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.

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.

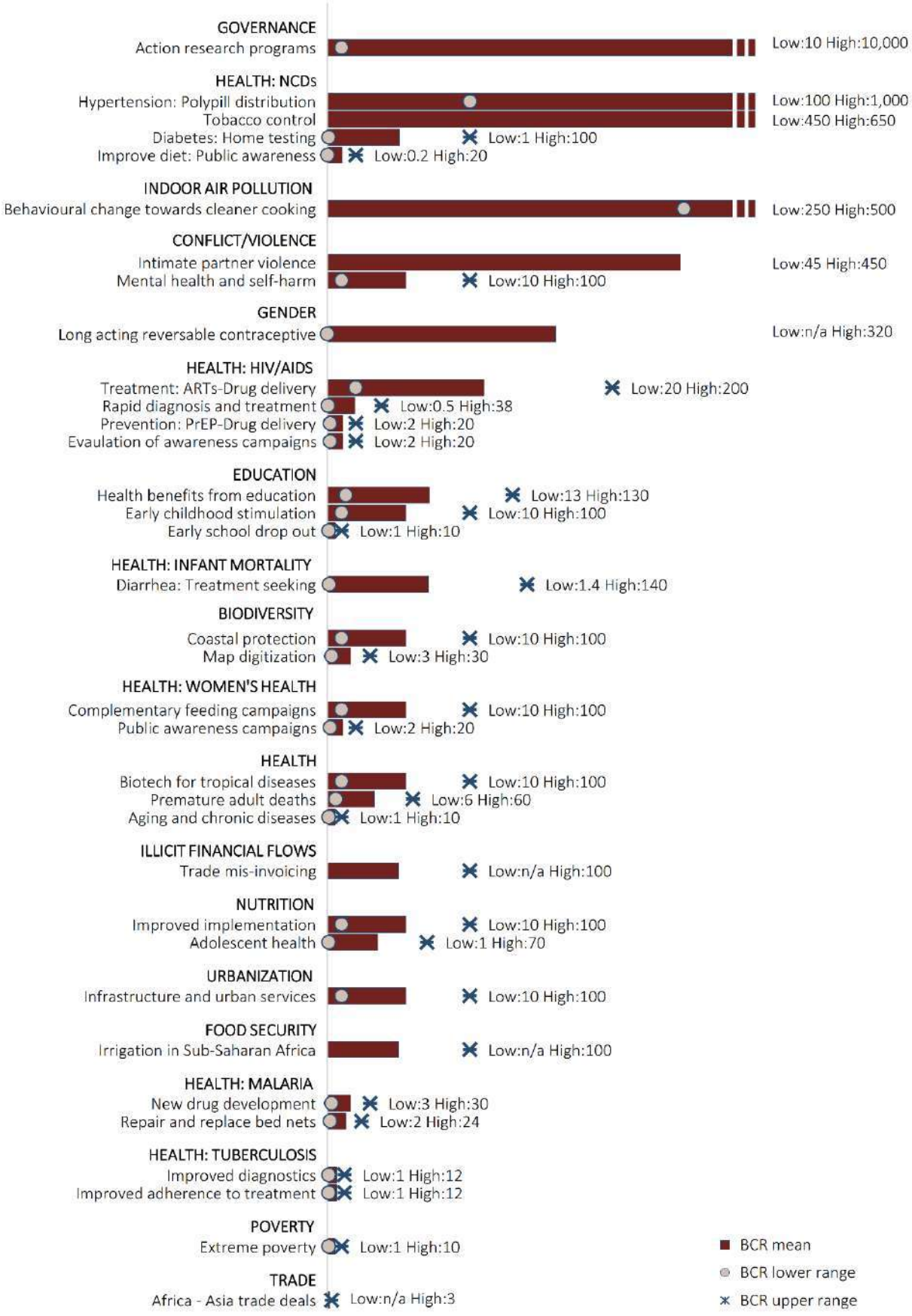
About one billion people will die from **tobacco** in this century, if current smoking patterns persist. R&D could help generate and implement politically feasible solutions, from estimating the most effective and least disruptive tobacco tax increases to creating packaging to reduce consumption. Each 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

[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.

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 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 **Social Problem**	COST = $1m-$10m p.a.	COST = $10m-$100m 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	• 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
R&D addresses **Technology Problem**	COST = $10m-$100m p.a.	COST = $100m-$250m 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	• Reducing premature adult mortality • Application of CRISPR technology to all 17 neglected tropical diseases
	R&D addresses problem of **low heterogeneity**	R&D addresses problem of **high heterogeneity**

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 urbanization and infrastructure development and a meta-study of the relevant

[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).

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 approximately 60,000 to 120,000 lives saved per year.

However, in order to achieve this health benefit, there would need to be additional

[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).

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

[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).

losses in 2018 are US$22.1bn. The assumption 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.

Costs of R&D: The research costs are estimated at approximately US$10m per year.

[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.

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

[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).

0.01% (US$100m) and 0.1% (US$1bn) per year 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%

[115] Figures from UNICEF, 2016. Available online: https://data.unicef.org/topic/nutrition/malnutrition/#. (Accessed on 07 April 2017).

growth rate in wages, 5% discount rate and working age from 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.

[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).

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% (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.

[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 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

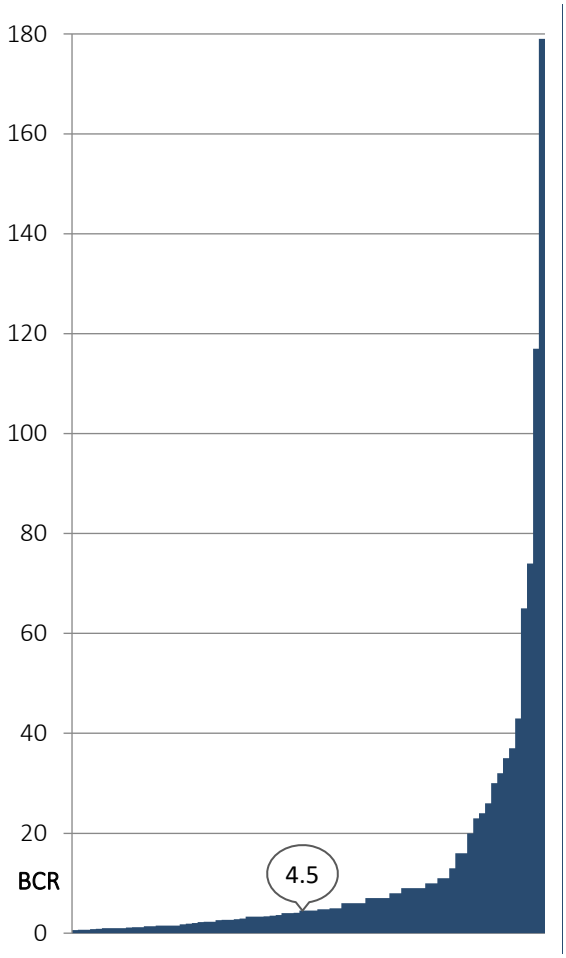
[120] Copenhagen Consensus conducts social CBAs. The 'social' aspect signals that the cost-benefit analysis accounts for and aggregates the costs and benefits of *all* relevant parties who are affected by the policy, and is distinct from 'private' cost-benefit analysis, which only concerns the impacts 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.

welfare than spending the remaining 95% on programs that are twice as efficient as the median intervention.

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, 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.

[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.

[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.

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 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.

[124] The exact calculation is (3700/61,120)^(1.5-1)*160.

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 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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