax increases. (WHO reports that 106 countries have raised taxes from 2012 to 2014, but only a handful of countries have used big, smart taxes). A global R&D effort would substantially increase local and global evidence to enable action.

Size of problem: The WHO and the Global Burden of Disease Project estimates that about 6 million people died prematurely from tobacco use in 2015 (Global Burden of Disease, 2015).

Cost of problem: The costs of smoking-attributable disease (ignoring smaller effects of passive smoking) are estimated at

approximately US$13 trillion from 2010-2020 (David Bloom, CC 12) or US$650bn per year.

Estimated potential benefit of R&D: Tripling real excise taxes would, in many LMICs, approximately double the average price of cigarettes (and more than double prices of cheaper brands), decrease consumption by about a third and increase tobacco revenues by about a third. Where government owns most of the industry, as in China, distinction between taxes and profit is fairly arbitrary, but still doubling the average prices would substantially reduce consumption and increase revenue. Worldwide, raising excise taxes to double prices would raise about another US $100 billion a year in tobacco revenues, in addition to the approximately US $300 billion that governments already collect on tobacco.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately between 450 and 650.

Health R&D: HIV/AIDS

Drug delivery for PrEP

Drug treatments known as PrEP can be effective at protecting vulnerable groups from HIV/AIDS but adherence is a big issue when lifestyles are erratic, regular medical access is unpredictable, and there is limited motivation for taking drugs when people are not actually ill. This proposal is focused on research and development into drug treatments which are longer lasting, for example for 3 months or more, and can be used by people during periods of particular vulnerability.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Size of problem: approximately 67 million DALYs per year (Global Burden of Disease 2015).

Cost of problem: US$3,000 x 67 million DALYs = approximately US$200bn

Estimated potential benefit of R&D: Estimated benefits are between 6,700 DALYs (0.01% of problem, US$20m) to 67,000 DALYs (0.1% of problem, US$200m). This is equivalent to roughly 150 to 1,500 lives saved per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 2 to 20.

Drug delivery for Antiretroviral Therapy (ART)

The effectiveness of current combination drug treatments mean that people living with HIV/AIDS can have a relatively normal life expectancy. However adherence can be limited, especially in developing countries where it is difficult to make regular medical visits and getting prescriptions can be challenging. Research and development is needed into improved drug delivery for ART, for example by using existing technologies such as patches, chips or injections to deliver the drug treatments. This would reduce the need for regular medical visits and for repeat prescriptions, making access to ART much easier and cheaper, potentially improving adherence rates.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Size of problem: Globally, approximately 1.2 million deaths per year are attributed to HIV/AIDS, and the number of DALYs is 67 million per year (Global Burden of Disease 2015).

Cost of problem: US$3,000 x 67m DALYs = approximately US$200bn

Estimated potential benefit of R&D: Estimated benefits are between 67,000 DALYs (0.1% of problem, US$200m) to 670,000 DALYs (1% of problem, US$2bn). This is equivalent to roughly 1,500 to 15,000 lives saved per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 20 to 200.

Public awareness campaigns

Public awareness campaigns are commonly used to influence behaviour change but little is known about their impact or effectiveness in tackling HIV/AIDS. For example, on-going and detailed evaluations of the impact and effectiveness of circumcision campaigns could add considerable value to improving future campaigns and therefore rates of circumcision, which in turn helps reduce the spread of HIV/AIDS.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Size of problem: The estimated size of the problem is approximately 67m DALYs per year (Global Burden of Disease 2015).

Cost of problem: US$3,000 x 67m DALYs = approximately US$200bn

Estimated potential benefit of R&D: Public awareness campaigns tend to have a relatively low impact, and are important alongside focused interventions. As such benefits are estimated at between 6,700 DALYs (0.01% of problem, US$20m) and 67,000 DALYs (0.1% of problem, US$200m). This is equivalent to roughly 150 to 1,500 lives saved per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 2 to 20.

Health R&D: Infant Mortality

Treatment seeking behaviour for diarrhea

Effective and low cost treatment for diarrhea is readily available, but is not used consistently, and diarrhea remains a common but preventable cause of death among small children and infants. Early treatment is critical in reducing mortality rates, however currently the potential seriousness of diarrhea is under-appreciated until the condition is very serious and treatment is much less effective. Research should focus on how to encourage early treatment seeking behaviour, especially by parents and carers of under-5s.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Size of problem: The estimated size of the problem of diarrhea among the under 5 year olds is approximately 45m DALYs per year (Global Burden of Disease 2015).

Cost of problem: US$3,000 x 45 million DALYs = approximately US$135bn

Estimated potential benefit of R&D: The expected benefit of this intervention is estimated to help avoid between 4,500 DALYs (0.01% of problem, US$14m) and 450,000 DALYs (1% of problem, US$1.4bn).

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1.4 to 140.

Health R&D: Malaria and other tropical diseases

New drug development to replace artemisinin

Research and development is required into new drug development for treating malaria, to anticipate emerging drug resistance, in particular to artemisinin, which has been critical to the successful treatment of P. falciparum malaria over the past several decades. Drugs need to be approved and ready for use as drug resistance spreads, or there is a risk that recent progress in tackling malaria will be significantly set back.

Costs of R&D: The cost of bringing a new drug to market to tackle 'diseases of the poor', taking account of failures, has been estimated at approximately US$100 to US$150 million in total[113].

Size of problem: An estimated 730,000 die from malaria each year, which is approximately 56m DALYs per year (Global Burden of Disease 2015).

Cost of problem: Artemisinin resistance is increasing in South East Asia. As of October 2016, WHO reports more than 10% failure (the threshold for changing first line treatment) of at least one of the five artemisinin combination therapies in all countries in the Greater Mekong Subregion.

Despite these failures, the World Health Organisation notes that: *"… ACTs remain the most effective treatment for uncomplicated falciparum malaria. Most patients with delayed parasite clearance are cured, as long as the partner drug remains effective."*

Additionally, artemisinin resistance appears not to have developed in Africa, where the greatest burden of malaria lies. The rationale for increased R&D for a replacement to artemisinin is therefore not primarily based on addressing a pressing existing problem of great magnitude, rather as insurance against increased drug resistance in the future.

We assume the current and expected future costs of artemisinin resistance are about 25% of the global burden of malaria. This includes the potential for ACT resistance in sub-Saharan Africa. Within one year, an estimated US$3,000 x 56m * 25% = approximately US$840m. Assuming a new drug could act as a replacement for artemisinin and would be effective for approximately 20 years, the potential cost of malaria over that period totals 20x$840m = US$17bn.

Estimated potential benefit of R&D: Assuming that the effectiveness of the new drug within developing countries is 10% and the chance of delivering it is between 1% and 10%, and given the cost of the problem is approximately US$17bn, the estimated potential benefit is between 0.1% (US$17m) and 1% (US$170m)

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1. However, if artemisinin resistance increases in the GMS or exhibits in sub-Saharan Africa, the BCR will increase substantially

Insecticide impregnated bed net replacement

Impregnated bed nets have been at the forefront of successfully tackling malaria over recent years, especially across Sub-Saharan Africa, where malaria is a major cause of death especially among infants. Following significant progress, however, the continued effectiveness of bed nets is dependent on not only their proper use, but also on timely repair and replacement given that their normal lifespan is between 2 and 5 years. Research is needed into distribution systems and incentive schemes to ensure that nets are maintained and replaced in timely manner so that they continue to be effective.

Costs of R&D: The research costs are estimated at approximately US$10m per year

[113] DND*i* (2014). An innovative approach to R&D for neglected patients. Ten years of experience & lessons learned by DND*i*. Available online: https://www.dndi.org/wp-content/uploads/2009/03/DNDi_Modelpaper_2013.pdf

Size of problem: The World Health Organization (WHO) estimates that approximately 35m cases of malaria per year since 2001 have been avoided in sub-Saharan Africa due to the widespread use of insecticide treated bed nets. Assuming that the case fatality rate from malaria is 0.3%, this implies that: 35m x 0.3% = 105,000 deaths have been avoided each year because of the use of bed nets. This is equivalent to 8m DALYs.

Cost of problem: US$3,000 x 8 million DALYs = US$24bn

Estimated potential benefit of R&D: Improving distribution and introducing incentive schemes for bed net replacement might ensure 0.1% to 1% more of current bed net users repair or replace their bed nets in a timely fashion. This in turn would lead to 35,000 to 350,000 fewer cases of malaria, and 105 to 1,050 fewer malaria deaths per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 2 to 24

Application of CRISPR technology to tropical diseases

Over the past few years, the biotech industry has developed CRISPR technology to edit gene materials and this has proven to be an effective way to tackle disease. While CRISPR research and development is expensive, once a new CRISPR technique is developed, it is cheap to apply. Research should be focused on diseases which affect poor people in developing countries.

Costs of R&D: The research costs are estimated at approximately US$100m per year. There are 17 tropical diseases.

Size of problem: Estimated impact of tropical diseases, DALYs 26m[114]

Cost of problem: US$3,000 x 26 million DALYs = US$78bn per year

Estimated potential benefit of R&D: estimated between 1% (US$800m) and 10% (US$8bn)

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 10 to 100

[114] Hotez PJ, Alvarado M, Basáñez MG, Bolliger I, Bourne R, et al. (2014). "The Global Burden of Disease Study 2010: Interpretation and Implications for the Neglected Tropical Diseases." *PLOS Neglected Tropical Diseases*, 8(7): e2865. doi: 10.1371/journal.pntd.0002865. Available online: http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0002865 (Accessed on 07 April 2017).

Health R&D: Maternal Health

Public information campaigns for pregnant women

Data in India (from 1999) shows that even where pregnant women have reasonably good access to medical facilities, they rarely visit a doctor. The assumption is that they do not think it's important or necessary. Research is needed into how to improve the effectiveness of public information campaigns which encourage pregnant women to access medical care.

Costs of R&D: The research costs are estimated at approximately US$10m a year

Size of problem: Maternal disorders total approximately 4m DALYs and neonatal disorders approximately 62m DALYs, giving a total of 66m DALYs (Global Burden of Disease 2015)

Cost of problem: US$3,000 x 66 million DALYs = approximately US$200bn

Estimated potential benefit of R&D: estimated between 0.01% (US$20m) and 0.1% (US$200m)

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 2 to 20

Evaluation of public information campaigns on complementary feeding

There are a lot of myths around what an infant and mother should eat which are taken very seriously, and these vary from country to country, and even within countries, they very from place to place. This can lead to a lack of awareness of what foods are important as a baby starts to eat solid foods alongside milk, known as complementary feeding, and in turn this can result in poor nutrition which has significant detrimental effects on infants. Poor nutrition in the first few years of life, can lead to stunting which impacts on both physical and cognitive development, and is difficult if not impossible to compensate for in adults. Research and evaluation is needed into public information campaigns on promoting good nutrition in complementary feeding, with a particular focus on: how to work within local dietary norms and habits; how to challenge unhelpful myths about what children and mothers should eat; and how to better inform people in meaningful ways with clear and accurate information.

Costs of R&D: approximately US$100m per year. The estimate is relatively high because of the need to be very country specific. Recent evidence indicates that context matters greatly when assessing the improvement of complementary feeding education on stunting outcomes. For example, the results from Hirvonen et al (2016) indicate that access to food markets is critical for complementary feeding promotion to be effective in diversifying diets and reducing stunting. Households more than 5km away from a market do not respond to complementary feeding education. Homestead food production of animal source foods can help to provide the dietary diversification that reduces the riks of stunting (Hoddinott, Headey and Dereje, 2015; Hirvonen and Headey, 2016). However, the strategy is not effective when animals and children share the same living space (Han, Kim and Park, unpublished) potentially because pathogen transmission between animals and children puts a greater toll on the child's immune system.

Size of problem: Assuming the main impact of inadequate complementary feeding is stunting, Unicef estimate there are approximately 156 million[115] children under-5 in developing countries who are stunted. The number of stunted children per year, ie in a cohort, is approximately (156/5) million = 31 million.

Cost of problem: We know from Hoddinott et al (2011) that the lifetime consumption of stunted children is reduced by 66%. If the average consumption per year is approximated by $3000 then the net present cost per stunted child is $33,000 assuming 4% growth rate in wages, 5% discount rate and working age from

[115] Figures from UNICEF, 2016. Available online: https://data.unicef.org/topic/nutrition/malnutrition/#. (Accessed on 07 April 2017).

16 to 55. Total cost of 31m stunted children is therefore 31m * $33,000 = $1 trillion per year.

Estimated potential benefit of R&D: estimated at between 0.1% (US$1bn) and 1% (US$10bn)

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 10 to 100

Health R&D: NCDs

Aging population and impact of chronic diseases

The composition of diseases in low/mid income countries is changing rapidly and radically, in particular as populations are aging and non-communicable diseases are having a greater impact. We know a lot about controlling and treating such conditions both medically and behaviourally from experiences in the developed world. However, behavioural issues in particular are likely to be very different in developing countries. Research should focus on understanding the social and cultural issues affecting chronic diseases in low to middle income countries, and in particular: behavioural, lifestyle, dietary habits, physical activity; and the potential role of tax incentives and other fiscal tools in shaping positive behaviours

Costs of R&D: The research costs are estimated at approximately US$100m per year.

Size of problem: The number of people over the age of 70 who die from chronic diseases is 23 million, meaning that 23 million older people are living with a chronic condition. The total global DALYs per year is 319 million. (Global Burden of Disease 2015)

Estimated cost of problem: The cost of the problem is estimated at US$3,000 x 319 million DALYs, which is approximately US$1 trillion.

Estimated potential benefit of R&D: Assuming that the R&D could bring an estimated potential benefit of between 0.01% (US$96m) and 0.1% (US$960m).

BCR: An order of magnitude estimate gives a BCR of approximately 1 to 10.

Distribution of polypill for hypertension and cardiovascular disease

R&D into distribution of polypill for treating hypertension and cardiovascular disease. The target audiences would be people with a diagnosis, people in high-risk groups, and possibly blanket coverage of people over a defined age. The cost effectiveness of targeting and distributing the pills to these different groups needs to be evaluated. In addition,

assessing existing and new distribution mechanisms for treatment, including information and training for health workers, and for government regulators and policy makers.

Costs of R&D into distribution of polypill: The research costs are estimated at approximately $10m per year.

Size of problem: The number of deaths reported from hypertension in 2015 is almost 1 million, and from cardio-vascular disease is almost 18 million, which is equivalent to 365 million DALYs (Global Burden of Disease, 2015).

Estimated cost of problem: US$3,000 x 365 million DALYs = approximately US$1 trillion.

Estimated potential benefit of R&D: Depending on a range of factors, such as timescales and affordability this may reduce the impact of hypertension by between 0.1% ($1bn) and 1% ($11bn) per year, or approximately 1,800 to 18,000 deaths annually from hypertension and cardiovascular disease.

BCR: An order of magnitude estimate gives a BCR of approximately 100 to 1,000

Affordable home testing for diabetes

Many people are not aware they have diabetes or are vulnerable to diabetes, and often the condition becomes serious before they seek treatment. The costs are then high in terms of medication and impact on livelihood and quality of life. Catching diabetes earlier, through research and development into low-cost, easy-to-use home and community-based tools would potentially have a huge impact. Based on existing self-testing technologies developed in the West, research into the kinds of adaptations required to produce an affordable test which could be distributed and used in developing countries would be beneficial to millions of people.

Costs of R&D: The research costs are estimated at approximately $10m per year

Size of problem: Using figures from the Global Burden of Disease for 2015, the following can be estimated, for World Bank regions (low income and lower middle income):

Condition/Region	WB Low Income	WB Lower Middle Income
Diabetes mellitus	3.5 million DALYs	28.3 million DALYs
Chronic kidney disease due to diabetes mellitus	0.5 million DALYs	4.4 million DALYs

This gives a total of approximately 37 million DALYs.

Estimated cost of problem: US$3,000 x 37 million DALYs = approximately US$110bn

Estimated potential benefit of R&D: Assuming that the key challenges are affordability and distribution, and that these are difficult to assess and predict but will likely be difficult in low and low/mid income countries, the impact of R&D is estimated at between 0.01% (US$11m) and 1% (US$1bn) per year.

BCR: An order of magnitude estimate gives a BCR of approximately 1 to 100.

Evaluation of public awareness campaigns to improve diet

One of the biggest challenges to improving health outcomes is diet, and changing practices and behaviours around eating and exercise to create more positive patterns. The impact of poor diet is not just on nutritional deficiencies, but on broader health outcomes and susceptibility to a range of acute and chronic conditions. Research to evaluate the effectiveness of public awareness campaigns in specific contexts and their impact on lifestyle and eating habits.

Costs of R&D: The research costs are estimated at approximately US$100m per year given the context specific nature of the issue, and that it is known to be difficult to change dietary habits and norms.

Size of problem: The figure for nutritional deficiencies for World Bank defined low to lower middle income countries is approximately 60m DALYs (Global Burden of Disease 2015). This is an underestimate of the size of the problem of diet, as poor nutrition has additional longer term effects, which are not confined to specific nutritional deficiencies, but associated with chronic conditions such as

for example cardiovascular disease and diabetes.

Estimated cost of problem: US$3,000 x 60 million = approximately US$180bn

Estimated potential benefit of R&D: The impact of the R&D would be to contribute to improving the effectiveness of public awareness and information campaigns on diet within local contexts. The impact is likely to be small, and is estimated as between 0.01% ($18m) and 1% ($2bn) per year.

BCR: An order of magnitude estimate gives a BCR of approximately 0.2 to 20.

Health R&D: Tuberculosis

Improved diagnostics for tuberculosis

Research and development is required into cheap diagnostic tools which are more sensitive to TB and can be used cheaply and accurately with target populations in different countries. Currently diagnostics either under or over diagnose TB, and a particular challenge is to identify people who are asymptomatic. This implies that a range of different tools are needed at different price points, for example, some would be used in a clinical setting and others as part of community health outreach. The R&D focus should be on matching the diagnostic tools with their application for at risk groups, ensuring that they can be incorporated into existing health systems and can easily be used effectively.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

Size of problem: An estimated 1.1 million people die from tuberculosis a year, equating to 40 million DALYs per year (Global Burden of Disease 2015).

Cost of problem: US$3,000 x 40 million DALYs **=** approximately US$120m

Estimated potential benefit of R&D: The impact of the R&D globally will be dependent on how effective the developed tools are, how easy they are to distribute and use, as well as their affordability in different country contexts. It will also depend on follow through in terms of treatment. Taking into account the likelihood of successful research and the likelihood of its effectiveness, there is estimated benefit of between 0.01% (US$12m) and 0.1% (US$120m).

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1 to 12.

Improving adherence to treatment

One of the biggest challenges in successfully treating TB is adherence to the full treatment regimen. Improving adherence involves a multi-dimensional approach, which covers not only the drugs available, but is also country specific in how it is implemented. Research and development might take the form of a package

of interventions focused on how treatment can be accessed and delivered in order to improve adherence, including: how drug treatment regimens can be shortened; promotion of the importance of completing the prescribed drug treatment; awareness raising of how to avoid spreading TB.

Costs of R&D: The research costs are estimated at approximately US$100m per year. The costs are high because of the expenses associated with developing and testing new drugs.

Size of problem: An estimated 1.1 million people die from tuberculosis a year, equating to 40 million DALYs per year (Global Burden of Disease 2015).

Cost of problem: US$3,000 x 40 million = approximately US$120m

Estimated potential benefit of R&D: Taking account the likelihood of successful research and the likelihood of its effectiveness, there is estimated benefit of between 0.1% (US$120m) and 1% (US$1.2bn)

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1 to 12.

Illicit Financial Flows R&D

System to tackle mis-invoicing in trade transactions

Trade mis-invoicing is by far the largest problem in illicit financial flows. Given current developments in technology and data analytics, research is needed into on how to use transaction level data collected from customs offices in real time to create models which help to signal potential illicit transactions before they are completed. Conducting feasibility studies in countries with government agreement and co-operation, could not only support tackling mis-invoicing at the national level, but could form the basis for the development of an international system. The potential for establishing a global framework for preventing mis-invoicing, rather than identifying and prosecuting after the event, would also likely lead to reductions in attempts at illicit transactions.

Costs of R&D: The research costs are estimated at around US$1m for a pilot

Benefits: if trade mis-invoicing in a single African country results in an estimated loss of government revenues amounting to approximately US$10bn - maybe this work will help stop approximately 10% (US$1bn) of losses. **The Tax Justice Network confirms the potential scale of this channel of illicit flows and many African countries are particularly vulnerable in this area.**

BCR: An order of magnitude estimate gives a BCR of approximately 100

Nutrition R&D

Improving implementation of nutrition interventions

There has been great progress in identifying nutrition needs and solutions, and current challenges are now centered on implementation and ensuring that these solutions reach people in the most effectives ways. One example would be research into the relationship between community level implementation of specific interventions and national level information and awareness campaigns. A second focus could be reviewing existing RCT research and researching how to scale up models from India where local women provide community based support in the form of nutritional education, home visits, group sessions, showing positive impacts. R&D would focus on scaling up the model to expand across India and to test its feasibility in other countries in South and South East Asia.

Costs of R&D: The research costs are estimated at approximately US$100m. The estimate is relatively high because of the need to be very country specific.

Size of problem: Unicef[116] estimate that globally 23% children under-5 are stunted, which is 156 million children. A single cohort is therefore 31 million children.

Estimated cost/benefit of problem: As mentioned previously (in the analysis on complementary feeding), the global cost of stunting is around $1 trillion per year in lower future productivity.

Estimated potential benefit of R&D: estimated potential benefit of the R&D is between 0.1% (US$1bn) and 1% (US$10bn) or about 31,000 to 310,000 fewer stunted children per year. The interventions are well researched and understood. The challenge is the implementation, so if the R&D is successful then there should be a relatively high likelihood of impact.

BCR: An order of magnitude estimate gives a BCR of approximately 10 to 100.

Adolescent health and nutrition

Adolescents are a large and growing population, and are increasingly a priority for national governments. Health related behaviours and habits apparent between ages 10 and 19 are found to impact on future adult health and life expectancy, in particular rising levels of obesity and mental health disorders. Research to identify a program of interventions specifically targeting adolescents, focused on issues such as health, diet, nutrition, and exercise where there are long term benefits, and that could then be supported through national government strategies and budgets. This would help increase the benefits from existing government spending, as well as potentially increase government spending on adolescents.

Costs of R&D: The research costs are estimated at US$10m per year over a number of years, and are assuming a cohort approach.

Size of problem:

- 1.8 billion adolescents and young adults in the world, aged 10-24 – of which 89% live in developing countries
- *http://www.healthdata.org/news-release/lancet-investing-adolescent-health-and-well-being-could-transform-global-health*
  - A cohort is therefore (1.8billion*89%/14) = approximately 114 m adolescents in the developing world.

Assume that the costs of an unhealthy lifestyle lead to the equivalent loss of 2 DALYs per person[117] over their lifetime so the total size of the problem for adolescents is 114m x 2 DALYs = 230m DALYs. The cost is experienced in the

[116] UNICEF Data: Monitoring the Situation of Children and Women. Availabline online: https://data.unicef.org/topic/nutrition/malnutrition/ (Accessed on 07 April 2017).

[117] May, AM et al (2015) The impact of a healthy lifestyle on Disability-Adjusted Life Year: a prospective cohort study. *BMC Medicine.* Available online: https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-015-0287-6

future but for the purposes of this rough calculation, the cost is under-estimated but then not discounted.

Estimated cost of problem: 230m DALYs x US$3000 = US$700bn

Estimated potential benefit of R&D: The potential for healthier lifestyles and behaviour in adolescents are between 0.01% (US$70m) and 1% (US$7bn).

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1 to 70.

Poverty R&D

Needs and characteristics of the very poor

The relationship between poverty, ethnicity, and exclusion among the poorest communities. Over the past 20 years, there has been dramatic progress as millions of people have been lifted out of poverty. The people who are now living in extreme poverty have different characteristics and different experiences than 20 years ago, and new research is needed to better identify who they are and what their needs are. In particular to research the relationship between economic and social marginalization, where certain minority groups in different countries seem to have been left out of recent economic development. For example Vietnam where 15% of the population are different ethnic minorities, research should focus on groups which are being left behind, are unable to access the benefits of urbanization, education etc. Identifying ways to target polices more effectively.

Costs of R&D: The research costs are estimated at approximately US$25m per year.

Size of problem: Assuming that the number of people dying from communicable, maternal, neonatal, and nutritional diseases is an indicator of the numbers living in poverty. The number of deaths in 2015 was 11 million people (Global Burden of Disease 2015).

Total global DALYs in 2015: 742m DALYs

Estimated cost of problem: The estimated global cost is US$3,000 x 742 million DALYs = US$2.2 trillion. Assume 10% of this population are marginalized and living in extreme poverty, US$220bn.

Estimated potential benefit of R&D: estimated between 0.01% (US$22m) and 0.1% (US$223m), or the equivalent of lifting 70,000 to 700,000 people out of poverty.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1 to 10.

Trade R&D

Opportunities for improved trade agreements between Africa and Asia

Given current indications of an increased turn to trade protectionism in the West (specifically the US and UK), there are nevertheless potentially beneficial trading opportunities for developing countries, and in particular between regional trading blocks in Africa and Asia. The recent focus on major trade deals such as TTP, means that the impact of regional trade potential in Asia has been under-researched and the opportunities and terms for developing countries to negotiate beneficial agreements is not well understood. R&D would help support better trade deals among Asian and African countries.

Costs of R&D: The research costs are estimated at approximately US$10m per year or $200m in perpetuity at 5%.

Potential benefits:

Global merchandise[118] trade, 2014, is US$18.5 trillion

Merchandise trade between Asia and Africa, 2014, is approximately US$360bn

The proportion of trade between Asia and Africa in terms of total global trade is therefore: US$(360/18,500) billion = approximately 0.02%

Estimated benefits: Assuming that the benefits from improved trading relationships are similar to what could be achieved with a successful Doha round, approximately US$330 trillion to 2100. Estimating the potential impact on improved trade between Africa and Asia:

0.02% x US$330 trillion = approximately US$65bn

Estimated potential benefit of R&D: assume approximately 1% (US$650m)

BCR: An order of magnitude estimate gives a BCR of approximately 3.

Urbanization R&D

Urban infrastructure

Research is needed into city planning and infrastructure development associated with rapid urbanization experienced in developing countries. Current estimates are that 2.5bn more people than at present will live in urban environments. Cities in Africa and Asia in particular are growing faster than ever, and a lot of money is being spent on infrastructure and it is clear that even more is going to be spent in the future. There are no existing relevant models of city development to inform current growth patterns. Research and development is needed to understand new forms of urban growth and to develop options for city planning and more specifically for effective infrastructure investment and maintenance. One specific issue is to research and assess ways to better manage and integrate private water and energy supplies with public supplies to ensure reliable services. Many of the benefits will relate to the efficiency gains made on existing investments into urbanization. (Additional closely related issues raised include research into improving policy and regulations supporting urban development, better understanding of the advantages and disadvantages of urban living and how to mitigate the disadvantages, improving sanitation infrastructure)

Costs of R&D: The research costs are estimated at US$100m per year.

Cost of problem: Estimated US$57 trillion[119] for 15 years up to 2030, two thirds of which is in developing countries. Assume that roughly half of that is for urban infrastructure, meaning approximately $1.27 trillion annually.

Estimated potential benefit of R&D: The benefit would be in reducing the costs of attaining a given set of services in the future. For the purposes of this calculation, we assume that there could be a savings of between 0.1%

[118] Figures are from World Trade Organization statistical report, available online at https://www.wto.org/english/res_e/statis_e/its2015_e/its2015_e.pdf. (Accessed on 07 April 2017).

[119] Dobbs, R., Pohl, H., Lin, D.Y., Mischke, J., Garemo, N., Hexter, J., Matzinger, S., Palter, R., and Nanavatty, R. (2013). "Infrastructure productivity: How to save $1 trillion a year." *McKinsey Global*

(US$1.3bn) to reducing 1% of the problem ($12.6bn) per year.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 10 to 100.

Additional benefits: Benefits are likely to be significantly higher, in particular to include improved quality of life (including health) and increased economic opportunities for the populations as well as on-going accumulated benefits.

Institute. Available online: http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/infrastructure-productivity (Accessed on 07 April 2017).

Methodological appendix

This document summarizes the methodological guidelines used to undertake the cost-benefit analysis in the *Prioritizing the Best Buys for Development Across the African Continent* project.

The analyses undertaken by commissioned experts were primarily 'back-of-the-envelope'; some based on recent academic publications. The guidelines were issued as an attempt to homogenize the work done across sectors.

In keeping with the vision of the Sustainable Development Goals and the African Union Development Agenda 2063, and given additional funding, which interventions would render high social, economic and environmental returns on investment? This is the principal question of the project.

To answer it, the Copenhagen Consensus Center, in collaboration with sector experts and the African Academy of Sciences, commissioned back-of-envelope cost-benefit calculations of **20-30 interventions** across a variety of sectors. Some are African Union Flagship programmes, others are interventions that we know, from experience, have high returns.

The selection of interventions was a collaborative process: Drawing from our previous work and in keeping with the vision and objectives of the African Union Development Agenda 2063, there were various exchanges between the Center and the expert in order to arrive at the final selection of interventions to be studied.

The academic analysis is predicated on an **injection of new money** available to decision makers. This means that all cost-benefit analyses are prospective and should take the existing coverage of interventions as the baseline.

The project output is a synthesis report, compiling the policy briefs for each intervention.

Each brief describes the problem and the proposed intervention, an explanation of the cost drivers and probable benefits associated with the scaling-up of the intervention, and an estimation of the order of magnitude of benefits over costs. Lastly, a discussion of the implications of scale-up of the intervention; an identification of countries in which the intervention may be replicated with similar results and any risks/challenges associated with its expansion in countries other than those under analysis; all of which will form part of each brief.

Introduction

As we enter the last decade to achieve the Sustainable Development Goals (SDGs), countries still face major challenges to ensuring that all people have the opportunity to lead healthy lives and reach their full potential. This is especially true in Africa, where many countries have the farthest to go to meet targets for health and wellbeing. The SDGs, along with the African Union's Development Agenda 2063 and national development plans, lay out a huge number of health and development priorities for countries to tackle in pursuit of those targets. Recognizing that time and resources are limited, it is essential to prioritize and focus on the areas that offer the greatest opportunity for impact.

Looking at the scientific priorities set by the SDGs, African Union Agenda 2063, and national development plans, which will give African countries the greatest return on investment?

The scope of problems across the continent far exceeds the resources available to address them. As such, this requires hard choices about where to invest first. One organizing principle, though by no means the only one, is that coordinative efforts should spend money on interventions that deliver the largest amount of social, environmental and economic good to African citizens for every unit of investment.

The Copenhagen Consensus' mission is to influence spending towards interventions and policies that do more good per unit of currency spent.

Cost-benefit analysis (CBA),[120] also referred to as benefit-cost analysis, is a well-established formal method for identifying interventions that maximize social welfare per unit cost, and is the primary methodology of the Copenhagen Consensus Center. Conceptually, the process of CBA is straightforward: an analyst identifies a given policy and estimates the impacts of this policy relative to a baseline scenario. These marginal impacts are classified into costs and benefits (more on this classification below), and converted into a common metric, typically into the local currency. All results are summarized as a benefit-cost ratio (BCR: benefits divided by costs).[121]

Theory of Change

All Copenhagen Consensus exercises are processes designed to inject more rationality into the debate around doing good for the world. Investments in highly beneficial interventions increases the likelihood that government and philanthropic spending becomes more effective on average. Because the influenceable pool of money is very large, even small changes in allocation can improve effectiveness and hence large improvements in social welfare.

For example, Figure 1 below depicts the span of BCRs from the recent *Rajasthan Priorities* project. The top intervention has a BCR of around 180, the median intervention a BCR of 4.5 and the lowest intervention a BCR of 0.9. Because our process aims to filter out very ineffective interventions before they are researched, it is possible the true distribution is 1 or 2 orders of magnitude wider at the lower end.

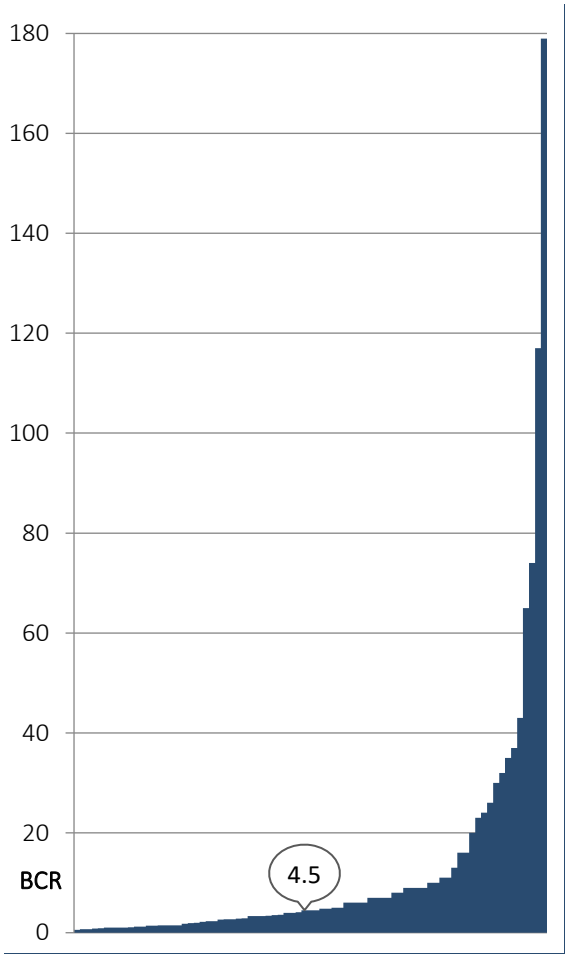
The implication of this large dispersion of effectiveness is that we focus on identifying the interventions at the top of the distribution and push strongly for their implementation. This is likely to be a superior strategy than making marginal improvements in existing interventions. In the case of the *Rajasthan Priorities* project, a decision maker with 100 rupees could spend 5% of her money on the top intervention and generate more social welfare than spending the remaining 95% on programs that are twice as efficient as the median intervention.

[120] Copenhagen Consensus conducts social CBAs. The 'social' aspect signals that the cost-benefit analysis accounts for and aggregates the costs and benefits of *all* relevant parties who are affected by the policy, and is distinct from 'private' cost-benefit analysis, which only concerns the impacts on a single party.

[121] Results of CBA can also be summarized in other ways, such as net benefits, internal rate of return or payback period. Copenhagen Consensus' preferred metric is the BCR as described below.

The implications of this for Copenhagen Consensus projects is that it is important that we canvas a wide range of policy options to increase the chances of finding these outliers. Additionally, given that the dispersion is so large, a high degree of precision is not typically required to identify outliers. While of course more precision is preferred to less, it is unlikely for example, that deeply investigating a particular methodological issue that will move an intervention from say, a BCR of 2.2 to 3.7 is required to achieve our aims.

COUNTRY-SPECIFIC INTERVENTIONS ORDERED FROM THE LOWEST BCR TO HIGHEST BCR



Source: Rajasthan Priorities project. The median intervention with BCR of 4.5 is highlighted.

For our country-level analysis, we like to survey a vast array of policy options, typically numbering 60 - 80 interventions. However, due to limited time for preparation, consultation and analysis, the *Prioritizing the Best Buys for Development Across the African Continent* project is limited to 20 - 30 interventions. Our experience informs us that some sectors will have several interventions, given the actual needs in human capital investment on the African continent and the high returns that can be expected due to reductions in mortality and morbidity. For example, the health sector has interventions addressing the lack of access to diagnostics and health personnel, infectious diseases like HIV and TB, chronic diseases like hypertension, malnutrition, maternal and neonatal health concerns, and the top causes of child and adult mortality (i.e. diarrhoea and gastrointestinal disorders and lower respiratory infections. All of this notwithstanding, we have identified other sectors in which high returns may be expected, either because they remove barriers to entry and make markets more efficient (e.g. Africa Continent Free Trade Area) or because technology reduces the costs of production (e.g. investment in additional R&D to increase agricultural output).

Academic exercise

The academic exercise of the *Prioritizing the Best Buys for Development Across the African Continent* project is premised on an **injection of new money available to decision makers**, that can only be spent on expanded or new programs. The specific amount is unimportant and conceptually, it only needs to be large enough to cover a reasonable amount of new projects but not so large that it would significantly distort prices in the relevant national economies.

Importantly, **because the money is new**, it implies:

1. the baseline for all CBAs is the existing absolute coverage level of interventions i.e. resources are not being taken away from what is currently being done
2. the CBAs are a prospective analysis of future expansions of existing programs, or standing up wholly new programs, and not an evaluation of past efforts

This feature is designed to conform to the economic concept of marginal analysis and it also assists in outreach and communication. Since one cannot use our results to predict what would happen if **existing** money was redistributed across portfolios, only what would happen with hypothetical **new** money, it

makes the exercise more politically palatable for decision makers and bureaucrats, increasing the chance that the information will be used.

It is important that economists are clear about the baseline scenario assumptions. The approach of considering only marginal money, suggests that the absolute coverage level of interventions is the baseline, with additional expansions (either due to population growth or expanding the scope of beneficiaries) subject to cost-benefit analysis. In terms of the problem being addressed by the intervention, the economist should estimate a baseline that is consistent with previous trends noting the main drivers of the problem (e.g. demographic transition, wealth, disease transmission etc…).

The unit of analysis in all our projects is an 'intervention'. **An intervention is a specific, concrete and time bound action that can be taken by policy makers** such as '*provide more TB screening and treatment*' or '*allow inter-country free movement of people'*. It is not an aspiration without means, e.g. '*eliminate poverty'*. Interventions are typically subset of wider of programs implemented by governments. For example "providing supplementary foods to mothers and children" is one intervention in the wider Integrated Child Development Services programme in India. **Our focus is generally at the intervention level, and not the programme or mission level.** Papers may cover one or more interventions according to the preferences, availability and expertise of the commissioned experts, and the interventions may fall under a particular programme, but the exercise should not be considered a programme evaluation.

There are some assumptions/data common to all analyses. **We encourage commissioned economists to refer to Section 5** for the most prominent assumptions that will be used in the *Prioritizing the Best Buys for Development Across the African Continent* project, as well as in the attached template.

To remain cost-effective, the Copenhagen Consensus encourages researchers to use existing primary data and to focus more on **generating consistent and comparable information for policy makers.** Consequently, there is no expectation that researchers will survey individuals, conduct experiments or engage in time-intensive data collection, without the express permission of the Copenhagen Consensus.

Methodological Guidelines

There are numerous textbooks that go deeper into the theoretical foundations of CBA and methods (e.g. Boardman et al., 2018) as well as guidelines that more fully lay out the steps of CBA (e.g. Robinson et al. 2019). These will not be re-explained here. Nevertheless, there are important, sometimes subtle methodological differences in how CBA is conducted by practitioners within the field. This section delves into some of the details of the Copenhagen Consensus approach to CBA.

Use of evidence

One of the main analytical challenges is discerning the appropriate evidence as it relates to the beneficiary population in question. Determining which models to adapt can be a complex judgment that should consider contextual relevance, study quality, and literature consistency. For this project, it is clear that preference should be given to high quality analyses from Sub-Saharan Africa, followed by other developing countries having similar socio-economic and demographic conditions. Use of effect sizes from carefully conducted meta-analyses is, of course, also encouraged. However, when the most contextually relevant studies have less robust experimental designs or the literature is divergent in its conclusions, then the parameter choice is less straightforward.

Overall, it is important that economists build a case for the parameters used in the broad calculations, referring to the literature for assumptions used.

Estimating all significant costs and benefits

Meaningful comparisons across interventions requires that all significant costs and benefits are accounted for. In some cases, this will be difficult to achieve due to imprecision or lack of data. In the case of the *Prioritizing the Best Buys*

for Development Across the African Continent project, the challenge is in estimating costs and benefits for a number of countries. Nevertheless, we encourage commissioned experts to make an attempt to estimate these costs and benefits, rather than leaving them off altogether.

We also encourage experts to include estimates of all costs and benefits that are likely to be significant in the analysis. This might entail examining benefits outside the primary aim of the intervention. For instance, when looking at climate change adaptation by planting mangroves, the benefit is not just climate protection, but also improved biodiversity and potential higher incomes to fishers. Likewise, an education intervention will not just increase earnings but will also improve nutritional profiles.

BCR vs. net benefits

While many CBAs highlight net benefits (B minus C), our preferred metric is the benefit-cost ratio (BCR), which is benefit (B) divided by cost (C). The reason for this is that in developing country contexts the ability to raise funds (through taxation or debt), or the ability to enforce regulation is constrained. This is perhaps different to developed countries, which can typically raise money and legislate with much greater ease. Given a fixed pool of available funds (as is the case in our 'thought experiment' set up, as well as in actual political decision making), a strategy that begins with implementing the highest BCR intervention and continues in decreasing order until money runs out will maximize social welfare. A strategy that starts with the highest net benefits intervention continuing in decreasing order, almost certainly will not.

For example, suppose a policy maker has $100 and is faced with the following options

	Benefits	Costs	Net Benefits	BCR
Policy A	$300	$100	$200	3
Policy B	$240	$60	$180	4
Policy C	$200	$40	$160	5

If the policy maker chooses based on the intervention with the highest net benefits, then she would choose policy A, run out of money and generate net benefits of $200. However, if ranked on BCR, she would implement policy C, and then policy B, before running out of money. This would generate $340 in net benefits.

Classification of costs and benefits

It is important that costs and benefits are classified consistently to ensure comparable BCRs. Robinson et al. (2019), suggest that inputs into a process (such as materials and labor) should be classified as costs, while outcomes (such as mortality risk reductions or increased productivity) should be classified as benefits. This approach is intuitive, and we generally ascribe to this methodology.

What should be included on the side of the cost equation? The total costs associated with the design and implementation of an intervention includes direct and indirect costs, as well as the opportunity cost. Take for example, an intervention to end child labour in India. The National Child Labour Project, has as its principal objective the decrease in the number of working children, ages 9 - 14, and particularly those engaged in hazardous occupations. One of the interventions associated with this programme is the establishment of special schools and rehabilitation centres, which provide bridge education, vocational training, mid-day meals, health care recreation etc. to the children, with the ultimate objective of preparing them to be mainstreamed into the formal education system.

A cost-benefit analysis of these special schools must take into account the capital costs (e.g. building construction) and the recurrent costs of making education and health services available (e.g. teachers, nurses, pedagogic materials). There is also the *opportunity cost* of the intervention: the foregone income to the household from child employment. The children's financial contributions to households being considerable, adding a small stipend to subsidize household expenditures, rather than assuming that the returns to education are sufficiently high, mitigates the next best alternative, which is sending the child to work. The National Child Labour Project does indeed include a stipend to families. In this case, an estimation of the foregone income would be

added to the cost side. Neglecting the opportunity costs of an intervention can not only result in sub-optimal financing but also the mis-targeting of beneficiaries, consequently undermining its success.

What should be included on the benefit side of the equation? In order to adequately capture the benefits of a proposed intervention, the beneficiary groups must be well-identified. It does not suffice to identify just women as beneficiaries: Are they living in rural or urban areas? Which age group is targeted? Which ethnic/social groups? Does marital status impact the delivery of the intervention? The more defined the beneficiary group, the more precise our estimates, the more likely planners will be able to adjust the intervention in order to maximize its effectiveness.

Furthermore, an intervention, which leads to cost reductions, should be included on the benefit side of the equation. Take, for example, the adoption and integration of information technology in government operations. Generally, the benefits of such interventions include a reduction in service delivery costs including fewer public servants needed to render services (a benefit); a time savings experienced by citizens using the service (a benefit), and a reduction in the number of times a citizen has to travel to a public office (also a benefit).

An additional principle we employ is that **absolute** benefits and costs should be considered where possible, with **no netting off benefits or costs**. For example if agricultural extension services cost $5 and this leads to increased farm revenue of $45, yet also increased farm costs of $10, we would estimate the benefits as $45, and the costs as $5 + $10 = $15 for a BCR of 3. We would **not** net off the revenue and costs (i.e. profit) for benefits of $35, costs of $5 and a BCR of 7. The reason for this is that the true resource cost of the intervention – the amount that is consumed from the fixed pool of funds available to society is $15 and not $5, and so the result from the first approach better captures the return on investment.

Treatment of transfers

Interventions involving transfers are an area where consistent classification matters greatly. Transfers tend to fall under the field of social protection and include unconditional cash transfers, conditional cash transfers, food transfers and subsidized insurance. In this case, the transfer appears as both a cost and a benefit in the BCR equation. It should **not** be netted out. For example, consider an unconditional cash transfer of $100. Suppose the administrative costs of delivering the transfer are $5 while the transfer delivers consumption-smoothing benefits of $10 to recipients. In this case, the benefits are $110, while the costs are $105 for a BCR of 1.04. If one were to net out the transfer (incorrectly), the intervention would appear as benefit = $10 and cost = $5 for a BCR of 2. However, as above, the real resource cost of the intervention is $105, not $5, so 1.04 is, in our estimation, more accurate reflection of the social return.

Time frame of analysis

In terms of the appropriate time frame of analysis, there is one principle: the time frame should be long enough to capture the most important future flow-on effects (typically benefits, but sometimes also costs) from a given intervention. The exact length will vary by analysis. For example, since infrastructure lasts for decades, CBAs of roads, public transport, sewage networks and other major capital works should take at least a 20 year (or more) time horizon to capture all the benefits. In contrast, the costs and benefits of say, crop insurance can be modeled as a one year steady-state intervention, since typically insurance covers only that year's crop, with next year's insurance covering next year's crop and so on.[122] Importantly, as long as the time frame used captures all material flow-on effects,

[122] That is not meant to imply that individuals do not take multiple years of insurance. However, modeling multiple years of crop insurance will not lead to materially different BCRs than a one year model, since the costs (premiums) and effects (insurance benefits) occur within a one year time frame.

differences in time do not affect the comparability of interventions when using benefit-cost ratio as the metric of interest.[123]

The analytical base year is 2018

For those economists not working from peer-reviewed publication and/or working on an entirely new intervention, the analytical base year for the *Prioritizing the Best Buys for Development Across the African Continent* project is 2018. This means that all costs and benefits should be reported in 2018 United States dollars. Costs sourced from earlier years should be inflated to the analytical base year using a GDP inflation index, though it is discouraged, when it can be avoided, to use data before 2016. Additionally, forecasts of costs and benefits only need to account for real growth and should ignore inflation. Additionally, all interventions should take the initial conditions of the year 2018 (or as recently as data allows) and assess the effects against this baseline.

Political considerations

All political costs regarding *the decision to implement* should be ignored, while political fall-out *in actual implementation* should be considered. In other words, all cost-benefit analyses should take as a starting point the hypothetical scenario where the decision is already made to implement the intervention. Costs associated with advocacy, campaigning, etc. to encourage implementation should be ignored. However, if the completed decision may make politicians decide to cheat or skim the process, this simply means a smaller benefit or a larger cost and should be included (along with all other risks, and challenges in implementation).

The concept of risk

BCR estimates should be revised downward to incorporate well-documented assessments of risk. For example, where it relates to microfinance, it is generally recognized that 2% of borrowers are at risk of default. This risk should be worked into the calculations; in this case, it is an additional cost to the lender.

Implementation failures

To the extent that the data allows, commissioned economists should account for implementation failures such as corruption and incompetence. The most straightforward way to account for this is to adopt parameter estimates from studies with high quality methods (e.g. randomized-controlled trial, difference-in-difference, regression discontinuity) which should theoretically embed all the vagaries of implementation into the effect size. However, recent literature around RCTs documents divergence between small-scale pilots and real-world implementation. In disciplines where these studies are not possible or uncommon, we suggest carefully considering to what extent the evidence represents ideal or non-realistic scenarios with respect to the actual local context and adjust accordingly.

Equity weights

As with most CBAs, as traditionally adopted, Copenhagen Consensus assigns an equal weighting to all costs and benefits regardless of who obtains or pays them. The one exception is for individuals who illegally obtained assets via corruption or theft, which we assign a weight of zero. So for example, in an intervention which reduces corruption, the loss of corrupted funds does not count as a cost in the societal cost-benefit calculation.

Jobs vs. output

Cost-benefit analysis, as is traditionally adopted, does not count the creation of jobs as a benefit. Instead the focus should be on the flow on effects of job creation – either output, income or consumption. The primary reason the value of jobs differs depending on the state of the labor market in question, and this is better determined by examining flow-on

[123] Referring back to the examples above: one might feel it is more appropriate to compare a 20 year road project to 20 years of crop insurance. However, 20 years of crop insurance will have approximately the same BCR as one year of crop insurance, since 20 years of crop insurance is just one year of insurance repeated 20 times i.e. BCR = 20 x benefits / 20 x costs = 1 x benefits / 1 x costs.

effects (the increase in output or the increase in incomes) rather than the monetary value of the number of jobs created.

If the intervention under analysis specifically targets job creation – such as a workfare program like India's rural guarantee scheme – economists need to examine the broader general equilibrium effects to understand the impact in a cost-benefit framework.

Important common assumptions and approaches for Prioritizing the Best Buys for Development Across the African Continent project

Wages and wage forecasts

Wages and wage forecasts are required for estimating productivity and education benefits as well as time costs / benefits. The Center encourages the use of GNI per capita forecasts where:

> Wages = GNI per capita * labor force participation * labor share of income

GNI per capita and GNI per capita growth for all Sub-Saharan African countries were distributed to experts.

Discount rates

We acknowledge there is considerable debate around the appropriate discount rate to use in economics, as well as the fact that discount rates differ with country context. Considering that we are analyzing countries at various stages of development, we would like experts to report BCRs at 5%.

Valuing mortality and morbidity

Valuations of mortality and morbidity follow recent guidelines developed under the Harvard led *Guidelines for Conducting Benefit-Cost Analysis* project (Robinson et al. 2019). These guidelines suggest a range of approaches. Given time constraints, we adopt one of these approaches for this project. Copenhagen Consensus' preferred approach is to convert each death avoided into years of life lost (YLL) avoided, using the relevant life tables, and to value each YLL at 1.3x GNI per capita. YLLs should not be discounted.

This preferred approach was derived by taking a VSL value of $9.4m USD (2015 dollars) – representing approximately 160 times income as measured by income per capita PPP - transferred to the continent using an income elasticity of 1.5. In 2017, GNI per capita PPP for sub-Saharan Africa was Int$3700 while the corresponding value for the US was Int$61,120 (World Bank, 2019). Using these figures and applying the approach documented in Robinson et al. (2019) suggests a VSL to GNI per capita multiplier of approximately 39x for the continent.[124]

Life years are valued using a constant value of statistical life year (VSLY). A VSLY is typically derived by dividing the VSL by the average life expectancy of an adult of average age, proxied by half the life expectancy at birth. In sub-Saharan Africa, life expectancy at birth is 61 (World Bank, 2019), implying 30.5-year life expectancy for an adult of average age. The value of a YLL therefore, as a function of GNI per capita is 39 / 30.5 = 1.3.

In terms of morbidity avoided, the *Guidelines* recommend adopting a cost-of-illness approach. However, this approach can be very data intensive. For parsimony, we suggest here estimating the Years of Life Lost to Disability (YLDs) avoided from morbidity benefits, and applying the same multiplier for YLLs i.e. 1.3xGNI per capita.

In summary all DALYs (whether YLLs or YLDs) should be valued at 1.3xGNI per capita and not discounted.

Value of time

Following Whittington and Cook (2019), we assess the value of time which can be put to use for productive purposes at 100% of wages, while time that cannot be applied to productive purposes is valued at 50% wages for the population in question. Analysts should be careful to include the cost of time required to

[124] The exact calculation is (3700/61,120)^(1.5-1)*160.

access the services provided by interventions, particularly for health programs.

In some instances, economists will have to value time of children. While there appears to be no agreed consensus on appropriate valuation, it seems reasonable that i) the value should be lower than productive adult's time and ii) very young children probably have a zero or even negative value of time (e.g. if children are not at school, adult caregivers are required). So we suggest applying a value of zero for the time of children less than 10 years old. This is consistent with the returns to education literature (e.g. Psacharopolous and Patrinos, 2018), which does not apply an opportunity cost of attending primary school before grade 5. For children aged 11 to 15, a value somewhere between children's and adult's time should be applied depending on the context, and potentially reflecting the value that children might contribute to agricultural activities or factory work. Individuals aged 16 and above should be considered adults.

Value of carbon emissions avoided

The value of carbon emissions avoided is drawn from a recent review of the social cost of carbon literature (Tol, 2018). According to this review, the marginal value of a ton of CO_2-eq avoided varies by discount rate. For a 3% discount rate the value is USD 25.30 / ton while for a 5% discount rate it is USD 7.60 / ton. Both figures are denominated in 2010 USD. For much higher discount rates, the effective value of carbon emissions avoided at USD 0 / ton.

To estimate the value of carbon emissions reduction also requires a growth factor in the social cost of carbon emissions, since the social cost grows over time as more CO_2-eq is released into the atmosphere. The growth factor should be set at 2% as per year (Tol, 2018). The equation for calculating the benefit of avoided carbon emissions is therefore:

$$Benefit = \sum_{t=0}^{n} \left[\frac{SCC_t(1 \times g)^n}{(1+r)^n}\right]$$

where *t=0* represents the year 2015, SCC is the social cost of carbon above in 2010 USD (note in Tol (2018) the emissions year and the currency year are different), g = 2%, r = discount rate.

Treatment of costs of raising funds

In some CBAs, analysts explicitly include the cost of raising funds or the cost of taxation. This is usually assessed as a fixed cost per dollar of investment. We recommend ignoring this in CBA since it affects all analyses approximately equally. The inclusion of this cost would add complexity without improving precision or our ability to identify outliers.

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