Global Britain, Global Solutions:

How British R&D can transform international development

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Foreword by George Freeman MP

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Contents

Executive Summary

- Investing in R&D is one of the most cost-effective types of international development, and one of the best ways for a Global Britain to take a lead in tackling global challenges. The UK is already a world leader in development research, but there is considerable potential to go further and integrate with the Government's wider innovation-led Industrial Strategy. There is more we could do to ensure that new initiatives, like the Global Challenges Research Fund and Ross Fund, focus on the most important problems or the most promising solutions. In this report, we argue that spending on R&D should be doubled and that more strategic oversight needs to be given to ensure resources are spent in an effective manner.
- We look at three key questions:
  - **Why spend more on R&D in development?** Is additional R&D good value for money compared to other potential investments? How many neglected opportunities are there for further research?
  - **What are the most important targets for R&D?** Working with the Copenhagen Consensus Center, we present the details of 40 potential R&D projects with quantified benefit cost ratios.
  - **How can development R&D be integrated with the Government's new Industrial Strategy**? How can we ensure a significant increase in resources doesn't lead to waste? How can we better target the Global Challenges Research Fund and other forms of development research at the most important problems and the most promising solutions?

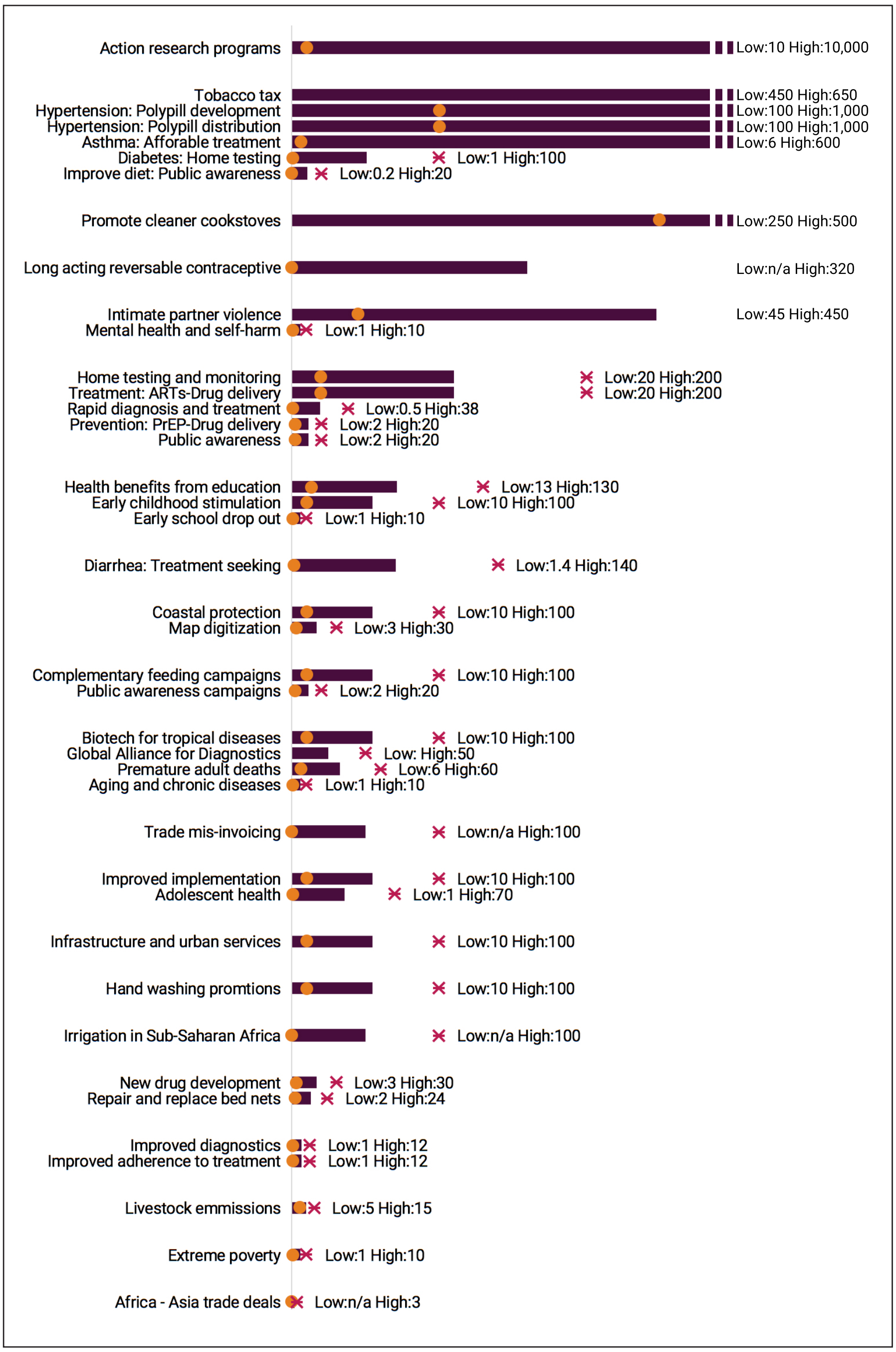
The Case for R&D

- The most important reason for spending more on research is that many of today's technologies are not enough to solve future global challenges or meet the 17 UN Sustainable Development Goals:
  - In health, new vaccines are constantly needed to keep ahead in the race with growing drug resistance, responsible for 700,000 deaths a year. Western-style medical systems are financially unrealistic for many developing countries.
  - In energy, today's renewables and battery technology are unlikely to be cost effective enough once intermittency is taken into account, to achieve an 80 percent reduction in $C0_2$ by 2050. Demand for energy is expected by the IEA to raise 40% by 2040.
  - In agriculture, 795 million people remain undernourished, while global food demand is expected to increase 70% by 2050, and the methods used to drive the original 'Green Revolution' have not proved successful when transplanted to sub-Saharan Africa.

- At the same time, new technologies in machine learning, FinTech, mHealth, and next generation transport offer opportunities for the developing world to leapfrog the traditional path of technological development. While only 30% of Africans have access to sewerage, 54% roads or 65% electricity, 93% have access to cell phone service.
- In 2015, British aid for R&D amounted to £419 million, an increase of 33% on 2014 in real terms and of 216% since 2010. The largest component of R&D aid has consistently been aid to research and scientific institutions and medical research, equalling £187 million and £86 million respectively in 2015. Looking at the wider R&D budget, the UK is the 7th largest spender on research – spending just 11% of the $134 bn spent by the US in 2013. In total, government financed R&D is only 0.48% of GDP compared to an OECD average of 0.66%.
- There is some controversy over what the appropriate threshold should be for judging cost effectiveness in development, with little systematic evidence of the effectiveness of existing interventions. Nevertheless, using evidence from health economics and direct cash transfers as our baseline suggest that a reasonable rule of thumb threshold for effectiveness is a benefit cost ratio (BCR) of 5 to 1. There is considerable evidence that well-targeted research projects are likely to be more cost effective than this. Despite only making up 5% of its current budget, DFID estimates an average internal rate of return of 10% from its research portfolio.
- There remain substantial research gaps and neglected areas for future work, with the best evidence on research gaps coming in the area of health. Between 1975 and 1999, just 16 out of 1393 new drugs were for tropical diseases and tuberculosis. Only around $3 billion a year or 1-2% of health R&D is targeted at infectious diseases in low and middle income countries, with just 10% of medical research dedicated to tacking conditions accounting to 90% of the global disease burden. In 2013, the Lancet Commission identified more than 500 specific research gaps, while the WHO has recommended that the current $3 bn in global health R&D spending be doubled.
- One potential objection to spending more on R&D is that additional funding may not be the only important constraint. Progress can also be held back by a shortage of talented researchers, theoretical breakthroughs regulatory hurdles and the difficultly of translating research into a sustainable business model. In practice however, while R&D will eventually run into diminishing returns, there remains significant capacity for a gradual expansion – and particularly so in the UK, given its underlying research strengths.

What are the most important priorities for future R&D?

- In order to better understand where additional resources on R&D could and should be spent, we asked the Copenhagen Consensus Center to use its network of the world's top economists to identify the best R&D options available to meet the UN's 17 Sustainable Development Goals: air pollution, biodiversity, conflict & violence, education, energy, food security, gender, governance, health, illicit financial flows, nutrition, population, poverty, trade, urbanization and WASH.
- Working with 32 academics and subject experts, the Center identified an initial 70-100 research ideas. Then this was narrowed down to a shorter list of 40 projects for which a first-order estimate of potential benefits and costs could be calculated. All but two of the projects pass our rule of thumb threshold for effectiveness. This suggests there remain substantial numbers of currently neglected, highly cost effective development R&D interventions.
- Among the most effective suggestions, were:
  - **Developing affordable treatment for asthma.** Asthma is largely under control in richer countries, but inhalers remain expensive and generally unaffordable in developing countries. *Estimated BCR: 6 to 600*
  - **Cheaper home monitoring and drug delivery for HIV/AIDs.** This would reduce the need for regular medical visits and for repeat prescriptions, enabling better self-management and higher drug adherence rates. *Estimated BCR: 20 to 200.*
  - **Developing a long acting reversible contraceptive.** This would not only provide enhanced control over child bearing, but could improve women's empowerment, labour market participation and health. *Estimated BCR: 320*
  - **Expanding the potential for irrigation in Sub-Saharan Africa.** Sub-Saharan Africa currently lags behind in irrigation development, with 93% of agriculture rain-fed. *Estimated BCR: 100*
  - **Creating a system to tackle mis-invoicing in trade transactions.** Trade mis-invoicing appears to be by far the largest problem in illicit financial flows, but big data presents new opportunities to tackle it. *Estimated BCR: 100*



Action research programs
Low:10 High:10,000
Tobacco tax
Low:450 High:650
Hypertension: Polypill development
Low:100 High:1,000
Hypertension: Polypill distribution
Low:100 High:1,000
Asthma: Afforable treatment
Low:6 High:600
Diabetes: Home testing
Low:1 High:100
Improve diet: Public awareness
Low:0.2 High:20
Promote cleaner cookstoves
Low:250 High:500
Long acting reversable contraceptive
Low:n/a High:320
Intimate partner violence
Low:45 High:450
Mental health and self-harm
Low:1 High:10
Home testing and monitoring
Low:20 High:200
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
Public awareness
Low:2 High:20
Health benefits from education
Low:13 High:130
Early childhood stimulation
Low:10 High:100
Early school drop out
Low:1 High:10
Diarrhea: Treatment seeking
Low:1.4 High:140
Coastal protection
Low:10 High:100
Map digitization
Low:3 High:30
Complementary feeding campaigns
Low:10 High:100
Public awareness campaigns
Low:2 High:20
Biotech for tropical diseases
Low:10 High:100
Global Alliance for Diagnostics
Low: High:50
Premature adult deaths
Low:6 High:60
Aging and chronic diseases
Low:1 High:10
Trade mis-invoicing
Low:n/a High:100
Improved implementation
Low:10 High:100
Adolescent health
Low:1 High:70
Infrastructure and urban services
Low:10 High:100
Hand washing promtions
Low:10 High:100
Irrigation in Sub-Saharan Africa
Low:n/a High:100
New drug development
Low:3 High:30
Repair and replace bed nets
Low:2 High:24
Improved diagnostics
Low:1 High:12
Improved adherence to treatment
Low:1 High:12
Livestock emmissions
Low:5 High:15
Extreme poverty
Low:1 High:10
Africa - Asia trade deals
Low:n/a High:3

How can development R&D be integrated with the Government's new Industrial Strategy?

- There are clear crossovers between the Government's R&D focussed Industrial Strategy and the use of R&D to tackle global challenges. At the same time, there are significant spill-overs between public and privately funded research. British research is the second most cited in the world, and we boast particular strengths in life sciences, data science, humanities and social sciences.
- The majority of UK research projects are chosen by individual scientists following their own curiosity. While this should continue and we should do more to reduce the bureaucratic constraints on our top scientists, there is also a role for greater central sharing of information and more challenge-orientated research alongside 'responsive mode' funding. We need both curiosity and challenge based research. Bringing together the Research Councils and Innovate UK into the new UK Research and Innovation creates new opportunities to improve the coherence of challenge based research in both domestic and development policy.
- As a recent review by the Independent Commission for Aid Impact concluded, the current highly decentralised structure for the Global Challenges Research Fund provides "insufficient strategic direction", with few formal processes to target resources or monitor performance. At present there is little actual strategy for the fund's use.
- In order to achieve the highest returns from development R&D, we suggest three broad principles:
  - While UKRI should not try and direct basic science, it can do more to share best practice, identify research gaps and support replication.
  - Wherever possible, challenge based funding should be structured on an outcomes-based model, open to both private and public sectors.
  - R&D allocation should be based strictly on what is best for global welfare, but by focusing on the UK's comparative advantages there are likely to be significant spill-over benefits for Britain's research and innovation base.

Policy Recommendations

- **The UK should double the proportion of ODA spending on R&D from 5% to 10% of the total budget, and work to create a steady ramp up of research capacity.** R&D is relatively neglected by the rest of the international development community, presents high returns compared to other forms of intervention and, given the strength of Britain's science base, the UK is well placed to take full advantage of greater spending. The UK should work to minimise disruption from Brexit, and continue as part of a Global Britain to play a key role in international scientific partnerships. Looking forward, we should take advantage of new freedoms in regulation or immigration policy to create the world's most efficient process for drug approval, and ensure the UK remains a magnet for scientific talent.
- **UKRI should create a new institution, the UK Innovation Challenge Agency, to jointly manage the Industrial Strategy Challenge Fund and the Global**

Challenges Research Fund. This new body should commission:

- expert-driven research agendas to highlight the most important unknowns, progress of current research programmes and likely future milestones
- where feasible, replication of the most important historic and new results
- literature reviews and meta analyses on the most important unknowns, working in collaboration with the "What Works' network and Policy Exchange's previously proposed Office for Aid Effectiveness
- oversight of new 'moonshot' high risk DARPA-style research programmes, such as the proposed Health Advanced Research Programme
- rigorous cost benefit analysis of R&D proposals to help decision-making and prioritisation of the most cost effective ideas
- ongoing benchmarks of UK sectoral and research comparative advantage to ensure the UK focuses on what it can do best
- stakeholder consultation and audits of current regulatory barriers to innovation, with an initial focus on post Brexit opportunities

- **The Innovation Challenge Agency should create a new series of Advanced Market Commitments for solutions to Global Challenges.** Advanced Market Commitments guarantee private sector innovators a set price if they are able to deliver a new product to market. They are used by donors to ensure developing interventions aimed at the developing world can be commercially viable. The UK has already helped fund the world's first Advanced Market Commitment for the development of pneumococcal vaccine, while the recent O'Neill review on tackling Antimicrobial Resistance recommended their broader use to develop new vaccines. The Innovation Challenge Agency should scope out a new generation of 5-10 AMCs aimed at tackling the most important global challenges. These could include a new malaria vaccine, higher yield GM crops, a digital education MOOC that can demonstrate sustained learning, or low cost forms of battery storage.
- **Alongside these specific challenge funds, the UK should pilot a Health Impact Fund and explore patent buyouts.** A Health Impact Fund could act as alternate reimbursement method to the patent system, making it easier for developing countries to access cheap drugs. Pharmaceutical companies that signed up to this would receive compensation from the total funding pool in proportion to the overall reduction in the global disease burden their innovation creates. The Government should commit initial seed funding to explore the viability of a full Health Impact Fund in future.
- **The UK should aim to be a world leader in emerging technologies in agriculture, medicine, FinTech, GovTech and transport, reducing regulatory barriers to automation and gene editing. At the same time, Britain's world leading expertise in AI and machine learning gives us the potential to pilot new 'leapfrog' technologies that could overcome poor levels of infrastructure or government capacity in developing countries.** The European Union's over reliance on the 'precautionary principle' has slowed progress in pharmaceuticals and GM crops, with significant spill-over effects in the developing world. Leaving the European Union offers Britain the opportunity to catalyse faster innovation and set its own, science-based regulatory standards.

Foreword

At this historic moment while we prepare to leave the European Union, it is more important than ever that Britain sets out a bold, optimistic path for the future. Rather than turn in on ourselves, we should turn outwards, creating a more Global Britain. With our commitment to defence, to security, to aid and crucially, our innovation and expertise, Britain can help to make the world a safer and more prosperous place. We should be proud of being the only major country to meet both the UN target of spending 0.7% of GNI on development and the NATO goal of 2% of GDP on defence.

Three hundred years ago, Britain pioneered the agricultural and industrial revolutions that brought about the modern era of economic growth. Today, we have the opportunity to harness British expertise in bioscience, digital health and agri-tech to help the developing world leapfrog old technologies and meet potential challenges, from antimicrobial resistance to energy sustainability. We can and should be the world's most innovative economy, inventing the new technologies and businesses that will solve the challenges of tomorrow.

British funding, scientists and entrepreneurs are already at the forefront of exciting new technologies, from nutrient-enhanced crops to allowing households in East Africa to use their phones to access cheap solar power.

As this report argues, R&D is one of the most cost-effective forms of development spending we know about - but there remain considerable research gaps where more funding is needed.

Public investment in development R&D can be a win:win - boosting global security and prosperity, while providing the seed capital to support a wider ecosystem of innovation at home. Many of these new technologies will not just help tackle the problems of the world's poorest people, but solve our own challenges. Britain's new generation of digital health start-ups, for example, cannot only bring modern medicine to some of the remotest parts of the world, but help the NHS meet the fiscal costs of growing health demand.

Crucially - we will not be a home for technology innovation without a public sector that is actually open to adopting, testing and providing a first market. We will never unlock our potential in the crucial Life Science sector if the NHS continues to be a barrier to innovation adoption.

Looking forward, the public and private sector should work together to identify where additional funding can be most effective, what our unique comparative advantages are and how we can remove any current obstacles in the way of innovation. In the NHS the Accelerated Access Reform (where the NHS fast tracks innovation in return for price discounts from industry) is the model to follow.

Brexit offers the opportunity for Britain to cement its position as a global leader in life sciences - and our new Industrial Strategy a chance to put innovation right at the heart of our national plan. It only makes sense that we keep innovation at the centre of our Aid Strategy too.

From Edward Jenner pioneering a smallpox vaccine to Alexander Fleming's discovery of penicillin, British scientists and innovators have always been at the forefront of tackling global challenges. As the Ebola crisis showed, UK life science R&D, aid, defence and Pharma industry were key to avoiding a global pandemic.

We should be proud of that - and make sure that Brexit is a catalyst for doing more of it, by being a catalyst for enhancing the UK as a crucible of both new R and D and global exporting of innovation.

George Freeman MP
Chair, Conservative Policy Forum   Chairman, Prime Minister's Policy Board

The Case for R&D

Is today's technology good enough?

The world faces many challenges. 750 million people live in extreme poverty, while 10 million a year die from diseases that could be cheaply prevented or managed. Over a billion people do not have access to electricity, and nearly two billion have no clean water. Increasing antimicrobial resistance could cost another ten million lives a year by 2050, and we cannot rule out a global pandemic, a bigger killer in the past than war.[1]

Overseas aid is both one of the best ways to address many of the world's challenges, and a powerful part of Britain's soft power, extending our influence. Now that the Government has confirmed that it will continue to spend 0.7% of GNI on aid, there should be a new focus on improving the effectiveness of aid spending. Our June report *Global Britain, Global Challenges* argued for the creation of a new Office for Aid Effectiveness, working with DFID to ensure that all major aid programmes are at least as effective as direct cash transfers.

In this report, we want to consider in detail one of the most effective types of aid: R&D. Spending on research can support the development of pro-poor products that would not be commercially viable otherwise, such insecticide-treated bed nets or crop varieties better suited to tropical conditions. The creation of new varieties of maize over the last fifteen years, for example, is estimated to have taken over a million people out of poverty.[2] As important as this direct kind of development, other types of research in the social sciences can help us identify what types of intervention are most effective, or better identify the deep causes of poverty.

Greater spending on research is supported even by many traditional 'aid sceptics' like Angus Deaton or William Easterly. Given that it is spent 'for' rather than 'in' developing countries, there is next to no risk of R&D aid being diverted away by corrupt officials or being used to prop up illiberal regimes. The risk of negative side effects or undermining political institutions is very low.

Even putting this to one side, there is a good case that R&D should make up a larger proportion of our aid budget. On average, R&D seems to have high returns compared to standard thresholds for effectiveness, and yet has traditionally been underfunded by international donors. Much of the international development community still sees aid through the cold war mind-set of direct government to government transfers. Since 1995, R&D has averaged only 0.9% of total aid, while by contrast in developed countries R&D makes up over 2% of OECD countries' GDP.[3]

Fundamentally, more research is needed because current technologies are not good or cost effective enough to solve future global challenges:

1 Adapted from Global Britain, Global Challenges, Jonathan Dupont, Policy Exchange, 2017

2 What is the evidence on the impact of research on international development?, DFID, 2014

3 OECD CRS database, http://www.oecd.org/sti/msti.htm

- In **health**, new vaccines are constantly needed to keep ahead in the race with growing drug resistance, which is already responsible for 700,000 deaths a year. It remains too difficult and expensive to accurately diagnose many diseases like TB,[4] and substantial gaps exist in our understanding of many diseases. Expanding Western-style medical systems is financially unrealistic for many developing countries – and is creating severe cost pressures even in advanced economies. At the same time, new technologies like CRISPR gene editing offer potentially revolutionary new treatment options.
- In **energy**, today's renewables and battery technology are unlikely to be cost effective enough once intermittency is taken into account to achieve the IPCC's recommended 80 percent reduction in $C0_2$ by 2050. The International Energy Agency expects demand for energy to rise by 30% by 2040. This is even if 500 million people remain without any access to electricity and 1.8 billion remain reliant on unclean biomass for cooking. Very little research has been done into the safe use of geo-engineering as an insurance policy against catastrophic climate change, while current methods of carbon capture remain highly expensive.
- In **agriculture,** the world population is expected to increase to 9.7 billion by 2050. The methods used to drive the original 'Green Revolution' have not proved successful when transplanted to sub-Saharan Africa. 795 million people remain undernourished, and global food demand is expected to increase by 70% by 2050. Better GM crops and new forms of AgriTech could potentially revolutionise yields, but will need to be optimised for the African climate.

At the same time, there are also opportunities for the developing world to use emerging technology to leapfrog the traditional path of technological development. While only 30% of Africans have access to sewerage, 54% roads and 65% electricity, 93% have access to cell phone service.[5] This is enabling developments like:

- In **FinTech**, digital currency M-Pesa, first created in 2007, now has over 30 million users with over 6 billion transactions in 2016.[6] Looking forward, the wider penetration of smartphones and more secure block-chain driven technology should enable a new generation of applications, from microfinance loans to access clean energy to more secure direct cash transfers.
- In **machine learning, 3D printing and big data,** smarter technology can help developing countries overcome some of the challenges of poor basic infrastructure. DFID is already trialling drone-based deliveries of blood and other essential medical supplies, while smart water pumps can reduce maintenance delays and monitor underling water supply.
- In **digital government,** both developing and advanced economies have the potential to automate much of the routine work of government. UK mHealth start-up Babylon is already planning to offer its telemedicine services to the entire population of an East African nation. Online education courses deliver the largest tangible career benefits in developing countries to those with low levels of education or social economic status.[7] More fundamentally, increased transparency can help spread democratic norms and reduce the opportunity for corruption or capturing resources.

4 A conversation with Anna Bershteyn on July 17, 2014, GiveWell, http://files.givewell.org/files/conversations/Anna%20Bershteyn%207-17-2014%20(public).pdf

5 Building on progress: Infrastructure development still a major challenge in Africa, Winnie V. Mitullah, Romaric Samson, Pauline M. Wambua, and Samuel Balongo, Afrobarometer, 2016

6 M-Pesa: Kenya's mobile money success story turns 10, Kieron Monks, CNN, February 24 2017 http://edition.cnn.com/2017/02/21/africa/mpesa-10th-anniversary/index.html

7 Who's Benefiting from MOOCs, and Why, Chen Zhenghao, Brandon Alcorn, Gayle Christensen, Nicholas Eriksson, Daphne Koller, Ezekiel J. Emanuel, Harvard Business Review 2015 https://hbr.org/2015/09/whos-benefiting-from-moocs-and-why

Box 1: How British research makes a difference

Britain is fortunate to host many of the world's leading research institutions, including many that are highly relevant to development. The **Liverpool School of Tropical Medicine** was the world's first research institution dedicated to tropical medicine, while the **London School of Hygeine & Tropical Medicine** today is regularly described as the world's leading centre for tropical medical research.

Publicly funded R&D helps support the wider research ecosystem, with significant spill-over effects for Britain's science base and the economy. While the universities of the 'Golden Triangle' (London-Oxford-Cambridge) are justifiably famous, significant research strengths exist right across the country, such as Norfolk's plant science **John Innes Centre** or the **Scottish Roslin Institute** that focuses on animal sciences.

Many research innovations benefit both Britain and developing economies. For example, UK expertise in improving crop yields supports the high productivity of British wheat and has led to British funded research contributing to almost half of the wheat produced in devleoping countries, producing annual economic benefits of $2.2 to $3.1 bn.[8]

Examples of UK funded research, development and technologies

Peek is a London based company, spun out of the London School of Hygiene & Tropical Medicine, that develops smartphone based visual assesment apps to allow ordinary people to screen the sight of others. This enables early detection and referal and freeing up specialists to spend more time working in hospitals. Over 100,000 children have now been screened in Kenya by their teachers, with 5% of these found to need a referall.[9]

VSV-EBOV is an Ebola vaccine, for which DFID helped fund the first clinical trials, in colloboration with the UK's Wellcome Trust and Jenner Institute. Initial results from phase III trials in Guinea have appeared promising, with no cases of Ebola reported among those who had received the vaccine.[10] Without a vaccine, future outbreaks of Ebola are highly likely, with the most recent outbreak killing over 11,000 people and inflicting a mortalty rate of 50%.

UAVAid is a British developed Unmanned Autonomous Vehicle Platform, specially designed for applications in development healthcare and emergency humanitarian response. Their drones have the ability to deliver 10 kg packages up to 150 km, or to hover and provide video surveillance for up to six hours. Much cheaper than a helicopter pilot and more reliable than satellite imagery, drones are increasingly used in maintaining the cold chain for medical delivery, surveying infrastructure or disaster situations, or monitoring fishery or forestry stocks.

Coartem Dispersible is the first high-quality, fixed dose child friendly treatment for malaria. Young children are disproportionally affected by malaria – killing a child in Africa roughly every two minutes – and the new drug is designed to be sweet tasting and dissolvable in water. Since its launch in 2009, 300 million treatments have been delivered to 50 malaria-endemic countries. The drug was created as a partnership between Novartis and the Medicines for Malaria Venture (MMV), of which the UK has been a key funder. Other DFID research has helped support the development of a much safer treatment for **sleeping sickness**, the first to be developed in 25 years, and a new vaccine against **Newcastle disease**, a viral bird disease that often infects small-scale poultry holders.

Hybrid Air Vehicles is a British based leader in hybrid aircraft, combining lighter-than-air airships with modern technology derived from helicopters or jet planes. The company's Airlander 10, the world's largest aircarft, is designed to be able to transport a 10 tonne payload, stay airborne for up to 20 days, and land in unprepared environments. This has applications for disaster relief, with the vehicle able to be configured as a 'flying hospital' or to rapidly bring in emergency supplies even where basic infrastructure is lacking.[11] Airlander 10 is currently in the middle of a flight test programme, while looking forward Hybrid Air Vehicles is planning on developing the Airlander 50 and ultimately Airlander 200.

MenAfriVac is a new low cost vaccine for meningitis, the initial clinical trials for which were the result of a parternship beween the US's CDC and UK's Heath Protection Agency. Over 235 million people have now been immunised, and by 2020 it is expected to prevent 150,000 deaths and 250,000 cases of severe disability. DFID is now funding further vaccine development to immunise against strands not covered by MenAfriVac, while the London School of Hygeine and Tropical Medicine is leading the largest ever project to better understand how meningitis spreads across Africa.

8 DFID Research Review, October 2016

9 Drones and phones: how mobile tech is fighting global diseases, Jacqui Thornton, London School of Hygiene & Tropical Medicine, August 2017 https://www.lshtm.ac.uk/research/research-action/features/drones-and-phones-how-mobile-tech-fighting-global-diseases

10 Final trial results confirm Ebola vaccine provides high protection against disease, World Health Organization, 23 December 2016 http://www.who.int/mediacentre/news/releases/2016/ebola-vaccine-results/en/

11 Hybrid Air Vehicles—addressing humanitarian needs with lighter-than-air transport, Joseph Dawson, Innovate DFID, Oct 31 2016 https://medium.com/frontier-technology-livestreaming/hybrid-air-vehicles-addressing-humanitarian-needs-with-lighter-than-air-transport-daf03e8781f2

M-Kopa Solar allows households in East Africa to use mobile phone payment to access cheap solar power, and avoid the use of polluting kerosene. So far, it has connected over 500,000 homes and 2 million people to solar power, creating an estimated $375 mn in savings over the next four years.[12]

Microbiocides are compounds that can be applied to protect against sexually transmitted diseases, including HIV. The UK has funded microbiocide research since the early nineties, and recently donated £15 million to support the development of monthly vaginal ring to prevent HIV, and the development of a new ring to combine this with a contraceptive. At present, HIV and maternal mortality are the leading cause of death for women of reproductive age in developing countries.[13] Modelling by the London School of Hygiene and Tropical Medicine suggests that even if a microbiocide was only 60% effective and used by a third of women in developing countries, over 6 million HIV infections could be prevented over 3 years.[14]

The **Smart Water System** is a project run by the University of Oxford, creating handpumps that use machine learning to automatically detect faults and SMS for an engineer. At present, a lack of maintenance means that at any one time around a third of handpumps can be broken. Initial trials of the system in Kenya showed an average reduction in pump downtime from 37 days to 2.[15] The data from the pumps is now being used to gain a more accurate picture of groundwater supplies and monitor water security.[16]

Super Spuds are new varieties of vitamin A enhanced sweet potato, which as of 2015 had reached 3 million farming households and was highly effective in savings lives ($15-20 per DALY). Around a third of children under five are at risk of illness and poor vision as result of vitamin A deficiency, and in total around two billion people around the world are estimated to be at risk of malnutrition. The UK has been a signficant funder of research into 'biofortification' through its contributions to global HarvestPlus project, helping develop nutrient-enhanced varieties of beans, maizes, wheat, rice and potatoes.[17] Other research has focussed on making more durable crops. **Scuba Rice**, for example, developed by the International Rice Research Institute and supporteed by DFID, can survive up to three weeks of total submersion in water.

Many of the most important innovations of the last two centuries have come from the private sector, or individual inventors following their own curiosity. Two-thirds of the £32 billion a year in British R&D is funded by business.[18] The so-called 'linear model of innovation', in which ideas are first publicly funded science and then go on to be commercialised by the private sector, is far too simplistic.[19] Neither should the importance of commercialisation or translation research be ignored. Alexander Fleming may have discovered penicillin, but it would not have to come to market without significant investment by private firms.

Nevertheless, there are many reasons a priori to expect the market to underfund basic science and research:

- New ideas are non-rivalrous and non-excludable, making it hard for innovators to fully capture the value from their innovation. Economist William Nordhaus calculated that innovators only capture 2.2% of the social value created by their inventions.[20]
- Private asset markets can be overly short-termist, and there are good reasons to believe that the appropriate intergenerational social discount rate is below going market interest rates. Given its scale and ability to self-insure against risk, government can often afford to take more risks and a longer term perspective than the private sector.
- While charitable foundations and personal donations can fill some of the gaps left by the private sector, without market discipline these sources often can fall prey to cognitive biases like scope insensitivity or favouring 'warm glow giving' rather than the most important causes.

12 http://solar.m-kopa.com/about/company-overview/

13 IPM Receives £15 Million from UK Government to Advance Innovative Health Products for Women, International Partnership for Microbiocides. http://www.ipmglobal.org/publications/ipm-receives-%C2%A315-million-uk-government-advance-innovative-health-products-women

14 Microbicides, WHO. http://www.who.int/hiv/topics/microbicides/microbicides/en/

15 DFID Research: Intelligent water pumps in rural Africa, DFID, 16 May 2013. https://www.gov.uk/government/news/dfid-research-intelligent-water-pumps-in-rural-africa; 'Smart Handpumps' to bring a reliable water service to rural Africa, University of Oxford, 2 July 2015, http://www.ox.ac.uk/news/2015-07-02-%E2%80%98smart-handpumps%E2%80%99-bring-reliable-water-service-rural-africa

16 'Good vibration' hand pumps boost Africa's water security, Matt McGrath, BBC News, 24 February 2017. http://www.bbc.co.uk/news/science-environment-39077761

17 Super spuds help beat hidden hunger in Uganda, DFID, 6 August 2012. https://www.gov.uk/government/case-studies/super-spuds-help-beat-hidden-hunger-in-uganda

18 UK gross domestic expenditure on research and development: 2015, ONS, 16 March 2017, https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2015

19 The "Smartest Guys in the Room" theory of innovation policy, Stian Westlake, 21st October 2016, http://www.nesta.org.uk/blog/smartest-guys-room-theory-innovation-policy

20 Schumpetarian Profits in the American Economy: Theory and Measurement, William D. Nordhaus, 2004, http://www.nber.org/papers/w10433.pdf

This matters all the more, because we know that in the past R&D projects have been among the most important interventions we know of:

- Alexander Fleming's accidental discovery of penicillin in 1928, beginning the modern anti-biotics age, is estimated to have saved change to many millions of lives.[21]
- The US' investment of $26 million into developing a polio vaccine in the 1950s is estimated to have prevented 160,000 deaths and generated a net benefit of $180 billion.[22]
- Norman Borlaug's Green Revolution created new high-yield disease-resistance varieties of wheat, which combined with bringing modern agricultural practices to Mexico, Pakistan and India, has been credited with saving up to 1,000,000,000 lives from starvation.[23]

Box 2: What is the average return from R&D?

While nobody doubts that some past individual R&D projects have had spectacular returns, what is the typical average return? Quantifying this is far from straight forward:

- In some areas, such as accelerating growth or improving health life expectancy, we have relatively established methods to value benefits. In other fields, we have much less agreement over how to commensurate different standards of value – with little standard practice in how much stimulating an additional year in employment should be valued, let alone more intangible goals like increasing democratic engagement or social tolerance.
- The link between original research and final impact is hard to measure. Causation is often overdetermined, and even if we could trace back to an original piece of research, it is difficult to judge the null hypothesis of what would have happened if that research did not exist. Would the steam engine still have emerged in the eighteenth century without research into the vacuum force in the seventeenth century? Would the web still have emerged in a different form in the 1990s without DARPA's earlier funding of packet-switching technologies in the 1960s? We don't know. The widespread occurrences of simultaneous invention, from Newton and Leibniz (calculus) to Alexander Graham Bell and Elisha Gray (the telephone), suggests that individual researchers aren't always as important as we might think.
- The gap between original research and final impact can have its own 'long and variable lags', stretching beyond the usual horizons of most studies. While much of private R&D seems to pay off in 1-3 years,[24] public R&D can experience much longer lags. Cardiovascular research, for example, is estimated to have taken on average 17 years to achieve its true impact.[25] Other research can take decades, if not centuries, to pay off.
- We know that paper citations follow a power law,[26] with the most popular papers cited orders of magnitude more than the average paper, and many never get cited at all. While the number of citations may not be a perfect proxy for overall impact, it seems reasonable that the distribution of impact is similarly broad. We see similar power laws in many other similar arenas, such as the distribution of firm profits or worker wages. Looking at the average or mean impact of R&D on its own is likely to be highly misleading.

Despite these challenges, there is a small literature that tries to work out the rate of return on both public and privately funded research:

- Most studies follow the top-down methodology set out in the influential work of Griliches (1979), decomposing growth into the proportion that can be accounted for by measurable inputs (labour, capital, intermediate inputs) and correlating the remainder (total factor productivity, or TFP) against R&D. While relatively simple in theory, these approaches face many measurement difficulties, including taking account of unpriced quality improvements, depreciation, spill-over effects and working out the 'stock' of R&D capital that already exists.
- Most studies find that the private return to private sector R&D is surprisingly high: in the order of 20-30%.[27] (For reference, the Treasury's Green Book assumes a real discount rate of 3.5%, and UK equities have averaged a real return of 5% over the long term.[28]) Given that

21 What if Fleming had not discovered penicillin?, Sulaiman Ali Alharbi, Milton Wainwright, Tahani Awad Alahmadi, Hashim Bin Salleeh, Asmaa A. Faden, Arunachalam Chinnathambi, 2014

22 The Astonishing Returns of Investing in Global Health R&D, Lawrence Summers, Gavin Yamey, 2015

23 Congressional Tribute to Dr. Norman E. Borlaug Act of 2006. https://www.gpo.gov/fdsys/pkg/PLAW-109publ395/html/PLAW-109publ395.htm

24 Rates of return to investment in science and innovation, Frontier Economics, June 2014, https://www.frontier-economics.com/documents/2014/07/rates-of-return-to-investment-in-science-and-innovation.pdf

25 Medical Research: What's it worth?, Health Economics Research Group & RAND Europe, Medical Research Council, 2008

26 Wrong Number: A closer look at Impact Factors, May 5 2015, https://quantixed.wordpress.com/2015/05/05/wrong-number-a-closer-look-at-impact-factors/

27 Measuring the Returns to R&D, Bronwyn H. Hall, Jacques Mairesse, Pierre Mohnen, December 2009, http://www.nber.org/papers/w15622.pdf; Rates of return to investment in science and innovation, Frontier Economics, June 2014, https://www.frontier-economics.com/documents/2014/07/rates-of-return-to-investment-in-science-and-innovation.pdf

28 http://monevator.com/uk-historical-asset-class-returns/

this is significantly higher than most companies internal 'hurdle rate', it remains a puzzle why companies don't invest more. Moreover, the 'social rate of return', including the wider spill-over benefits that don't go back to the original inventor, can be even bigger, two to three times higher than this.

- There is less research looking at the impact of specifically public funded R&D, with much of the evidence focusing on the returns from government research in agriculture, where social returns often averaged 30-40%. A more recent study from Haskel et al (2014) finds a social rate of return of 20% from publicly funded science and research, although this does not include potential additional benefits from additional crowded-in private R&D.
- Other studies have looked in depth at the rates of return of health research – and in this more constrained field, have been able to use more bottom-up methods. One 2009 study into the impact of cardiovascular research, for example, looked at the proportion of clinical guidelines that was attributable to UK research, and used this alongside aggregated studies on additional QALYs generated by specific interventions on patient groups.[29] Further research has updated this with new estimates of the crowding-in effect of publicly funded R&D, and suggests that the total rate of return, taking in both economic and health effects, is in the order of 2^{4}-28%.[29]

How much do we currently spend on R&D?

Britain is already a world leader in development R&D, but we could do still more.

In 2015, British aid for R&D amounted to £419 million, an increase of 33% on 2014 in real terms and of 216% since 2010. Overall, R&D makes up about 5% of the UK's total ODA budget.[30]

British aid for development comes from several different funding streams:

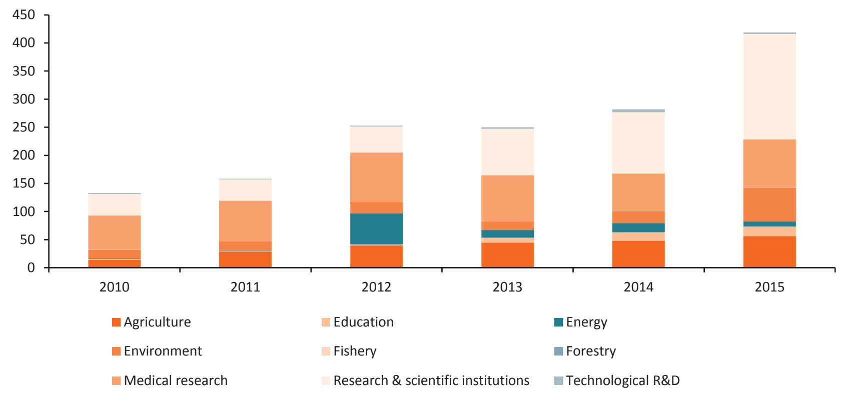
- In recent times, DFID by itself has spent around 3% of its total budget on research, over the next four years, it plans to spend £390mn per annum.
- A £1.5 billion **Global Challenges Research Fund** to be spent 2016-2021 "to ensure UK science takes a leading role in addressing the problems faced by developing countries." This fund is managed by BEIS, but largely delivered through the Research Councils and National Academies.
- A £1 billion **Ross Fund** to be spent 2016-2021 on "research and development in products for infectious diseases…. [enabling] the development and testing of vital vaccines, drugs, diagnostics, treatments and other technologies to help combat the world's most serious diseases in developing countries." This fund is jointly managed between DFID and the Department of Health.
- A £735 million **Newton Fund** to be spent 2014-2021 providing match funding for partner countries to promote development through science and innovation partnerships, with a focus on increasing capacity, collaboration and translation. This fund is managed by BEIS.

The largest component of R&D aid has consistently been aid to research and scientific institutions and medical research, equalling £187 million and £86 million respectively in 2015. While aid to research and scientific institutions had by far the largest growth in absolute terms over 2010-2015, the components that grew more rapidly in relative terms were educational and energy research. Overall, the breakdown of R&D ODA largely matches other OECD countries, with slightly more spent proportionally on medical research, and slightly less on agriculture.

29 Medical Research: What's it worth?, Health Economics Research Group & RAND Europe, Medical Research Council, 2008
Public medical research drives private R&D investment, February 2016, https://www.kcl.ac.uk/sspp/policy-institute/publications/SpilloversFINAL.pdf

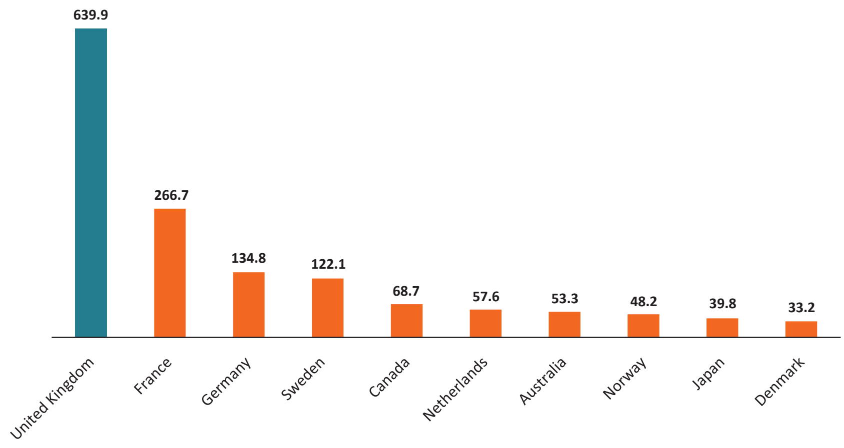
30 Author calculation from OECD CRS, converted from dollars

Figure 1: UK ODA to R&D (Development Initiatives £mn)



In absolute terms, however, the UK is an outlier, spending significantly more according to the OECD's DAC data on R&D than any other donor - more than half again than France, the second largest.

Figure 2: UK ODA R&D compared to other DAC donors (Development Initiatives)

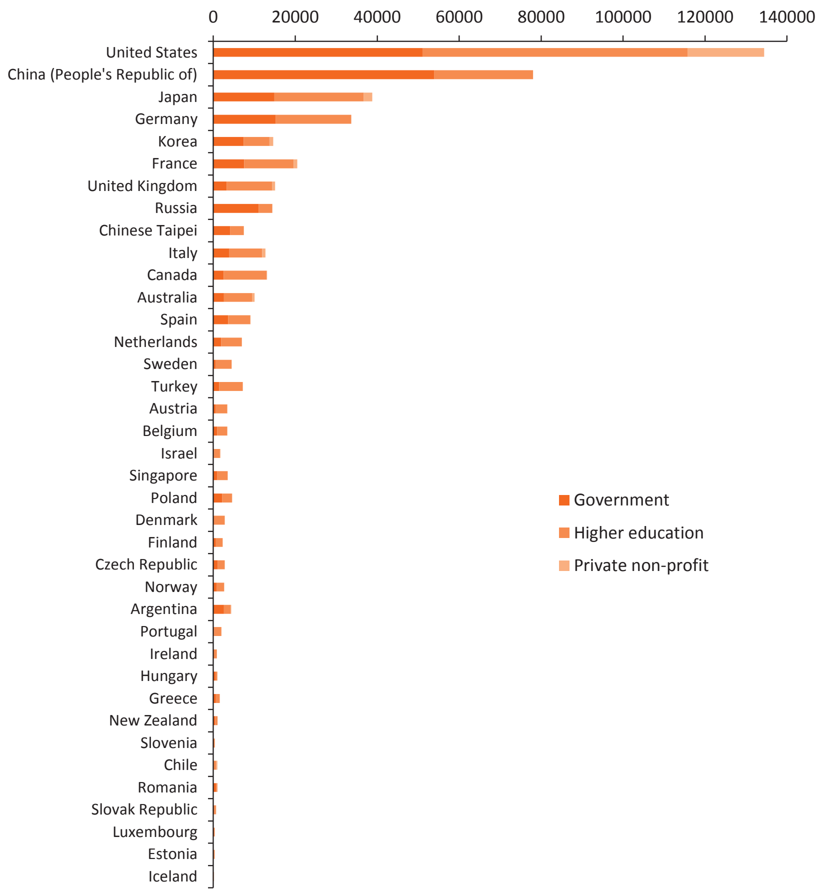


We shouldn't put too much emphasis on this ranking. There is significant inconsistency in how OECD countries record R&D as part of their ODA, and more fundamentally, given its non-rivalrous nature, it is hard to draw a clear line between public R&D that should count a global public good and that which primarily benefits your own country.

We know that there are significant research spill-overs internationally – and while R&D in advanced economies often prioritises our own needs, it does not mean that basic research in, for example, better battery storage or treating cancer, will not also help developing countries further down the road. Official ODA R&D is likely only a small part of the story when it comes to developing countries.

Looking at the wider R&D budget and excluding business spending, where the argument for it being a global public good is weakest, the UK is only the 7th largest spender on research – spending just 11% of the $134 bn spent by the US in 2013.

Figure 3: Total Non-Business Spending on R&D (GERD, 2013, $mn, OECD)



Overall, non-business spending on R&D has largely been flat in the UK since the financial crisis. The Government's Science budget was frozen in cash terms during the Coalition Government, and then in real terms from 2015-2020 during the 2015 Spending Review at £4.7 billion.

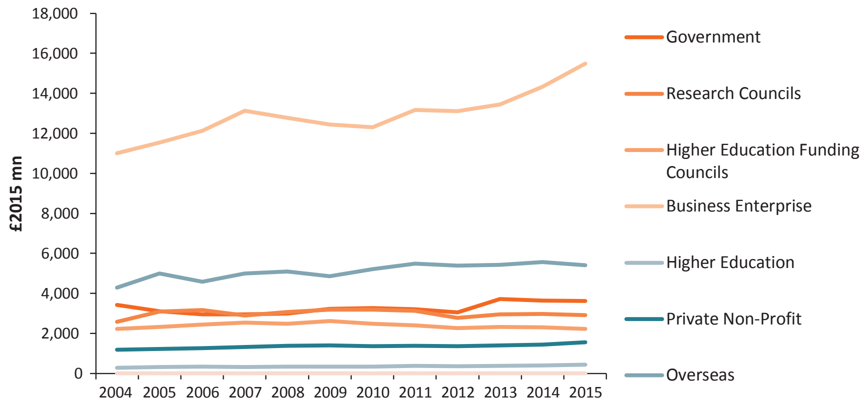
Some in the R&D community have gone as far as to argue that initiatives like the Global Challenges Research Fund or Ross Fund do not actually represent any real new money or re-ordering of priorities, but instead a relabelling of part of existing government budgets.

This is likely too sceptical. Most independent reviews suggest that the new research streams are being spent on genuinely ODA-eligible research.

In any case, post Brexit the Chancellor Philip Hammond announced an additional increase of £2 billion for government R&D, the largest rise in forty years. At the same time, the 2017 Conservative Manifesto committed to raising

UK spending as a proportion of GDP to match the OECD average within ten years, to increase the number of scientists working in the UK and to create a regulatory environment that encourages innovation. Higher spending on research is increasingly important not just to the Government's approach in development, but also its wider Industrial Strategy too.

Figure 4: UK Real Spending on R&D (GERD, ONS)



Should we spend more on development R&D?

Is the UK right to ramp up the proportion of ODA going toward R&D – and should we be spending still more?

There is some research on the average rate of return for publicly funded research as a whole (see Box 1), which while imperfect, suggests that the return could be as high as 20%, an order of magnitude higher than the normal threshold for public investments.

Unfortunately, there is very little statistical research on R&D specifically related to development, how this relates to the average return from other development initiatives, and most importantly, what the *marginal* rather than average return is likely to be.

While we cannot answer this question with pure econometric evidence, that does not mean we are completely in the dark.

What would we need to know to figure out the potential marginal return?

- **Importance.** What returns are likely from additional research, and do they exceed the opportunity cost? How do they compare to the deployment of the technologies and the methods we already have?
- **Neglected.** How many gaps are there in the current research base? Will new resources be truly additional, speeding up the development of new technologies, or simply crowd out already existing funders?
- **Traction.** Is a lack of money really the most important bottleneck, or is it likely to run rapidly into diminishing returns? Do the majority of new discoveries come from already funded 'superstar' researchers, with additional manpower unlikely to make much difference?

In the rest of the chapter, we will go through each of these in turn.

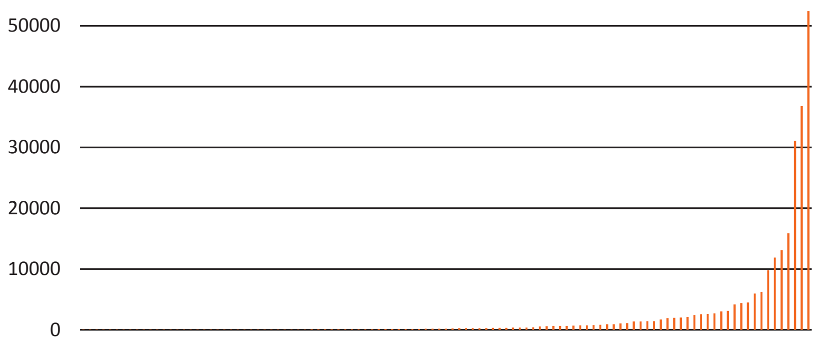
How does R&D cost effectiveness compare to direct deployment?

In general, we have two primary methods for comparing the cost effectiveness of different interventions:

- **Disability Adjusted Life Years per $ (DALYs).** In health, there is an extensive data looking at the cost effectiveness of treatments in terms of the additional years in life expectancy they can achieve, adjusted for the quality of life experienced.
- **Benefit-cost ratio.** In order to compare a broader range of interventions, we can look at the ratio between the net present value of total benefits and total costs. While any project with a BCR above 1 is theoretically worthwhile, the Treasury normally insists on at least a 2.0 BCR to allow for optimism bias.

As you might expect, cost effectiveness can vary massively. The 2006 Disease Control Priorities Project (DCP2) compiled data on 110 interventions, ranging over multiple orders of magnitude from $3/DALY for treating soil-transmitted helminthic infections to $52,449/DALY for Kaposi's sarcoma. Similarly, the Post 2015 Copenhagen Consensus Center found BCEs that ranged from 0.3 for cutting outdoor air pollution to the colossal 2,011 for reducing world trade restrictions.

Figure 5: Cost effectiveness of Different Health Interventions (DCP2, $/DALY)



The most developed thinking on cost effectiveness comes in the field of health, where interventions are often cost effective if they cost less than 3x GDP per capita per DALY, or highly effective if they cost less than 1x GDP per capita per DALY. For low income countries, this is currently equivalent to around $2000 or $600 respectively.[31] (In the UK, NICE judges interventions to be cost effective if they cost less than £20,000 to £30,000 per QALY – which again, is in the region of British GDP per capita.)

Inevitably, these thresholds are somewhat arbitrary, and in recent years many have argued that they are not demanding enough. There is some evidence that

31 GDP per capita, World Bank, http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

average health expenditure in developing countries already tends to be below the 1x GDP per capita threshold for high effectiveness,[32] while charity evaluators estimate that some of the most effective charities operate at around $100 per DALY.[33] Woods et al (2016) suggest that based on opportunity cost – the marginal cost effectiveness of already existing interventions in a country – reasonable thresholds should be set somewhere between 1-51% of GDP for Malawi (the poorest country in the world) and between 4%-41% for Cambodia (on the border between low and middle income).[34]

If we take an average, this implies a cost effectiveness threshold of somewhere in the order of 20-25% of GDP, or the equivalent of around $120-$150 for low income countries. This is equivalent to a benefit-cost ratio of 4-5. Given that there are good reasons to think that health projects are among the most effective of development initiatives, this is unlikely to set an overly generous high threshold when considering the ODA budget as a whole. Any intervention that meets this threshold is likely to be highly effective.

Coincidentally, this threshold is also around the same level of effectiveness as the Copenhagen Consensus Center estimated for using money transfers to end extreme poverty[35]: a BCR of 5:1. Our June report *Global Britain, Global Challenges* recommended that we should ensure all interventions are at least as effective as this, or at least as efficient as direct cash transfers.

Is development R&D likely to be cost effective against a rule of thumb threshold of $120 / DALY, or a BCR of 5:1?

There are good reasons to think that this is not implausible, with many past estimates of potential R&D projects suggesting returns in this ballpark, if not significantly better:

- DFID estimates that its current research portfolio has an average expected internal rate of return of 10% or over, [36] equivalent to BCR of 7 over 20 years.
- The Office for Health Economics found a cost per DALY of $12-$107 for public private partnership R&D into vaccines, and $12 to $17 for drugs.[37]
- The Center for Global Development estimated that an advanced market commitment for new treatments for malaria could deliver DALYs at $15.[38]
- Bio Ventures for Global Health estimates that new vaccines for tuberculosis could save DALYS at $6 to $26 per DALY.[39]
- The International Aids Vaccine Initiative estimated that an advanced market commitment to pay for a vaccine for AIDs could deliver DALYs at $21-$67.[40]
- The Global Priorities Project estimates that the marginal return on research into major neglected tropical diseases is around $71, although some diseases such as malaria potentially had substantially higher returns.[41]
- The 2013 Lancet Commission estimated that investing $800-900 million per year in order to create a HIV vaccine of 50% efficacy by 2030 would achieve a benefit-cost ratio between 2 and 67.[42]
- The Post 2015 Consensus by the Copenhagen Consensus Center estimated that research to increase food yields had a BCR of 34, while investing 0.5% of GDP in green energy research would achieve a BCR of 11.[43]

32 Cost Per DALY Averted Thresholds for Low- and Middle-Income Countries: Evidence From Cross Country Data, Jessica Ochalek, James Lomas, Karl Claxton, Centre for Health Economics, December 2015, https://www.york.ac.uk/media/che/documents/papers/researchpapers/CHERP122_cost_DALY_LMIC_threshold.pdf

33 GiveWell cost effectiveness analysis – November 2016, https://docs.google.com/spreadsheets/d/1KiWfiAGX_QZhRbC9xkzf3I8IqsXC5kkr-nwY_feVlcM/edit#gid=115155829

34 Country-Level Cost-Effectiveness Thresholds: Initial Estimates and the Need for Further Research, Beth Woods, Paul Revill, Mark Sculpher, Karl Claxton, 2016, http://www.sciencedirect.com/science/article/pii/S1098301516000644

35 Post-2015 Consensus: Poverty Assessment, John Gibson, Copenhagen Consensus Center, http://www.copenhagenconsensus.com/publication/post-2015-consensus-poverty-assessment-gibson

36 DFID Research Review, October 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/564075/Research-review4.pdf

37 Donor Investment choices: Modelling the Value for Money of Investing in Product Development, Public Private Partnerships as Compared to Other Health Care and Non-Health Care Interventions, A. Gray, P. Fenn et. al., Office of Health Economics, 2006

38 Making Markets for Vaccines: Ideas to action, Ruth Levine, Michael Kremer & Alice Albright (Co-Chairs), Centre for Global Development, 2005

39 Tuberculosis Vaccines: The Case for Investment, BIO Ventures for Global Health, 2006

40 An Advance in Market Commitment for Aids Vaccines: Accelerating the Response from Industry, International AIDS Vaccine Initiative, 2006

41 New UK aid strategy - prioritising research and crisis response, Global Priorities Project, 2015

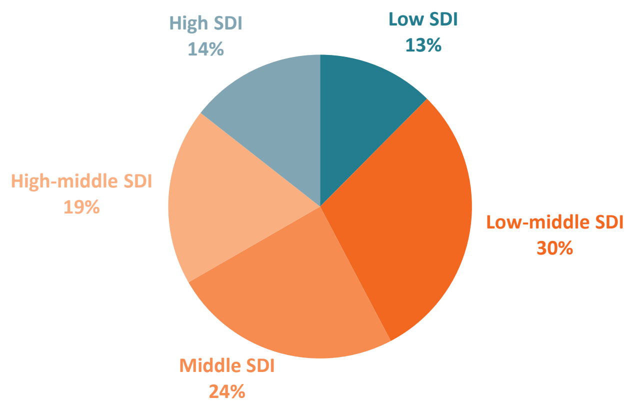
42 Global health 2035: a world converging within a generation, The Lancet, 2013, http://www.globalhealth2035.org/sites/default/files/report/global-health-2035.pdf

43 Post-2015 Consensus, Copenhagen Consensus Center, http://www.copenhagenconsensus.com/post-2015-consensus

Is development relevant R&D currently neglected?

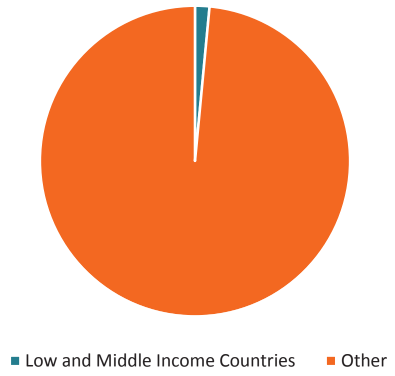
It would be surprising if it wasn't. All the standard public goods arguments for R&D apply even more strongly for work targeted at the developing world, where potential profitability and cash ROI is likely to be significantly lower.

Figure 6: Global Disease Burden by Level of Development (2015)



Between 1975 and 1999, just 16 out of 1393 new drugs were for tropical diseases and tuberculosis.[44] Only around $3 billion a year or 1-2% of total R&D is targeted at infectious diseases in low and middle income countries,[45] with just 10% of medical research dedicated to tackling conditions accounting for 90% of the global disease burden.[46] While they are less studied, similar distributions likely apply in other areas such as energy or agriculture. A priori, it seems extraordinarily unlikely that this is an efficient distribution of resources.

Figure 7: Research targeted at low and middle income countries



44 Priority Research Areas for Basic Science and Product Development for Neglected Disease, Sue. J. Goldie, Jennifer S. Edge, Christen Reardon, Cherie L. Ramirez, 2013, http://globalhealth2035.org/sites/default/files/working-papers/goldie-team-rd-cih-working-paper.pdf

45 Global health 2035: a world converging within a generation, The Lancet, 2013, http://www.globalhealth2035.org/sites/default/files/report/global-health-2035.pdf

46 Discovery & Translation Science – Strategy Overview, Gates Foundation, http://www.gatesfoundation.org/What-We-Do/Global-Health/Discovery-and-Translational-Sciences

Getting more specific, the 2013 Lancet Commission identified more than 500 research gaps in "basic science and product development (diagnostics, drugs, vaccines, and vector control) for tuberculosis, malaria, HIV/AIDS, childhood pneumonia or diarrhoea, and neglected tropical diseases,"[47] while overall the WHO has recommended the current $3 billion in global funding on R&D should be doubled.[48] In the next chapter, we will consider many other potential gaps where further development related R&D could be helpful.

Beyond this, there is now considerable evidence from econometric evidence, case studies and surveys that private and public sector research are normally complements rather than substitutes, with crowding out taking place only rarely.[49] One recent study found that an extra £1 of publicly funded health research crowds in an additional £0.83 - £1.07 of private sector R&D spend.[50]

It is reasonable to question whether crowd-in effects would be so strong for development related work, where potential market profits are far weaker. The flip side of this, however, is that crowd-out effects between public and private sector are also likely to be very weak.

Is further R&D spending likely to run into rapid diminishing returns?

It would be naïve to simply assume that there is always a linear relationship between the amount spent on R&D and the rate of innovation. It is notable that internationally there is no correlation at all – an R^2 of 0.0001 - between the proportion of GDP spent on R&D, and GDP per capita.[51]

Three potential future bottlenecks are worth taking especially seriously:

- Research can be *talent-constrained*, with most progress coming from a relatively small minority of superstar researchers who are already amply funded.
- Research can be *theory-constrained*, with a shortage of basic new ideas, tools or intellectual models to use to attempt to solve old problems.
- Research can be *translation-constrained*, with no sustainable business model or long term funding to iterate, develop and diffuse the research into real world applications.

We will consider the potential bottleneck from translation in more detail in the last chapter when we look at how development R&D should be integrated with the Government's new Industrial Strategy.

First, however, we will consider whether extra financing is likely to run into a shortage of research staff or promising projects to finance.

Talent

Talent-constraint in the academic world seems to be a real problem. Anecdotally, many academics report that at the margin they are more short of talented staff than financing.[52] Ex post, we know that research impact, at least as measured by paper citations, follows a power law,[53] and provides reasonable evidence for the superstar model. The most popular papers are cited orders of magnitude more than the average paper, with many never getting cited at all. No matter how much you spend, you can't simply materialise an extra Richard Feynman.

47 Global health 2035: a world converging within a generation, The Lancet, 2013, http://www.globalhealth2035.org/sites/default/files/report/global-health-2035.pdf

48 Research and Development to Meet Health Needs in Developing Countries: Strengthening Global Financing and Coordination, World Health Organisation, 2012, http://www.who.int/phi/CEWG_Report_5_April_2012.pdf

49 The Impact of Publicly Funded Biomedical and Health Research: A Review, Bhaven N. Sampt, 2011, https://www.ncbi.nlm.nih.gov/books/NBK83123/

50 Quantifying the economic impact of government and charity funding of medical research on private research and development funding in the United Kingdom, Jon Sussex, Yan Feng, Jorge Mestre-Ferrandiz, Michele Pistollato, Marco Hafner, Peter Burridge and Jonathan Grant, 2016, https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-016-0564-z

51 Author calculation based on OECD data.

52 Biomedical Research, 80,000 Hours, https://80000hours.org/career-reviews/biomedical-research/

53 Wrong Number: A closer look at Impact Factors, May 5 2015, https://quantixed.wordpress.com/2015/05/05/wrong-number-a-closer-look-at-impact-factors/

Nevertheless, the ex-ante distribution of research potential is not necessarily the same as the ex-post power law distribution of impact we see in the data. One model of research is that it is a lottery: individual researchers have a roughly equal chance of finding a new idea or research approach, but some ideas have orders of magnitude more impact.

Equally, pure talent is clearly not the only thing that matters, and contrary to the superstar model, the hard sciences are, if anything, getting ever more democratic. Between 1996 and 2015, the average number of authors per paper has increased from 3.2 to 4.4[54], with an average increase of 4.4% per year in science and technology.[55] By 2000, the average number of authors per paper in medical numbers was 7,[56] and in the last two decades 'hyperauthorship', or papers with more than 50 authors, has been far from unusual in physics or biomedicine. Much of the latest research in the life sciences is largely 'hypothesis free', based on extensive trial and error, or using big data to randomly search out interesting patterns in the data. While bravura discoveries might get the press attention, much of actual progress derives from incremental improvements increasing affordability.

Given these trends, it is difficult to sustain belief in the superstar, heroic lone genius model of innovation – or at the very least, those geniuses need a lot of support. While in the short term any particular field may be talent constrained, if we think research deserves more of society's resources, steady and predictable increases in resources and salaries should attract a greater supply of talent. Talent constraints are a good argument for ramping up spending gradually rather than all at once, but not for no rise at all.

Ideas

Is the stock of ideas unlimited? Probably not – but we are a long way from exhausting it. Few people today take the apocryphal Lord Kelvin view that, "There is nothing new to be discovered in physics." In a world of machine learning, big data and CRISPR, there remain ample frontiers to explore.

Nevertheless, while we may not completely have run of ideas that does not guarantee that they won't become harder to find. There are good theoretical reasons to expect investment in R&D to be roughly log-linear, with exponential increases in funding only producing steady increases in benefits.[57]

Empirically, this model seems to match the data well. Overall research productivity seems to be going down, full stop. Between 1998 and 2015 the number of worldwide patents issued increased by 185%[58], but neither growth nor a narrower measure of productivity (TFP) has accelerated. New drugs now seem to cost over $1 billion to develop, while new research by Bloom et al (2017) suggests that idea TFP is declining across industries with substantial increases in the number of researchers not being met by any faster rate of progress. While the effective number of researchers working on crop yields has grown anywhere from 3-25 times, the rate of yield growth has stayed steady at around 1.5% a year. Similarly, rates of increase in US life expectancy have remained steady at around 1.8 years per decade since 1950, while research effort has increased by a factor of 9 since 1970.[59]

54 Why research papers have so many authors, The Economist, November 24th 2016, http://www.economist.com/news/science-and-technology/21710792-scientific-publications-are-getting-more-and-more-names-attached-them-why

55 Increasing number of authors per paper in Korean science and technology papers, Hyunju Jang, Kihong Kim, Sun Huh, Hyungsun kim, 2016, http://www.escienceediting.org/journal/view.php?doi=10.6087/kcse.70

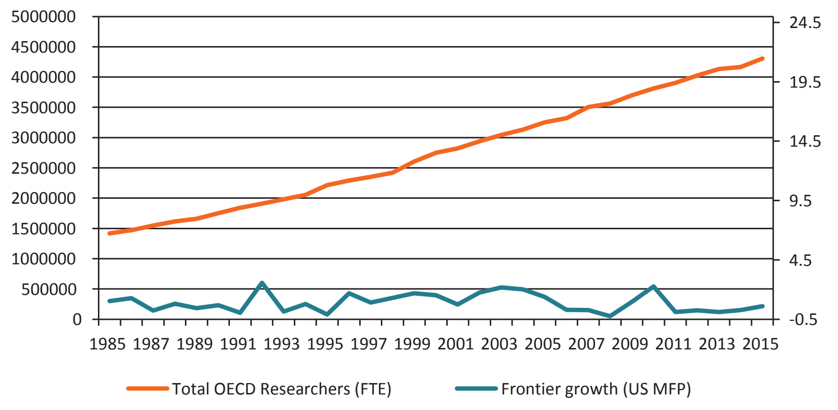
56 Science and the Rise of the Co-Authors, Hilda Bastian, November 25 2015, http://blogs.plos.org/absolutely-maybe/2015/11/25/science-and-the-rise-of-the-co-authors/

57 The law of logarithmic returns, Owen Cotton-Barratt, Global Priorities Project, 2015, http://globalprioritiesproject.org/2015/02/the-law-of-logarithmic-returns/

58 Patent applications filed under the PCT,OECD

59 Are Ideas Getting Harder to Find?, Nicholas Bloom, Charles I Jones, John Van Reenen and Michael Webb, 2017, https://web.stanford.edu/~chadj/IdeaPF.pdf

Figure 8: Declining rate of research productivity (Bloom et al)



This isn't solely because ideas are getting harder to find. Similar types of cost disease and decreased levels of productivity are a pervasive phenomenon crossing over into many other parts of the public sector, including healthcare, education and infrastructure. Are ideas really becoming more difficult to find, or has increased bureaucratisation and over regulation simply made them more expensive?

Nevertheless, even if R&D productivity is declining, this does not necessarily undermine the case for further investment. The private sector has mostly chosen to respond to declining productivity by increasing investment to maintain constant rates of improvement.

According to the estimates by Bloom et al (2017), average idea TFP is decreasing by around 5% a year – suggesting that even if ideas are running out, they are only doing so relatively gradually. Like most things, R&D eventually runs into diminishing returns, but there is little evidence of an abrupt cut off.

What is more, given that research targeted at developing countries has been relatively neglected so far, if anything, development R&D is less likely to be at the point of strongly diminishing returns.

In short, in development there remains a substantial number of important neglected problems. By ramping up funding gradually, we can help build a pipeline of new talent. While there may be diminishing returns as R&D spending increases, our best evidence suggests that this happens gradually, rather than falling off a cliff. In total then, greater spending on R&D at the margin has the potential to be a highly cost effective form of intervention.

What are the most important priorities for future R&D?

As we have seen, there are good in-principle reasons to believe that spending on R&D is highly effective compared to other forms of intervention, and that significant neglected opportunities remain for future research.

In order to test this further, we asked the independent Copenhagen Consensu Center to perform an original survey of potential R&D options to help meet the UN's 17 Sustainable Development Goals: air pollution, biodiversity, conflict & violence, education, energy, food security, gender, governance, health, IFF, nutrition, population, poverty, trade, urbanization and WASH.

Working with 32 academics and subject experts, the Center identified an initial 70-100 research ideas, before narrowing this down to a tighter list of 40 projects for which a first-order estimate of potential benefits and costs could be calculated. All but two of the projects pass our rule of thumb threshold for effectiveness (BCR >5), suggesting that there remains a substantial number of currently neglected, highly cost effective development R&D interventions.

In this chapter, the Copenhagen Consensus Center explain their methodology and how they have estimated benefit-cost ratios for the different R&D options, before giving details of the top ten most cost-effective options. Details on all 40 projects, the complete list of contributors and additional R&D ideas are included as appendices.

Box 3: The Copenhagen Consensus Center

Copenhagen Consensus was conceived more than a decade ago by Dr. **Bjorn Lomborg** to address a fundamental but overlooked question in international development: In a world with limited budgets and attention spans, how do we find effective ways to do the most good for the most people?

The think-tank Copenhagen Consensus developed a ground-breaking benefit-cost ratio methodology, and has conducted global, regional and national research and advocacy projects, working with more than 300 of the world's top economists, including seven Nobel laureates.

In 2004, 2008 and 2012, Copenhagen Consensus commissioned in-depth studies to help set global priorities for development spending and philanthropic investment. The process aims to add prices and sizes to the policy-maker's menu. The idea is to render this process less arbitrary, and to provide evidence upon which informed decisions can be made by politicians, policy advisers, and others.

This approach has shaped spending decisions. The World Bank quoted Copenhagen Consensus in 2006 when it created a new strategy on combatting malnutrition. Findings on the benefits of investing in nutrition were cited by U.K. Prime Minister David Cameron when $4,150 million was pledged by governments at G8 meetings for Global Nutrition for Growth. The NGO alliance InterAction referred to Copenhagen Consensus analysis when it pledged $750 million on nutrition.

Colombian President and Nobel Peace Prize winner Juan Manuel Santos said that Copenhagen Consensus research on biodiversity led to a quadrupling of the size of protected marine reserves.

Copenhagen Consensus projects have shown that an informed ranking of solutions to the world's problems is possible, and that cost-benefit analysis can contribute to a clearer focus on the most effective ways to respond to challenges on a national, regional or global level.

Introduction

Drawing upon past findings, a cost-benefit methodology developed through national, regional, and global research and advocacy projects, and utilising specialist expert input, Copenhagen Consensus has undertaken a study of R&D opportunities across the major fields of international development.

Although limited by time and resources, this analysis identifies 70 R&D proposals that are worthy of more thorough and detailed evaluation.

For 40 of these proposals, data was sufficient to perform an initial analysis that identifies a first-order magnitude of costs and benefits.

Proposals are explored in the areas of governance, non-communicable diseases, air pollution, gender, inter-personal violence, HIV/AIDS, food security, education, infant mortality, illicit financial flows, biodiversity, education, women's health, urbanisation, and water and sanitation.

The study indicates that most R&D proposals identified, if well designed, would constitute a very good use of resources, with social, environmental, and economic benefits to society greater than the cost.

An initial ranking of these 40 proposals was undertaken, which highlights areas where investment in R&D could lead to significant benefits for every pound spent.

This demonstrates that prudent investment in R&D initiatives could greatly assist in advancing international development goals in an effective, cost-efficient manner.

Overview of Approach

With brief time and limited resources, it has been impossible to conduct in-depth cost benefit analyses of R&D options or undertake a full-scale prioritization exercise.

Nevertheless, we believe that it is vital that conversations about development include information on costs, benefits and priorities for R&D. With this in mind, this report offers a preliminary scoping of the R&D opportunities across all fields of international development. It should be seen as a starting point from which detailed analysis could and should be undertaken.

This report makes three main arguments.

First, development R&D is often an extraordinarily good investment that promises to deliver benefits worth many times its cost. However, it is crucial to focus on the right investments. If spending is done poorly and without regard to economic arguments, it is possible that the opportunity to generate billions of pounds of social, environmental and economic good could be missed.

Second, there are many promising areas for research and development. We outline these and make preliminary estimates of their costs and benefits.

Third, the benefits from R&D investment can be identified and compared as a way of maximizing the return on development funding and bringing about the most global good. There is the potential that a pound spent on the top proposals outlined in this report could achieve £100 or even more of social good. An initial prioritization based purely on the BCRs is presented, providing an indication of the diversity of R&D ideas that are likely to achieve the most for every pound spent.

The approach builds on the recent global research project, the Post-2015 Consensus. This studied the United Nations' Global Goals (also known as the Sustainable Development Goals) for 2016-2030. Copenhagen Consensus commissioned research from more than 80 economists from around the globe.[60] For this report, we have worked with many of these economists, although we were limited by the timeframe and researchers' availability.

We asked each economist to identify the best R&D options within his or her area of expertise, to ensure that all major fields of international development were covered.

A broad understanding of R&D was used. Traditionally, R&D is most often associated with technology and product development, but for the purposes of this report, R&D is understood to also encompass policy and implementation issues.

Between them, the economists identified around 70 concrete ideas considered worthy of R&D investment. For 40 of these ideas, we present a preliminary assessment of costs and benefits, and we have been able to undertake a rough 'back of the envelope' calculation that provides an order of magnitude for a benefit cost ratio (BCR).

For others, it was not possible in the time available to carry out the calculations. This was either because there was not enough readily available data from which to estimate costs and potential benefits, or because the proposal was complex and would require more detailed assumptions. The ideas that have not been analysed are included in Appendix B of this report.

In assessing costs and benefits, we identified the first-order magnitude of the cost of the problem, the likely cost of the R&D, and the likely scale of the proposal's impact on the cost of the problem.

Copenhagen Consensus used existing data and evidence to make these estimations, and drew 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 nevertheless represents a well-informed, initial expert assessment and an order of magnitude.

Bringing these estimates together in a cost-benefit calculation provides a very basic assessment of the cost of the R&D compared to the likely benefits. This allows us to begin to categorise proposals by their effectiveness, from those that are likely to only just cover their costs with similar benefits, to others that will achieve extensive global benefits for a small cost.

It is worth emphasizing that we are describing *global* costs and *global* benefits accruing to citizens across the world along with improved environments in the UK and abroad.

Thus, while these R&D proposals may bring considerable benefits for modest costs, the benefits measured are social, environmental and economic. Especially in developing countries, these proposals would not be *privately* profitable, and in many cases there would be no way to monetise the benefits for the spender. That is why it is crucial that many proposals should be funded by a donor such as the UK because resources already set aside will be utilised to do the most possible good for the world.

It is very clear that investing in R&D supports international development in a very effective and cost-efficient way.

60 Information about the project and 1800+ pages of peer-reviewed research are available at www.post2015consensus.com.

Development R&D is often very efficient

Past Copenhagen Consensus research projects have looked in-depth at three concrete development R&D proposals: agricultural R&D to achieve yield enhancement; R&D to develop an HIV vaccine; and increased green energy R&D.

All three analyses demonstrated that the benefit-cost ratio of R&D can be very high and thus very attractive: for agricultural R&D, for every pound 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 each pound; and for green energy, it is likely that ambitious green energy R&D investment will return at least £11 for each pound spent, and is likely much higher. This is a clear indication that development R&D can be very effective. Of course, it also means that if the best development R&D projects are *not* chosen, the potential loss can also be great. This means that it is important to choose carefully.

This work also showed that estimating the benefits and costs of R&D requires a substantial amount of academic work, including examination of many scenarios, and large or even global models that are run with a variety of assumptions.

To illustrate, the assessment of the impact and benefits of an HIV/AIDS vaccine involved consideration of three scenarios. In one, a cure was developed. Two other scenarios made differing assumptions on the level of political will and resource allocation provided to improve treatment access. 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 a substantial acceleration of current progress would require additional vaccine research investment of approximately $100 million annually, on top of existing investment of around $900 million. This figure was used as the basis for further analysis. Additional assumptions were made about the elasticities of the 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.

This analysis, like those into agricultural R&D and energy, hinged on very specific assumptions about 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 agricultural R&D where the intended key benefit is a yield increase, the fundamental assessment of the annual yield increase is based on a literature review but is essentially an estimate. In the R&D for an AIDS vaccine, multiple assessments of future scenarios[61] and of the elasticities of accelerated time-to-product are crucial for generating the results. In green energy, the choice of comparison along with estimates of early-vs-late R&D success generates a wide range of plausible BCRs.

For these reasons, this study must liberally apply assumptions and expert assessment. In an ideal world, it would be possible to indicate specific BCRs rather than provide rough estimates. However, limited time and resources set a hard back-stop to what is possible. More in-depth, sophisticated analysis would allow us to peer further into the future, but we would still not know the unknowable. Thus, we can only ever approximate which are 'good' and 'less good' R&D projects. This in itself, however, is a useful contribution to the better allocation of development R&D resources.

61 Scenario I-III likelihoods

Estimating BCRs for development R&D projects

Identifying R&D ideas and the size of the problem being addressed

In order to arrive at a well-rounded sense of possible projects we took as our starting point the areas covered by the UN's Global Goals (also known as the Sustainable Development Goals) for 2016-2030. Copenhagen Consensus undertook a major review of the SDG targets for its Post-2015 Consensus project. For this analysis we reached out to the economists who worked on the Post-2015 project.

Because of the tight timeframe and the limited availability of researchers, we have consulted with a subset of these researchers, outlined in Appendix A. Through telephone interviews, we asked the researchers to provide their informed opinions on the best and most important development R&D opportunities within their areas of expertise.

In some cases, the ideas were clear and concrete, but in other areas, the ideas needed additional clarification. In all cases, the ideas are not presented as fully formed research proposals. Some areas of international aid, such as health and agriculture, have a stronger track record of applying cost benefit analysis to R&D. Overall, this meant it was easier to make estimates in such fields, than in, for example, education where R&D is not as developed.

Where the economists were able and willing to provide 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 proposals listed in the main section of this report. First, we estimated the cost of the R&D activities. The framework 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 proposal, in terms of the number of people dying or in disability adjusted life years (DALYs), or some other recognised measure. We made use of data from the Global Burden of Disease, from UN agencies, as well as from the Copenhagen Consensus' own research and other peer-reviewed studies.

In the third step, this was converted to an estimate of the cost of the challenge, and therefore the potential benefit in coming up with a solution. For the purposes of this study, we standardised the value of a global DALY, which is estimated across all areas at $3,000.

In addition, following the Global Burden of Disease methodology, all DALYs used in this report are not age-weighted. For almost all analyses, we standardised the costs and benefits 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 would become unnecessary.

The fourth step, which in this report is perhaps the most speculative and 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 R&D, and the potential impact of the R&D in practice. Because of the speculative nature of this step, we were conservative in our assessment, and the potential impact of the R&D was framed in terms of a range of percentages. The fifth and final step was to calculate a benefit-cost ratio by taking the figures reached in earlier steps. This gave a broad order of magnitude estimate for the BCR, and in almost all cases is presented as a range of possible values. While these should not be treated as definitive, they provide initial guidance on where R&D investments could achieve the most good.

A basic framework for assessing R&D costs

Before describing the research ideas, it is useful to outline the basic framework for assessing the costs of each R&D proposal. 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. 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 cookstoves or why parents do not seek health treatment when their children have diarrhoea are examples of social problems. Solving these problems typically requires investigation of a social science nature, for example, randomised controlled trials assessing the cultural root causes of the issue and the efficacy of potential solutions.

Technology problems are those 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, prototyping, piloting trials of increasing size, iteration, refinement and rollout. Designing new medical drugs, new seed varieties or new diagnostic tools are examples of solutions to technology problems.

For a given level of problem heterogeneity, we assume that R&D that addresses social problems has a 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.[62] Research can be as simple as measuring which out of multiple approaches *already used by individuals* is more effective at addressing a certain problem in specific contexts. It can also involve understanding why certain cultures might not prefer to use or cannot readily adopt existing technology used elsewhere. And it can involve testing approaches that might improve the uptake of 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

62 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.

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 shown to be just as intractable as technology problems, for example reducing corruption. We are merely noting that the expected costs of investigation for social problems tend to be lower than for technology problems. For example, a typical randomized control trial experiment in economics might cost $1m-$3m in total. 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 cookstoves appear to be culturally specific, and we can have little confidence that a solution in one country will be replicable elsewhere. On the other hand, a disease such as malaria shows reasonable homogeneity across regions in terms of transmission, symptoms and response to treatment. Indeed, 95 percent of 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 with malaria will work in a similar fashion on a person elsewhere with the same strain. 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 outlines the costs for each and where each R&D suggestion falls within the framework.

Figure 8: R&D cost estimate matrix

	R&D addresses problem of **low heterogeneity**	R&D addresses problem of **high heterogeneity**
R&D addresses **Social Problem**	**COST = $1m-$10m p.a.** Irrigation in sub-Saharan Africa Better use of Insecticide impregnated bednets Distribution of polypill for hypertension Expanding early childhood stimulation programs Opportunities for improved trade agreements between Asia and Africa Better promotion of hand-washin	**COST = $10m-$100m p.a.** Better promotion of clean cook stoves Intimate partner violence Identifying health gains from education Early school drop out Action research programs for governance Public awareness campaign for HIV/AIDs Treatment seeking behaviour for diarrhea Public information campaign for pregnant women Public information campaign on complementary feeding Public awareness campaign to improve diet Improving adherence to TB treatment Mis-invoicing in trade transactions Better implementation of nutrition interventions Chronic disease in LMICs Understanding needs and characteristics of the very poor Urban infrastructure Adolescent health and nutrition Mental health and self-directed violence
R&D addresses **Technology Problem**	**COST = $10m-$100m p.a.** Coastal protection and map digitization Greenhouse emissions from livestock Long lasting reversible contraceptive Drug delivery for PrEp Drug delivery for ARTs Rapid diagnosis and treatment for HIV/AIDS Home testing and monitoring of HIV/AIDS New drug development for artemisinin Polypill for hypertension Affordable treatment for asthma Affordable home testing for diabetes Improved diagnostics for TB	**COST = $100m-$250m p.a.** Reducing premature adult mortality Application of CRISPR technology to all 17 neglected tropical diseases Global alliance for diagnostics

Estimating the effectiveness of the R&D proposal and its potential impact

As earlier 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 identified an order of magnitude estimate for how much each R&D proposal 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; and
- 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.

Urbanisation 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 urbanisation in many countries and in particular developing countries.

Research into city planning and infrastructure development associated with the rapid urbanisation 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 in the future. 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 for development R&D to help urbanisation 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 urbanisation 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 the project made the costs entirely disappear).

What is the cost of lack of well-coordinated infrastructure with regards to urbanisation and infrastructure? The McKinsey Global Institute (2013)[63] 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 t about $19 trillion, or on a per-year basis about $1.27 trillion.

63 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 at: http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/infrastructure-productivity (Accessed on 07 April 2017).

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 this $100 million per year produce in terms of benefit. With an in-depth literature review of urbanisation and infrastructure development and a meta-study of the relevant R&D projects and their effectiveness, it could potentially be possible to estimate an interval for the R&D spending's likely annual benefit. However, this approach would for resource constraints alone fall outside the current project, and moreover it would have to be repeated across all 40 proposals to make possible a comparison. Even then, it is likely that many of the proposals would find few (or no) studies that could help link future R&D spending to very specific benefit outcomes.

Therefore, we have in the current study chosen to base our estimates on expert elicitation – essentially asking the relevant economic experts 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 urbanisation 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 costs 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, 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 or pound spent will provide benefits that are about 10 to 100 times higher, as an order of magnitude. It is 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:

Urbanisation and infrastructure

Research into city planning and infrastructure development associated with rapid urbanisation 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 urbanisation.

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

What projects were most effective?

Past research by Copenhagen Consensus has shown that development R&D can be an extraordinarily good investment.

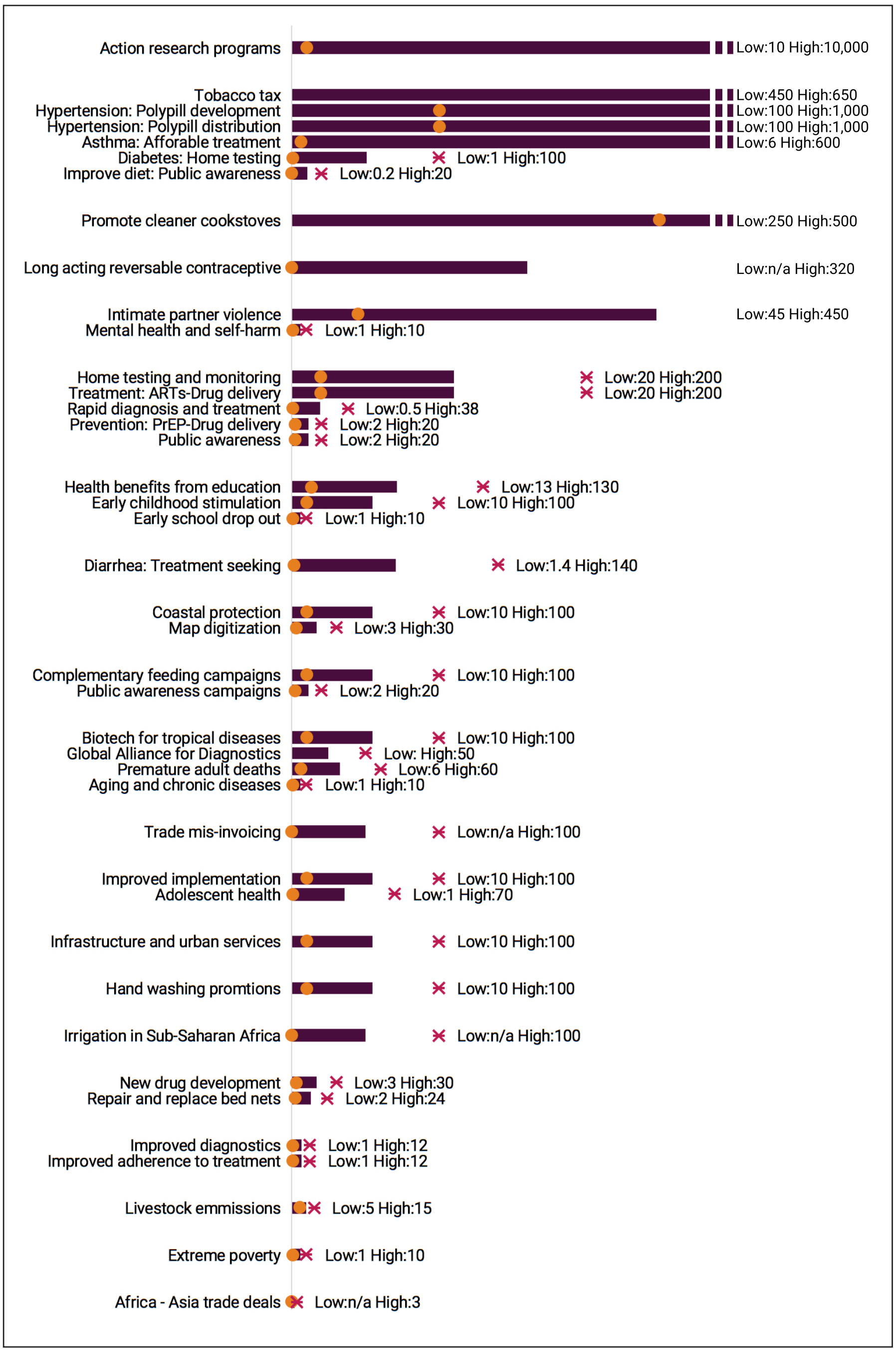
This study has identified 40 promising development R&D proposals. Many of these are likely to have a phenomenal impact on development, and should be prioritized in the near future.

It is worth repeating the caveat from the introduction: with limited time and resources, in-depth cost benefit analyses have not been performed on the various proposals, nor a full-scale prioritization exercise undertaken.

Instead, we have performed an initial, expert-guided process to form a preliminary scoping of R&D opportunities across all fields of international development. The results represent a starting point, from which more detailed analysis could and should be undertaken.

The economists identified around 70 concrete ideas that they considered worthy of R&D investment. Based on expert input, a preliminary assessment was made of the costs and benefits of 40 concrete policies.

Here is an overview of our findings, ranked according to the mean of the high and low BCRs.



To go into more detail, while nearly all our surveyed projects were highly cost effective, we identified 10 that deserve to be at the forefront of any additional development R&D spending:

1) Improve the promotion and adoption of cleaner cooking solutions

The challenge is the limited adoption of existing improved 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 2015 estimates that 2.9m people died prematurely from illnesses resulting from household air pollution from solid fuels in 2015 (Global Burden of Disease, 2015).

Cost of problem: The costs arising from the health effects of household air pollution are estimated at approximately US$333bn per year[64].

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[65] [66], promotion has been much more successful in China[67], 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.[68] 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 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, they 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 report below.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 250 to 500.

64 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 at: http://www.copenhagenconsensus.com/sites/default/files/air_pollution_assessment_-_larsen.pdf (Accessed on 07 April 2017).

65 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. (2012) "The Low Demand for New Cookstove Technologies," Proceedings of the National Academy of Sciences, 109(27): 10815-20, July 2012

66 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

67 Smith. K., Shuhua G., Kun H. and Daxiong Q. (1993). "100 million cookstoves in China: How was it done?" World Development, Vol(21): 941-961

68 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 at: http://www.copenhagenconsensus.com/sites/default/files/air_pollution_assessment_-_larsen.pdf (Accessed on 07 April 2017).

2) 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. 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[69] given the complex and 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 the incidence of domestic violence among teenagers in the United States by more than 56%[70]. Encouragingly, there appears to be evidence that the program can be translated to developing countries. Another study piloted the same program in Haiti and found that it has had some success in increasing knowledge of dating violence[71]. 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 the prevalence of domestic violence in sub-Saharan Africa 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

3) Action research programs

Action research is a particular approach and type of research and 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 hundreds of years of learning that has taken place in rich countries into ten 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 t implementing teams, providing insight, increasing problem-solving capacities, as well as directly improving individual project efficiency and quality. The benefits

69 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 at: http://www.copenhagenconsensus.com/publication/post-2015-consensus-conflict-and-violence-assessment-hoeffler-fearon (Accessed on 07 April 2017).

70 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.

71 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, 2016, 9(3): 178-189.

of learning and improved performance are 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 methodology can be applied across a range of different issues, including education, social care, and health. The key factor 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 10,000. This is a particularly wide range as the effectiveness of the research will depend very much on the exact context and programs being researched.

4) Polypill for hypertension and cardiovascular disease

Research and development is needed to **bring to market** a polypill for treating hypertension and cardio-vascular disease. A variety of polypills for treating hypertension have been developed in recent years but have not yet been widely adopted. Combination pills have been used effectively in a range of other conditions, including HIV, TB and malaria but have not been taken up in treatment for hypertension and cardio-vascular disease. Polypills are cost effective, they are cheaper than taking separate medication, and adherence to treatment is much higher. Several pills have been developed, especially where costs can be kept down by using generic drugs. For example, 'polycap' is one version, developed in India for a domestic market. Current research is focused on the effectiveness of different combinations, and especially in determining risks and benefits for different populations with different combination pills.

Costs of R&D into developing the polypill for market: The research costs are estimated at approximately $10m per year. This is a low figure for new drug development because there has already been so much progress and there are some polypill drugs in this field that are either ready or almost ready for distribution. Additional R&D is not needed for the early stages of drug development.

Size of problem: According to World Health Organization (WHO) figures, raised blood pressure accounts for the loss of 57 million DALYs.[72]

The number of deaths reported from hypertension in 2015 is almost 1 million, and from cardio-vascular disease it 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.

72 WHO. Global Health Observatory Data, Raised Blood Pressure. Available online at: http://www.who.int/gho/ncd/risk_factors/blood_pressure_prevalence_text/en/ (Accessed on 07 April 2017).

Estimated benefit of intervention: Depending on a range of factors, such as timescales, affordability and distribution, this may reduce the impact of hypertension on DALYs 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.

R&D into the **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

5) Taxing Tobacco: 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 over 500.

6) 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. Additional benefits include the empowerment of women and all the subsequent 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 of 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[73]:

Women – 12,430,000 per year
Newborns – 23,710,000 per year
Total is approximately 36 million DALYs- per 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

73 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

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.

7) Affordable treatment for asthma

R&D into a cheap and easy to distribute treatment for asthma. Asthma is largely under control in richer developed countries, but the medication commonly available (inhalers) is expensive and is generally unaffordable in developing countries. Research is needed into an affordable and easy to use medication that would be accessible to people with both asthma and other chronic respiratory conditions.

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

Size of problem: From the Global Burden of Disease, the estimated annual DALYs for asthma in low to middle income countries is 20m.

Estimated cost of problem: US$3,000 X 20 million DALYs = approximately US$60bn per year.

Estimated potential benefit of R&D: There is evidence from Brazil that integrated programs focusing on preventative care and distribution of inhalers can have significant effects (79% reduction) on asthma related hospitalizations in a developing country setting[74]. That said, there is limited evidence of its applicability in other resource settings. We, therefore, assume a wide range of possibilities for this R&D. It may reduce the impact of asthma by between 0.1% ($60m) and 10% ($6bn).

BCR: An order of magnitude estimate gives a BCR of approximately 6 to 600.

8) Treatment and symptom management for people with HIV/AIDS

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.

74 Lasmar L, Fontes MJ, Mohallen MT, Fonseca AC, Camargos P.(2009) "Wheezy Child Program. The Experience of the Belo Hoizonte Pediatric Asthma Management Program." World Allergy Organization Journal December, 2009. Vol(2):289–95. Available online at: https://link.springer.com/article/10.1097/WOX.0b013e3181c6c8cb

Current **home testing and monitoring of symptoms** for people with HIV/AIDS is expensive. Research and development is needed into cheaper and effective kits so that people can monitor themselves at home or be checked by front line health workers in the community, rather than needing regular trips to a clinic. This will enable better self-management and prompt treatment seeking behaviour when it is necessary, as people will be able to make improved judgements about their condition and their need for medical attention.

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: 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.

9) 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 hectares and full adoption of the technology can generate annual net revenues of $22 billion per year for irrigated farmers. Potentially 185 million people could benefit.
Treadle pumps	24 million hectares for treadle pumps, with annual net revenues of $19 billion per year. Potentially 243 million people could benefit.
Communal river diversions	20 million hectares for communal river diversions, with net revenues of $14 billion per year. Potentially 113 million people could benefit.
Small reservoirs	22 million hectares for small reservoirs, with net revenues of $20 billion per year. Potentially 369 million people could benefit.
Total potential benefits	**$75 billion** per year.

Additional benefits include increased food security, improved nutrition, and increased trade.

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.

10) System to tackle mis-invoicing in trade transactions

Trade mis-invoicing appears to be by far the largest problem in illicit financial flows – albeit estimates using national-level data are inevitably subject to high uncertainty. Given current developments in technology and data analytics, research is needed into 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. In addition, such an assessment would allow for substantially greater confidence in the actual scale of the phenomenon. 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 1% (US$1bn) of losses.

BCR: An order of magnitude estimate gives a BCR of approximately 100.

Conclusion

Almost all of the proposals will result in benefits to society worth more than they cost. Many will produce outstanding returns for the resources invested into them.

Let's examine in more detail the ten highest-ranked proposals.

In first place (but with a very broad range of possible results), the action research proposal is distinct in that it is essentially an approach that can be applied to a range of issues, from health and education to transport, water and sanitation, and so on.

The focus is on improving the capacity and learning of local providers, and in particular government departments. The idea is that by conducting research as a partner, in an iterative way with a focus on delivery, overcoming problems, improving systems, and learning, then systemic changes and improvements can start to take root and grow sustainably. This is one reason the range of BCRs is so large: for a relatively small investment, the potential impact can be huge but requires an ongoing commitment.

Many of the other top-ranked proposals come from the health sector. The top two health interventions focus on R&D of development and distribution of a polypil for hypertension and cardiovascular disease.

Since hypertension and cardiovascular disease cause about one-third of all deaths on the planet and drugs exist to tackle both, it stands to reason that cheaply developing simpler and more affordable treatments would amount to major breakthroughs.

The health effects of tobacco are well documented and understood, and although the potential and effectiveness of controlling tobacco use through taxation is also known, there is less understanding of how to implement relevant policy in developing countries. Research through a global programme to evaluate and provide evidence to policy makers on the impact of tobacco taxes in different fiscal contexts, and in particular in low to middle income countries where tobacco use is generally less regulated.

Household air pollution is another leading cause of global death, and it is not surprising that research into improving the distribution and uptake of cookstoves has a high estimated BCR. Such stoves have been developed and are known to be effective. It makes a lot of sense to focus investment on developing better ways to promote their use.

A long-acting contraceptive has the potential not only to help women gain greater control over their fertility, life chances and participation in the labour market, but also to help reduce maternal mortality. In turn, this has a major impact on families and young children who would otherwise grow up without a mother. Effective contraception could also be one of the more effective ways to mitigate the effects of climate change, by reducing the pace of population growth, and thus humanity's carbon footprint[75]. The development of long-acting, reversible, effective and affordable contraceptives would be a great R&D investment.

In developed countries, asthma is well-managed and controlled, and medications are widely used. However, in low to middle income countries, medication is relatively expensive and inaccessible to most people who need it. Given the prevalence of asthma and the fact that we know how to treat it, it is entirely reasonable to think that R&D into more affordable treatments would bring rapid benefits and should be a priority.

Violence in the home has a devastating effect on millions of lives, but has few well recognised and proven solutions. The cost to society of intimate partner violence is dramatic – estimated at US$4.4 trillion – and is clearly one of the most significant challenges the world faces. Investing in research to better identify which interventions make a difference in which contexts, and how to replicate success in other settings, is clearly money well spent.

HIV/AIDS has received much more scientific and policy attention. Progress in drug treatments and expanded access means that many people living with HIV can experience a similar life expectancy to people without the condition. While this is commonplace in developed countries, this is not the case in much of Sub-Saharan Africa. Improving diagnostics alongside better drug delivery could potentially transform the lives of people with HIV, and R&D could be hugely beneficial.

Sub-Saharan Africa also suffers from some of the poorest food security in the world. Investment into a range of irrigation techniques is likely to bring about significant improvements for every pound spent on R&D. One of the biggest challenges facing African agriculture is developing irrigation systems geared both to the local setting and to the smallholders who would be the main beneficiaries. Moving away from dependency on rainfall would dramatically improve yields and the capacity of farmers to manage smallholdings. As with many of the R&D ideas presented here, a lot is already known, and investing in R&D that is focused on expanding and replicating existing solutions is sure to deliver quick and significant benefits.

The table below lists the top R&D ideas by the average benefit cost ratio, showing the potential for impact of R&D on a wide range of international development issues.

75 O'Neill, B. et al (2010). "Global Demographic Trends and Future Carbon Emissions" in Proceedings of the National Academy of Science of the United States of America. Vol(107) 41: 17521–17526. Accessed online at: http://www.pnas.org/content/107/41/17521.full

Table 1: Top 15 R&D proposals by mean BCR

	Topic	Research Focus	Proposal	Bcr Lower	Bcr Upper	Bcr Mean
1	**Governance**		Action Research	10	10000	5005
2	**Health: Ncds**	Hypertension/Cvd	Polypill Development	100	1000	550
3	**Health: Ncds**	Hypertension/Cvd	Polypill Distribution	100	1000	550
4	**Health: Ncds**	Control Tobacco Use	Tobacco Tax	450	650	550
5	**Air Pollution**	Cookstoves	Distribution	250	500	375
6	**Gender**	Contraception	Long Acting		320	320
7	**Health: Ncds**	Asthma	Asthma Treatment	6	600	303
8	**Conflict/ Violence**	Intimate Partner Violence	Scalable Solutions	45	450	247.5
9	**Health: Hiv/Aids**	Treatment	Home Testing And Monitoring	20	200	110
10	**Health: Hiv/Aids**	Treatment	Arts-Drug Delivery	20	200	110
11	**Food Security**	Irrigation	Ss-Africa		100	100
12	**Iff**	Mis-Invoicing	Real Time Transactions		100	100
13	**Education**	Beneficial Externalities	Health	13	130	71.5
14	**Health: Infant Mortality**	Diarrhoea	Treatment Seeking	1.4	140	70.7
15	**Biodiversity**	Coastal Protection	Supplementary Protection In Mangrove Areas	10	100	55
	Education	Early Childhood Education	Expanding Programs Internationally	10	100	55
	Health	Tropical Diseases	Crispr	10	100	55
	Health: Women's Health	Complementary Feeding	Public Information	10	100	55
	Nutrition	Implementation	Implementation	10	100	55
	Urbanization	Infrastructure		10	100	55
	Wash	Hand Washing	Promotion	10	100	55

When governments examine real-world development R&D spending, it is likely that a small fraction would be well spent embarking on a more thorough and detailed evaluation of the broad range of development R&D proposals.

However, this analysis highlights a range of development R&D proposals that are worthy of consideration.

Proposals that appear in the top-ten list deserve being at the forefront of any additional development R&D spending. Moreover, the analysis indicates that most R&D proposals, if well designed, would constitute a very good use of resources. Well-considered R&D spending that leads to breakthroughs in solving regional and global challenges would significantly advance international development aims.

How can development R&D be integrated with the Government's new Industrial Strategy?

The UK's Research Strengths

The Government has set one of is central priorities to be the creation of a modern Industrial Strategy, intended to boost national productivity and close the gap between the best and the worst performing regions.

While the final shape of the Industrial Strategy is still being designed, the January Green Paper explicitly defined the first core challenge it would address to be to "build on our strengths and extend excellence into the future." As a mature economy, the UK's comparative advantage has to come from innovation and high end services, rather than cheap labour or natural resources. According to the latest Global Innovation Index, the UK is the fifth most innovative country in the world behind Switzerland, Sweden, the Netherlands and the US.[76]

Key to sustaining and building on this performance is to take better advantage of the UK's research base, seeking to make the UK as good at commercialising new research as it is in coming up with original discoveries. As well as committing to raise UK R&D to the OECD average, the Government has announced an additional £2 bn for government R&D, and a new Industrial Strategy Challenge Fund targeting six key sectors: healthcare and medicine, robotics and artificial intelligence, batteries for clean and flexible energy storage, self-driving vehicles, manufacturing and materials of the future, satellites and space technology.

There are both obvious and non obvious crossovers between an R&D focussed Industrial Strategy, and R&D used to tackle global challenges. To start, even if undertaken purely for the profit motive, almost all research has some element of public good, with social returns from research on average four times as large as private returns.[77] Many of the most important projects to tackle global challenges, from new drugs to cheaper forms of energy storage, will largely be delivered by commercial companies. Beyond this, both private and public research help build up a shared ecosystem of ideas, workers and facilities.

British research is the second most cited in the world, and the UK is home to four of the world's top ten universities. [78] While we produce only 2.4% of world GDP, we are responsible for 8.1% of total citations and 6% of patents. The UK has particular strengths in life sciences, humanities and social sciences, but we remain significant players even in fields where our economy has been less traditionally strong, such as energy or material sciences.

76 Global Innovation Index 2017. https://www.globalinnovationindex.org/

77 Have R&D Spillovers Changed?, Brian Lucking, Nicholas Bloom, John Van Reenen, 2017. https://people.stanford.edu/nbloom/sites/default/files/lbv_ssrn.pdf

78 http://www.topuniversities.com/university-rankings/world-university-rankings/2016

Table 1: UK Citation Share 1996-2016 (Scimago)

Type	Citations	H-Index	Citation Share	Rank
All	60,988,844	1213	8.1%	2
Agriculture and Biological Sciences	13,962,462	734	8.0%	2
Arts and Humanities	3,190,676	519	11.4%	2
Biochemistry, Genetics and Molecular Biology	13,962,462	734	8.0%	2
Business, Management and Accounting	1,230,010	274	11.2%	2
Chemical Engineering	1,956,273	362	5.5%	3
Chemistry	4,579,397	459	5.5%	3
Computer Science	2,572,889	383	6.4%	2
Earth and Planetary Sciences	3,752,044	417	8.9%	2
Economics and Finance	901,107	256	10.9%	2
Energy	48,008	223	5.1%	3
Engineering	4,176,344	423	5.9%	2
Environmental Science	3,132,493	372	8.1%	2
Immunology and Microbiology	3,850,522	444	8.7%	2
Materials Science	3,467,322	396	5.4%	4
Medicine	23,236,410	884	9.0%	2
Pharmacology, Toxicology, Pharmaceuticals	2,201,964	347	7.7%	2
Social Sciences	3,227,978	329	13.5%	2

Looking in more detail, the UK has existing or emerging areas of excellence in several fields that will be central to addressing future global challenges:

- **Life Sciences, Pharmaceuticals and Medicine.** The UK has three of the top five universities for medicine in the world, the second highest number of Nobel prizes in Physiology or Medicine, two of the top four medical journals in the Lancet and BMJ, and the world's most cited interdisciplinary science journal in Nature. (For more detail, see our 2016 briefing note *The Impact of UK Aid Research Spending.*)
- **Agriculture.** The UK is aiming to become a world leader in AgriTech, building on the strength of its existing research base and facilities like the John Innes Centre or Roslin Institute. In the last few years, the Government has created a new Agri-Tech Leadership Council, Agri-Tech Catalyst, Centre for Agricultural Informatics and new Centres for Agricultural Innovation. (For more detail, see our recent report *Farming Tomorrow.*)
- **Machine Learning and Data Science.** AI and big data are strong candidates to be the next General Purpose Technology, with widespread applications across most fields of the economy – and the potential to transform healthcare, transport, agriculture, and finance. London is already the global capital for FinTech and the European overall tech hub, while British based companies like DeepMind are leading the world in fundamental advances in the technology.
- **Economics and Social Sciences.** As our work with the Copenhagen Consensus Center demonstrated, R&D on implementation and solving social problems

can be as important as inventing basic technology. The UK is second only to the US in citations in Economics, producing 2.6 times as many citations in the last twenty years as Germany or Canada. Six of the top 25 Economics university departments are located in the UK, equal to every other non US country put together.[79]

Table 2: G7 Patent Applications filed under the PCT (2013, OECD)

	Total Patents	Biotechnology	ICT	Nanotechnology	Medical technology	Pharmaceuticals	Environment-related technologies	Electrics	Share of World GDP
Canada	2.1	3.5	2.0	0.9	2.0	3.2	3.0	1.8	1.5
France	4.6	4.0	3.6	3.8	3.5	4.1	4.8	3.5	2.4
Germany	13.7	7.7	10.8	11.7	9.0	8.5	22.2	13.7	3.5
Italy	1.8	1.1	0.7	0.5	2.2	1.9	1.7	0.8	2.0
Japan	9.6	7.3	10.0	12.3	4.6	8.9	11.8	11.5	4.7
UK	6.0	6.6	5.2	5.8	5.7	7.3	5.5	4.5	2.4
US	40.7	51.3	47.4	51.9	52.6	48.7	29.6	40.4	16.0

One of the core elements of the new Industrial Strategy is a series of 'sector deals', designed to help business and government work together on common concerns in skills, research, supply chains, funding or regulation. The first of these, released in August 2017 and led by Sir John Bell, focussed in on the Life Science industry. While the report did not explicitly consider research aimed at developing countries – a slightly strange omission – its headline recommendation was the creation of a new Health Advanced Research Programme (HARP), taking inspiration from the US's DARPA and focussing on significant 'moonshot' style challenges. This follows a similar call in July for a new ''Faraday Challenge' to develop British leadership in battery technology and, of course, the creation of the Industrial Strategy Challenge Fund itself.

The new focus on challenge-led research creates a common agenda between development R&D and the wider Industrial Strategy, and a significant break from the standard model of British research. Is this a good idea? And even if it is, how can we assure that resources are allocated effectively?

79 https://www.topuniversities.com/university-rankings/university-subject-rankings/2017/economics-econometrics

Curiosity and Challenge Based Research

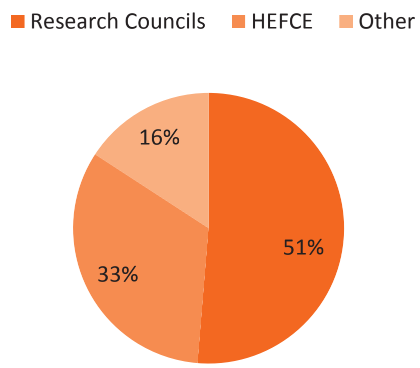
The majority of research projects in Britain are chosen by individual scientists following their own curiosity, rather than to meet a specific societal challenge. (Another way to describe the two categories, as used in the recent Nurse review of Research Councils, is the difference between *discovery* and *applied research*.)

Under the dual funding system, public funding is split between direct funding for individual projects managed by the Research Councils (£3 bn) and core grants to institutions managed by HEFCE (£1.9 bn). These numbers are before the additional £2 bn announced in the 2016 Autumn Statement - the exact breakdown of which remains unclear.

HEFCE research is allocated according to backwards looking measures of research quality by previous institutions, leaving the allocation of future resources to the discretion of individual universities.

In theory, Research Council funding is split between their own strategic priorities – a more challenge based form of funding – and 'responsive mode', where researchers are able to come forward with their own priorities. In practice, around half of Research Council funding takes the form of the latter[80], and even strategic priorities are often broad brush enough to allow researchers' significant discretion.

Figure 9: UK Science and Research Funding in 2017/18



This curiosity-driven model of research has many advantages. Fundamental discovery is by its very nature hard to predict and manage in a top down fashion. Those at the front line are best qualified to know what the most truly promising questions are – and this only becomes trueer as the nature of research becomes more specialised. While the Government continues to try and better measure impact after the fact through initiatives like the new Research Excellence Framework, such metrics are always imperfect: much research only pays off decades later, or delivers non-monetary forms of value that are hard to measure. What is more, curiosity-driven research is precisely the sort of research that is most likely to be underfunded by the private sector.

But curiosity-driven research also has its downsides. The UK often struggles to translate research into real world products and interventions, and there are

80 Setting priorities for publicly funded research, House of Lords Science and Technology Committee, 2010 https://publications.parliament.uk/pa/ld200910/ldselect/ldsctech/104/104ii.pdf

strong incentives to move slowly and avoid risk rather than create something 'good enough' and iterate. Engineer Eric Drexler argues, half seriously, that if the automobile industry had been designed through the academic process, specialist international conferences would still be arguing over the right rubber to use for the tyres.

Like any special interest group, academia can become dominated by its own cultural prejudices and group confirmation bias. The recent 'replication crisis' demonstrated widespread unreliable results in multiple fields, including social psychology, medical research and economics. One study found only a third of psychological studies could be successfully replicated.[81] Most real world projects require cross over collaborations between disciplines, whereas academic progress encourages fields to become ever more specialised and silo-ed.

Challenge-based research, of course, has its own flaws. It is no easier to 'pick winners' in research than in other types of Industrial Strategy. 'Push' research, where committees or politicians try to choose the most promising approach to solve a problem, can be susceptible to politicisation and chasing fads. Over bureaucratisation of science slows progress, and reduces researcher autonomy. It is probably not a coincidence that many of the most innovative organisations of the twentieth century from the Manhattan Project to DARPA to Bell Labs thrived in a 'skunkworks' model, separated from the normal bureaucratic hierarchy.

Ever since the launch of the first development enterprise challenge fund in 1997 ("the UK Business Sector Challenge Fund"), challenge funds have been a popular part of the development toolkit, with DfID itself having sponsored at least 14. At their best challenge funds can share many of the benefits of innovation prizes, which have a history going back to at least the eighteenth century: stimulating additional pro-social innovation, remaining flexible over the methods used, and using open competition to focus resources on the most promising projects.

Despite their popularity, there is little systematic evidence on the relative effectiveness of challenge funds, with the most positive evidence anecdotal.[82] There are clear challenges in designing a fund well: there are advantages to being specific, but target the fund too narrowly and the quality of recipients is likely to be low; if the fund is to be effective, may consume a not inconsiderable part of the budget; judging the true additionality created is very difficult. Even if the particular project you fund is truly additional, how do you ensure that you are not simply crowding out another project without the benefits of public subsidy?

In reality, despite some of the rhetoric around the Haldane Principle, publicly funded research has always been a mix of curiosity and challenge. As soon as a budget is involved, no academic has complete autonomy to follow their curiosity – but they are still ultimately responsible for coming up with Their own new research projects. Politicians have always played a role in setting the broad allocation of research funds, while scientific niches have become so specialised that inevitably more detailed allocations have to be made by people who are not an expert in every area.

81 Estimating the reproducibility of psychological science, Open Science Colloboration, 2015. http://science.sciencemag.org/content/349/6251/aac4716

82 Understanding challenge funds, Claudia Pompa, ODI, October 2013, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9086.pdf; Meeting the challenge: How can enterprise challenge funds be made to work better, Adam Brain, Nilima Gulrajani and Jonathan Mitchell, EPS-Peaks, April 2014, http://www.geg.ox.ac.uk/sites/geg/files/How%20can%20enterprise%20challenge%20funds%20be%20made%20to%20work%20better.pdf

Box 4: The History of Government Funded Research and Development

With the notable exception of the military, organised R&D was largely unknown in either public or private sectors until the beginning of the twentieth century.

The first significant direct government payment for civil R&D came with the creation in 1900 of a National Physical Laboratory, jointly funded by the private and public sector, but under the management of the Royal Society. In 1909, as part of Lloyd George's People's Budget a new Development Fund for agricultural education and research was introduced, leading to the creation of a network of agricultural research stations. Shortly after, the introduction of National Insurance in 1911 led to the creation of a new national fund for medical research, and the establishment of a Medical Research Committee to advice on how best to spend it.

In 1915, the wartime Government created a new Department of Scientific and Industrial Research, intended to reduce the UK's dependence on foreign industries. At the same time, the move towards nationalisation of key energy and transport industries saw the state increasingly taking direct responsibility for many areas of industrial research.

Following a 1918 report on Machinery of Government by Richard Haldane, the Medical Research Committee was converted into a new Medical Research Council with its own Royal Charter. Although it is unclear to what extent this was intended at the time, this report was later pointed to as the origin of the 'Haldane principle' that decisions regarding general research should be made by independent scientists without political interference. Over the next decades, more research councils were created, merged and re-organised, leaving us eventually with today's seven: Arts and Humanities, Biotechnology and Biological Sciences, Engineering and Physical Sciences, Economics and Social, Medical, Natural Environment, Science and Technology Facilities.

While basic science in the UK has thrived, there have been repeated attempts to improve transfer out to industry. In 1949, the Government created a new National Research Development Corporation, which would go on to make substantial investments in industries such as computers and hovercrafts. In the early 1990s, a new generation of 'Faraday Partnerships' research centres were created between academia and business, but were ultimately to be undermined by a lack of core funding. In 2004, a new non-departmental Technology Strategy Board was created, later rebranded to Innovate UK, and with it in 2012 a new network of Catapult centres, again as a collaboration between business and the public sector.

In 2015, the Nurse Review recommended bringing the seven councils together under a single organisation to better improve strategic thinking and manage cross-cutting priorities. The Government accepted this recommendation, and went still further, merging Innovate UK into the new UK Research and Innovation (UKRI) to better align basic and applied research. Despite this significant increase in centralisation, the Government has been keen to emphasise it is not trying to 'direct science' – and for the first time, a version of the Haldane Principle has been included into law. UKRI is expected to play a central role in the management of the new cross cutting Industrial Strategy Challenge Fund and Global Challenges Research Fund.

How challenge-led is the Global Challenges Research Fund?

In development, responsibility for the Government's new flagship Global Challenge Research Fund has largely been devolved to its delivery partners, namely the Research Councils, National academies and Funding Councils. BEIS is explicitly not geting involved with research decisions beyond initial funding allocations to each delivery partner, limiting its oversight to a Research and Innovation ODA Board that approves decisions over procedures by the delivery partners themselves. Research funding is largely allocated through the standard 'dual system' process, with the Research Councils and Academies allocating funding through thematic calls for competitive applications, and the Funding Councils awarding resources based on past research excellence.

The delivery partners co-ordinate their own procedures through a 'GCRF Strategic Advisory Group', which in June 2017 published its own "UK Strategy for the Global Challenges Fund." Unfortunately, this document is relatively vague, stating little more than that should be challenge-led, ODA compliant, and high quality. As long as the research is ODA eligible, there is no prioritisation of individual countries, while research should be aimed at tackling one of twelve very broad challenge areas. (In practice, these areas seem to be a slightly edited version of the UN's SDGs – and it is not clear why these were not just used officially as a criteria.) While this is all sensible as far as it goes, it is hard to describe this as a strategy.

In practice, allocation of resources is near entirely being left to peer review. While nobody wants to compromise the spirit of the Haldane Principle, more co-ordination would likely allow a more efficient allocation of resources.

As a September 2017 review by the Independent Commission for Aid Impact argued, the current highly decentralised structure provides "insufficient strategic direction… [creating] a scattered portfolio of research projects, rather than a concentration of effort on pressing global development challenges. In our view, a transformative research agenda would call for more focussed objection especially in high-priority and high-Impact areas and a more deliberate targeting of resources towards achieving them."[83] Few formal processes have been put in place to monitor performance, identify research gaps or UK comparative advantage, judge value for money, share best practice, or co-ordinate with other major UK funding streams, such as DFID's research or Ross Fund.

How can we can create a more strategic system for the Global Challenges Research Fund or, for that matter, all of Britain's development or wider challenge-led research funding? How can we gain the benefits of both curiosity and challenge research, ensuring that research is well targeted at solving the most important challenges while still maintaining the benefits of academic autonomy? Finally can we ensure that research funding brings in the private sector, who ultimately will be responsible for much of the delivery?

We suggest three broad principles:

- While UKRI should not try and direct basic science, it can do more to share best practice, identify research gaps and support replication.
- Wherever possible, challenge based funding should be structured on an outcomes-based model, open to both the private and public sector.
- R&D allocation should be based strictly on what is best for global welfare, but by focusing on the UK's comparative advantages there are likely to be significant spill-over benefits to Britain's research and innovation base.

Policy Recommendations

The UK should double the proportion of ODA spending on R&D from 5% to 10% of the total budget and work to create a steady ramp up of research capacity.

As we have seen, R&D is relatively neglected by the rest of the international development community, and given the strength of Britain's science base, the UK is well placed to take full advantage of greater spending. Research presents some of the highest potential returns of any form of development intervention, and there exists a substantial pipeline of potential projects or gaps in the current research base.

83 Global Challenges Research Fund, ICAI, 2017. http://icai.independent.gov.uk/html-report/global-challenges-research-fund/

Greater spending on R&D has a potential to be a unifying project for aid supporters and critics, avoiding many of the traditional worries over negative side effects or funding corruption. Increasing development R&D would synergise well with the Government's wider pledge to increase UK research funding to the OECD average.

Given the lags in training new scientists or building facilities, research funding should not be doubled overnight, but instead gradually ramped up under an open roadmap – giving institutions the time they need to invest in greater capacity.

Despite existing pledges to increase funding, many scientists have expressed concern about the potential impact of Brexit on the sector. Given the Government's guarantee of Horizon 2020 financial commitments, most concerns focus on the potential impact of new regulatory or immigration barriers.

Some regulatory divergence is probably inevitable. The most important economic opportunities from Brexit come from the ability to strike our own trade deals and create a more innovation friendly regulatory system. Neither will be possible without regulatory divergence from European rules. This is likely to particularly affect life sciences, such as pharmaceuticals, medtech and agricultural research.

Nevertheless, the UK should continue to work closely with European bodies such as the European Medicines Agency where collaboration is clearly in everyone's best interest, such as with large scale clinical trials. Mutual recognition can achieve many of the same benefits as complete regulatory harmonisation, and even if this cannot be negotiated on a reciprocal basis, the UK can choose to unilaterally accept other countries standards, minimising the regulatory burden. Singapore, for example, offers expedited approval to medicines that have already received approval from other bodies such as the FDA or EMA. Policy Exchange's forthcoming paper *Global Champion: The Case for Unilateral Free Trade* explores in more detail how a system of mutual or unilateral recognition of regulation could work.

Leaving the European Union, also offers the chance to significantly reform the immigration system. In principle, this should allow for a significant expansion of high skilled Tier 2 visas (or a future equivalent), and ease the process for bringing in scientists from non EU countries, helping the Government meet its commitment to increase the number of scientists working in the UK. The sciences are expected to require 180,000 – 260,000 new staff between 2015 and 2025, with around a quarter of current academics non-UK nationals.[84] In the short term, the Government should monitor carefully its £100 mn Rutherford Fund to attract high skilled foreign researchers, and consider raising it if necessary.

UKRI should create a new institution the UK Innovation Challenge Agency to jointly manage the Industrial Strategy Challenge Fund and the Global Challenges Research Fund

Given the obvious overlap between different research agendas, rather than haphazardly create multiple challenge-led institutions for every sector – a HARP for the Life Sciences, a Faraday Challenge in Energy, and so on – it would be better to create a single strategic body to implement best practice and co-ordinate challenge-led research. This body would emphatically not try to 'direct British science' or overrule peer review.

Instead, it would serve two core purposes, seeking to co-ordinate rather than control:

84 Life Sciences Industrial Strategy - A report to the Government from the life sciences sector, 2017 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/640696/life-sciences-industrial-strategy.pdf

- **Building the evidence base lying behind the selection of development and industrial challenges, developing a coherent, data driven and open process.** The Innovation Challenge Agency (ICA) would extend the work undertaken by the Copenhagen Consensus Center for this paper - seeking out the most cost-effective targets for future global research – then see which of these research gaps the UK had a particular comparative advantage in.
- **Co-ordinate and share learning among researchers, without seeking to direct the pursuit of research or contravene the Haldane Principle.** While the ICA would provide guidance, individual researchers would still be free to completely ignore it – and the majority of funding remain allocated on a 'response mode' basis.

As part of its work, the Innovation Challenge Agency could commission:

- expert-driven research agendas to highlight the most important unknowns, progress of current research programmes and future likely milestones
- where feasible, replication of the most important historic and new results
- literature reviews and meta analyses on the most important unknowns, working in collaboration with the "What Works' network and Policy Exchange's previously proposed Office for Aid Effectiveness
- oversight of new 'moonshot' high risk DARPA-style research programmes, such as the proposed Health Advanced Research Programme
- rigorous cost benefit analysis of R&D proposals
- ongoing benchmarks of UK sectoral and research comparative advantage to ensure the UK focuses on what it can do best
- stakeholder consultation and audits of current regulatory barriers to innovation, with an initial focus on post Brexit opportunities

After five years, an Independent review should look at the performance and wider impact of the Innovation Challenge Agency on Britain's research ecosystem- and whether it should continue as a permanent institution. At the same time, as well as increasing challenge funding, UKRI should also identifying the best researchers in each field and giving them more untied resources to spend as they wish - we will need a mix of both curiosity and challenge based research to succeed in future.

The Innovation Challenge Agency should create a new series of Advanced Market Commitments for solutions to Global Challenges.

The Global Challenges Research Fund (GCRF) is a £1.5 billion ODA eligible fund running from 2016-2021, aimed at ensuring that "UK science takes the lead in addressing the problems faced by developing countries, whilst developing our ability to deliver cutting-edge research." [85] By 2020, the combination of it and the Newton Fund, which fund science and innovation partnerships with developing countries, will make up 10% of the UK's total science budget.

Unfortunately, beyond saying that research should be high quality and aimed at meeting the UN's Sustainable Development Goals, the official strategy for the GCRF is frustratingly vague about how it will ensure the new fund will deliver impact and additionality.[86] Neither DFID nor UKRI necessarily have the

85 UK Strategy for the Global Challenges Research Fund (GCRF), June 2017. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/623825/global-challenges-research-fund-gcrf-strategy.pdf

86 UK Strategy for the Global Challenges Research Fund (GCRF), June 2017. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/623825/global-challenges-research-fund-gcrf-strategy.pdf

expertise needed to select the most important research projects, and much of the prioritisation process is opaque to the outside world. Many in the science community are sceptical about the GCRF, believing it has been used to cover cuts elsewhere, and there are concerns that the GCRF will be used to fund research that would have taken place anyway under normal domestic funding streams.

Outcomes based funding methods avoid many of these problems. They create transparency over how much the funder values a solution, remain open minded about the best solution, encourage competition between different approaches and ensure that we only actually pay when real impact has been achieved. While they can sometimes appear more convoluted and expensive upfront than simple 'push funding' of the best looking solution, this is largely because the real risk of picking winners is hidden off the Government's balance sheet. Unfortunately, many initially promising projects such as the recent $500 mn 'RTS,S' candidate for a malaria vaccine later turn out to be less effective than hoped.[87]

Advanced Market Commitments are a particular form of outcomes based funding, in which non-profit funders guarantee to pay a particular solution at a guaranteed price. They are intended to address the current massive imbalance in private sector R&D, where the vast majority of for profit research is aimed at the problems of wealthy, advanced economies. Without external support, developing new drugs to treat the problems of the developing world would simply not be profitable.

While most research on Advanced Market Commitments has focussed on their potential in the pharmaceutical industry, there is no reason in principle why they could not be used to tackle a much broader array of problems. In the energy space, the analogous Contracts for Difference are a widely used mechanism to support private sector investment in renewable energy generation.

The UK has already helped fund the world's first Advanced Market Commitment in 2009 for the development of pneumococcal vaccine for a cost of under $3.50 a dose.[88] The guarantee succeeded in incentivising new drugs from both GlaxoSmithKline and Pfizer, which have now been widely rolled out across 20 countries. The challenge in designing an AMC is setting the right price: too low and it will not drive private investment, but set it too high and the public sector will risk overpaying. The reported internal rates of return seen by GlaxoSmithKline and Pfizer were in the order of 10-20%, suggesting that in this case around the right balance was struck. The recent O'Neill review on tackling Antimicrobial Resistance recommended the broader use of AMCs to support the bringing to market of new vaccines which would not be commercially sustainable otherwise.

The Innovation Challenge Agency should follow up the success of the initial AMC by scoping out a new generation of 5-10 AMCs aimed at tackling the most important global challenges, from neglected tropical diseases to climate change. These could include a new malaria vaccine, developing a long acting reversible contraceptive, a digital education MOOC that can demonstrate sustained learning, or low cost forms of battery storage. Given these would only have to be paid out and appear on the UK balance sheet if they were successful, they would represent a highly cost effective form of R&D – and in practice, if the UK takes the lead in the original process design, it will probably not be hard to find other co-funders. Beyond being a good thing to do in itself, the process of evaluating and costing a new range of AMCs will help DFID and the ICA prioritise its wider research effects. If the process is a success, there is the potential to extend it out to other domestic priorities and the wider Industrial Strategy Challenge Fund.

87 Setback for Malaria Vaccine: Time for an AMC?, Owen Barder, CGD, 2012. https://www.cgdev.org/blog/setback-malaria-vaccine-time-amc

88 Is the Price Right? Evaluating Advanced Market Commitments for Vaccines, Amanda Glasman, CGD, 2013. https://www.cgdev.org/blog/price-right-evaluating-advanced-market-commitments-vaccines

While these AMCs would be open to anyone, in practice they would be chosen and managed from the UK British companies that are likely to have a head start in pursuing them. There are likely to be significant spill-over effects into the wider UK research and innovation base, developing key sectors such as the life sciences or AgriTech, and supporting the Government's wider Industrial Strategy.

Alongside these specific challenge funds, the UK should pilot a Health Impact Fund and explore patent buyouts.

While 90% of preventable diseases occur in developing countries, just 10% of global healthcare resources are spent for them. While pull mechanisms like Advanced Market Commitments can help, requiring less picking of winners than traditional push forms of funding, inevitably, given the overhead involved, they can only address a small subset of potential challenges or solutions.

One funding mechanism that avoids this narrowness is the proposal by philosopher Thomas Pogge and economist Aidan Hollis for the creation of a new Health Impact Fund. At present, the current process of drug discovery and development is largely underwritten by the monopoly profits drug companies are temporarily granted under the patent system. While theoretically it might be possible to waive these patents for poorer developing countries, in practice the potential for drugs to leak back to advanced markets makes it very help for pharmaceutical companies to price discriminate, and offer low cost drugs to developing countries. At the same time, under WTO rules all members are required to respect patent rights, cutting off the possibility of cheap generics until patents run out.

Under the Health Impact Fund, pharmaceutical companies would have an alternative reimbursement route to the current patent system. Pharmaceutical projects that signed up would agree to distribute their new drugs at marginal cost, ensuring cheap access. In return, they would receive compensation from the total funding pool, in proportion that every applicant had to measured reductions in the global burden disease, as measured by QALYs. In effect, this acts as a generic Advanced Market Commitment for any improvements to health. In principle, this aligns market profits with human welfare, using the power of the market to tackle the biggest global health challenges.

The creation of a real Health Impact Fund would be a fairly revolutionary change to today's financing of life sciences, and would probably require at least in the order of $6 billion a year. However, Incentives for Global Health, a NGO setup to develop the proposal further, estimate that we could learn more and judge better the viability of a true Health Impact Fund with the creation of a 'miniHIF', costing in the order of $60 – 200 mn.[89] The UK should put forward initial seed funding for this, and look for other international partners to raise the balance.

As recommended by economist Michael Kremer, another way to engage the private sector and to ensure a commercial return to development-relevant R&D and the widespread availability of cheap drugs is simply to buy out private sector patents. While this would probably have to include some kind of contract for manufacture – many new drugs involve specialist, embedded knowledge beyond their patent – in principle, there are circumstances where this could be highly effective. DFID should commission an independent review to explore the cost effectiveness of potential options for a patent buyout.

89 The Heath Impact Fund (HIF), Thomas Pogge, Aidan Hollis, 2015. http://healthimpactfund.org/wp-content/uploads/2016/02/mini-HIF-proposal-2016.pdf

The UK should aim to be a world leader in emerging technologies in agriculture, medicine, FinTech, GovTech and transport, reducing regulatory barriers to automation and gene editing.

The UK is in a unique position to take advantage of the coming wave of technological advances in machine learning and gene editing: the world's second best research base; leading global companies like GlaxoSmithKline or Deepmind; a liberal regulatory culture, at a time when the US is becoming more restrictive; and the opportunity after leaving the European Union to further reduce regulatory barriers. As Sir John Bell's Life Sciences Industrial Strategy recommended, over the next decade the UK has the potential to take advantage of its current research assets to create significant new industries in medical genomics and machine learning driven diagnosis.

Many of these new technologies have obvious applications to development. CRISPR precision gene editing could be used to create a new generation of higher yield crops, or develop vaccines to tackle tropical diseases. Automated vehicles and 3D printing can help deliver essential supplies to areas where basic infrastructure is lacking, while machine learning can support automated diagnosis and telemedicine. At the same time, FinTech, digital currencies and blockchain have the potential to enable a new generation of secure financial productions and more transparent government, with less chance for public funds to leak out through corruption.

Unfortunately, while innovation is proceeding apace in some areas such as digital currencies or telemedicine, in others regulatory barriers are standing in the way of rapid deployment. The European Union, in particular, has over relied on a 'precautionary principle', which has sometimes been used as a disguised protection for European farmers or to ban new technologies, even if there is no scientific evidence of harm. The extra regulation created by the EU's Clinical Trials Directive alone is estimated to have reduced non-commercial clinical trials activity by 50% and double the administrative burden,[90] and it takes EU firms three times longer and costs ten times as much to bring new chemical products to market than in the US. While the US has ten types of commercially planted GM crops on more than 70 million hectares, Britain has none.[91]

These restrictions have not just affected innovation within the European Union, but had significant spill-over effects on the developing world. Much of African regulation on GM crops has followed the EU's over emphasis on the precautionary principle – not least, because the EU is a major export market. Only three countries in Sub-Sahara allow the cultivation of GM crops.[92] This is despite the fact that the safety of GM crops has been widely recognised by leading scientific authorities such as the Royal Society of Medicine or the European Commission's Chief Scientific Advisor.[93]

Leaving the European Union offers Britain an opportunity to catalyse faster innovation, and to develop new technologies to better tackle global challenges. As part of the Government's new Industrial Strategy Sectors, particularly in life sciences, it should make a commitment to audit and identify barriers standing in the way of innovation. As our report *Farming Tomorrow* recommended, Britain should introduce a new Innovation Principle to complement the Precautionary Principle, ensuring that no new regulations are brought in without considering their wider impact on innovation. The Foods Standard Agency should set its own science based regulatory standards for UK agriculture, and in general, while we should pursue mutual recognition of regulation wherever possible, we should be prepared to accept some regulatory divergence when necessary.

90 Policy Statement: EU Clinical Trials Directive, Cancer Research UK, 2010

91 What GM Crops are Being Grown and Where?, The Royal Society, 2015

92 Can GMOs Deliver for Africa?, Kimberly Elliott and Janeen Madan, Center for Global Development, April 2016, https://www.cgdev.org/sites/default/files/CGD-Policy-Paper-80-Elliott-Madan-GMOs-for-Africa.pdf

93 The Evidence on GMO Safety. Ramez Naan, 2013, http://rameznaam.com/2013/04/28/the-evidence-on-gmo-safety/

Appendices

Appendix A: 40 Proposals for R&D Projects

Working with 32 academics and subject experts, the Copenhagen Consensus Center identified an initial 70-100 potential research ideas, before narrowing this down to a tighter list of 40 projects for which a first-order estimate of potential benefits and costs could be calculated. All but two of the projects pass our rule of thumb threshold for effectiveness.

In this section, we give full details of the 40 projects, organised by the UN's 17 Sustainable Development Goals: air pollution, biodiversity, conflict & violence, education, energy, food security, gender, governance, health, illicit financial flows, nutrition, population, poverty, trade, urbanization and WASH.

Air Pollution

Improve the promotion and adoption of cleaner cooking solutions

The challenge is the limited adoption of existing improved cookstove 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. Cookstoves 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 2015 estimates that 2.9m people died prematurely from illnesses resulting from household air pollution from solid fuels in 2015 (Global Burden of Disease, 2015).

Cost of problem: The costs arising from the health effects of household air pollution are estimated at approximately US$333bn per year[94].

94 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 at: http://www.copenhagenconsensus.com/sites/default/files/air_pollution_assessment_-_larsen.pdf (Accessed on 07 April 2017).

Estimated potential benefit of R&D: It is possible that improved promotion would improve uptake of cookstoves by 10-20%. While research has noted resistance to cook stoves in India and Bangladesh[95 96], promotion has been much more successful in China[97], suggesting that there is potential for enhanced adoption if the right conditions are implemented.

The effectiveness of improved cookstoves in reducing the health burden are typically around 20%, depending on the type of cookstove used, the surrounding environmental conditions and whether cooking occurs inside or outside the main living areas.[98] 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 expenditure on top of the proposed R&D investment. The households which adopt and use the new cookstoves would also need to spend on their maintenance and, for LPG based stoves, they 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 report below.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 250 to 500.

Biodiversity

Coastal protection

Research is needed 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 risks are currently increasing with climate change and where there is not a full evaluation of the combinations of protective interventions that 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 true 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.

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

Cost of problem: The projections[99] 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 adds approximately US$1.24bn per year, meaning that estimated 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.

95 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. (2012) "The Low Demand for New Cookstove Technologies," Proceedings of the National Academy of Sciences, 109(27): 10815-20, July 2012

96 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

97 Smith. K., Shuhua G., Kun H. and Daxiong Q. (1993). "100 million cookstoves in China: How was it done?" World Development, Vol(21): 941-961

98 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 at: http://www.copenhagenconsensus.com/sites/default/files/air_pollution_assessment_-_larsen.pdf (Accessed on 07 April 2017).

99 Hallegatte, S. et al.(2013). "Future Flood losses in major coastal cities." Nature Climate Change 3, 802-806. 18 August. Available online at: http://www.nature.com/nclimate/journal/v3/n9/full/nclimate1979.html (Accessed on 07 April 2017).

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. R&D is required 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[100]. However, in reality much less is actually spent on biodiversity conservation. Waldron et al (2012)[101], 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.

Conflict & Violence

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. 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[102] 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 the incidence of domestic violence among

100 Cressey, D. (2012). "Cost of Conserving Global Biodiversity Set at $76 Billion." Scientific American, Nature. Available online at: https://www.scientificamerican.com/article/cost-conserving-global-biodiversity-set-76-billion/ (Accessed on 07 April 2017).

101 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

102 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 at: http://www.copenhagenconsensus.com/publication/post-2015-consensus-conflict-and-violence-assessment-hoeffler-fearon (Accessed on 07 April 2017).

teenagers in the United States by more than 56%[103]. 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[104]. 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 the 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 in 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.

Size of problem: The number of people dying from self-harm is 830,000, or 34 million DALYs (Global Burden of Disease, 2015).

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

Identifying health gains from education (going beyond narrow economic benefits)

Considerable progress has been made to understand the relationship between education and economic benefits, and there is growing evidence on a range of non-market effects and 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.

103 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.

104 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, 2016, 9(3): 178-189.

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[105]. 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.

Early school drop out

Research is needed into the causes of children dropping out of school early, in particular what is the relationship between drop out rates, gender, and child labour 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)[106] 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)[107] 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: This equates to 0.1% (approximately $10m) and 1% (approximately $70m) in benefits, which means in practise that the benefits of research could mean 13,000 to 130,000 children stay in school.

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 1 to 10.

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[108]. More investigation is needed on how to structure and deliver programmes in different contexts and how to scale them up cost effectively.

105 UNESCO, 2012, Chapter 2 Financing Education for all, Global Monitoring Report, available online at: http://www.unesco.org/fileadmin/MULTIMEDIA/HQ/ED/pdf/gmr2012-report-ch2.pdf accessed: 24 April 2017

106 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 at: https://www.unicef.org/publications/index_78718.html# (Accessed on 07 April 2017).

107 UNESCO. (2014). Education for All Global Monitoring Report. Teaching and Learning: Achieving quality for all 2013/4. UNESCO.

108 Gertler, Paul, et al (2014). "Labor market returns to an early childhood stimulation intervention in Jamaica." Science 344, no. 6187 (2014): 998-1001.

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

Size of problem: Unicef[109] estimate that globally 23% of children under-5 are stunted, which is 156 million children. A single cohort is 31 million children.

Estimated cost of problem: As mentioned previously (in the analysis on complementary feeding), the global cost of stunting is around $1 trillion per year in lower future productivity.

Estimated potential benefit of R&D: This intervention has shown to be as effective as averting stunting in the Jamaican context. However, the absolute value of improvement in wages (35%) is lower than the improvement in avoiding stunting altogether (66%). We, therefore, estimate the benefits as between 0.01% (US$100m) and 0.1% (US$1bn) per year 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.

Energy:

Technologies to reduce greenhouse emissions from livestock

Livestock emissions are a significant source of greenhouse gases, and research is needed into how gut bacteria in cattle can be managed or manipulated to reduce emissions from cows. Currently livestock emissions vary across the globe, and there are limited coordinated efforts to reduce emissions. In practice, it would be a relatively cheap and effective way to tackle greenhouse gas emissions.

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

Size of problem: Cattle account for approximately 2.1Gt CO_2 equivalent[110] per year.

Cost of problem: Assuming a tonne of CO_2 is costed at $5 at a 5% discount rate, and $22 at a 3% discount rate, based on the biggest meta-study of median estimates from Tol (2011)[111], this gives a total annual cost between US$10bn and US$46bn.

Estimated potential benefit of R&D: Assume that this particular technology may be able to mitigate approximately 10% of the problem associated with livestock emissions, assuming the higher estimated costs of US$46bn, this means a potential benefit of upwards of US$5bn per year. If the estimated likelihood of R&D success is approximately 10% to 30%, then the potential benefit is estimated to be between 1% (US$50m) and 3% (US$140m).

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 5 to 14.

Food Security

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:

109 UNICEF Data: Monitoring the Situation of Children and Women. Available online at at: https://data.unicef.org/topic/nutrition/malnutrition/ (Accessed on 07 April 2017).

110 Food and Agriculture Organization (FAO). "Reducing Enteric Methane for improving food security and livelihoods." Available online at at: http://www.fao.org/in-action/enteric-methane/background/why-is-enteric-methane-important/en/ (Accessed on 07 April 2017).

111 Tol, R.S.J. (2011). "The Social Cost of Carbon", Annual Review of Resource Economics. Vol 3 (2011): 419-443. Available online at at: http://www.annualreviews.org/doi/abs/10.1146/annurev-resource-083110-120028 (Accessed on 22 May 2017).

Motor pumps	Can profitably irrigate 30 million hectares and full adoption of the technology can generate annual net revenues of $22 billion per year for irrigated farmers Potentially 185 million people could benefit.
Treadle pumps	24 million hectares for treadle pumps, with annual net revenues of $19 billion per year Potentially 243 million people could benefit.
Communal river diversions	20 million hectares for communal river diversions, with net revenues of $14 billion per year Potentially 113 million people could benefit.
Small reservoirs	22 million hectares for small reservoirs, with net revenues of $20 billion per year Potentially 369 million people could benefit.
Total potential benefits	**$75 billion** per year

Additional benefits include increased food security, improved nutrition and increased trade.

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.

Gender

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 include 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 of 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 per year
Newborns – 23,710,000 per year
Total is approximately 36 million DALYs per 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 contraceptives 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

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 hundreds of years of learning which has taken place in rich countries, into ten 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 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.

<u>Possible example.</u> 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 10,000. This is a particularly wide range as the effectiveness of the research will depend very much on the exact context and programs being researched.

Health Systems

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 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.

Global Alliance for Diagnostics

A global alliance for diagnostics could bring the same level of dedicated research and development into bringing about a transformation in diagnostics as has taken place in treating infectious diseases over recent years. This could help rationalize approaches to diagnosis, creating a set of diagnostic tools that could be used easily in developing country settings. It would bring about the development of core generic diagnostic tools and tests for treatable conditions such as tuberculosis, malaria, HIV and hypertension - tools which could be used easily and quickly at home or in the community. Such tools would focus in particular on diseases where early diagnosis can be critical to effective and affordable treatment. Existing tests exist, but are not always appropriate for developing countries and currently focus more on disease specific diagnoses, rather than a more generic or holistic approach which could be used easily by front line health workers.

Costs of R&D: The research costs are estimated at approximately US$100m per year.

Size of problem: Number of people dying from tuberculosis, malaria, HIV/AIDS and hypertensive diseases was more than 4 million (Global Burden of Disease, 2015), equating to 183 million DALYs.

Cost of problem: US$3,000 x 183 million DALYs = approximately US$550bn

Estimated potential benefit of R&D: The estimated benefits could be 40,000 lives saved per year, or around 1% of the total problem (US$5.5bn benefit).

Estimated BCR: An order of magnitude estimate gives a BCR of approximately 50.

Taxing Tobacco: 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: 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 that 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 where 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.

Rapid diagnosis and treatment

Currently testing and treatment for HIV/AIDS can require multiple visits to medical facilities, and in Sub-Saharan Africa this is a major block to treatment uptake. Research and development into community based or home testing which is accurate, cheap, mobile and easy to use in developing countries, for example building on current developments in oral swab testing. This would provide a quick diagnosis enabling immediate access to treatment, rather than relying on repeat visits of health workers or to clinics. Earlier diagnosis and faster access to treatment once there is a diagnosis are cost effective, improving adherence and health outcomes.

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

Size of problem: Assume that the people who will benefit are those who are currently not diagnosed, on an annual basis, approximately 840,000 people[113]. The difference between life expectancy of someone receiving treatment compared to someone not being treated is approximately 30 years[114]. The estimated size of the problem is 25 million DALYs.

Cost of problem: US$3,000 x 25 million DALYs = approximately US$80bn

Estimated potential benefit of R&D: Expected benefits are that between 84 (0.01% of problem, US$8m) and 8,400 additional people are diagnosed (1% of problem, US$800m).

Estimated BCR: An order of magnitude estimate gives a BCR of between approximately 1 and 80.

113 In 2015 there were 2.1 million new HIV infections (https://www.avert.org/global-hiv-and-aids-statistics). There are approximately 37 million people living with HIV, of which 40% are not aware they are infected, approximately 15 million people (https://www.avert.org/global-hiv-and-aids-statistics). Assume that the key beneficiary group are the 40% per year who are not getting diagnosed/accessing treatment – 40% of 2.1 million people = 840,000

114 The calculations are based on assumptions that the latency of HIV is an average of 10 years, and the onset of AIDS and death is then an additional 3 years, so therefore, on average, someone without a diagnosis or treatment will live 13 years from the time of contracting the infection. With treatment, the average life expectancy is a further 43 years. The years of life lost are therefore 30 years per person. (http://www.aidsmap.com/Life-expectancy-now-considerably-exceeds-the-average-in-some-people-with-HIV-in-the-US/page/2816267/).

Home testing and monitoring

Current home testing and monitoring of symptoms for people with HIV/AIDS is expensive. Research and development is needed into cheaper and effective kits so that people can monitor themselves at home or be checked by front line health workers in the community, rather than needing regular trips to a clinic. This will enable better self-management and prompt treatment seeking behaviour when it is necessary, as people will be able to make improved judgements about their condition and their need for medical attention.

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: 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. They are important alongside focused interventions. 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: Infant Mortality

Treatment seeking behaviour for diarrhoea

Effective and low cost treatment for diarrhoea is readily available, but is not used consistently, and diarrhoea 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 diarrhoea is under-appreciated until the condition is very serious and subsequently 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 diarrhoea 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: Malaria and other tropical diseases

New drug development to replace artemisinin

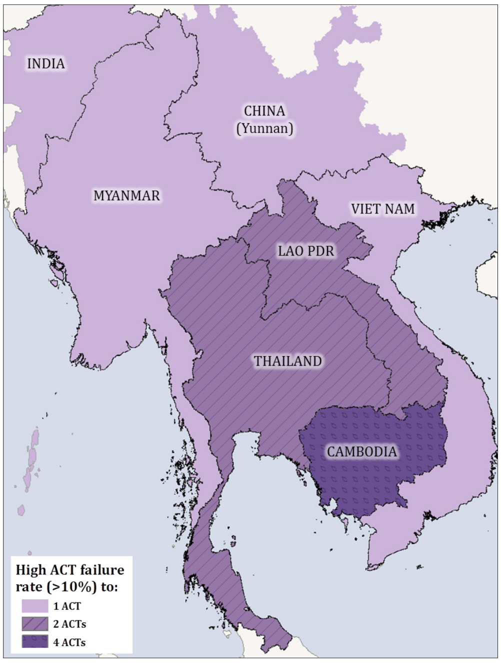
Research and development is required into new drug development for treating malaria, to anticipate emerging drug resistance, in particular to artemisinin, which has been critical to the successful treatment of *P. falciparum* malaria, mainly since 2000. Drugs need to be approved and ready for use as 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[115].

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 (see figure below).

Situation of ACT failures in the Greater Mekong subregion



There are currently five ACTs recommended by WHO: artemether-lumefantrine, artesunate-amodiaquine, artesunate-mefloquine, artesunate-sulfadoxine-pyrimethamine (ASSP) and dihydroartemisininpiperaquine. A sixth ACT, artesunate-pyronaridine, was given a positive scientific opinion by the European Medicines Agency (EMA) under article 58 and is being considered for recommendation by WHO. By default, ASSP is considered having a high failure rate in the region as quadruple and quintuple dhfr and dhps mutations are fixed.

Source: Artemisinin and artemisinin-based combination therapy resistance status report, October 2016, WHO.

115 DNDi (2014). An innovative approach to R&D for neglected patients. Ten years of experience & lessons learned by DNDi. Available online at: https://www.dndi.org/wp-content/uploads/2009/03/DNDi_Modelpaper_2013.pdf
Lubell Y., A. Dondorp, P. J. Guérin, T. Drake, S. Meek, E. Ashley, N. P. J. Day, N. J. White and L. J. White, 2014, 'Artemisinin resistance – modelling the potential human and economic costs', Malaria Journal , 13:452

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 preparation for increased drug resistance in the future.

Lubell et al (2014) estimate an additional 116,000 malaria deaths, $32m in medical costs and $385m worth of productivity losses per year when widespread artemisinin resistance eventuates. Assuming that resistance to ACT would begin in 10 years time and last 20 years before a replacement is found, the cost of artemisinin resistance in present value terms is $43bn discounted at 5%.

Estimated potential benefit of R&D: It is assumed that R&D would speed up the arrival of a new drug such that the effects of artemisinin resistance would be negated – i.e. it would be as if artimisinin resistance had never occurred. Assuming that the effectiveness of the new drug within developing countries is 90%, the chance of delivering it through R&D is between 1% and 10%, and given the cost of the problem is approximately US$43bn, the estimated potential benefit is between US$400m and US$4bn.

Estimated BCR: An order of magnitude estimate gives a BCR between 3 and 30.

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.

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[116]

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

Health: 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 total 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 vary from place to place. This can lead to a lack of awareness about both appropriate frequency of feeding as well as types of food that are important as a baby starts to eat solid foods alongside milk, known as complementary feeding. 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 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 which promote complementary feeding, with a particular focus on: how to work within local and cultural 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.

116 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 at: http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0002865 (Accessed on 07 April 2017).

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 risk 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[117] children under-5 in developing countries who are stunted. The number of stunted children per year, for example 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 as US$3,000, then the net present cost per stunted child is US$33,000 - assuming 4% growth rate in wages, a 5% discount rate and working age from 16 to 55. Total cost of 31m stunted children is 31m x US$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: NCD

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 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.

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

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.

Polypill for hypertension and cardiovascular disease

Research and development is needed to bringing a polypill for treating hypertension and cardio-vascular disease to market. A variety of polypills for treating hypertension have been developed in recent years but have not yet been widely adopted. Combination pills have been used effectively in a range of other conditions, including HIV, TB and malaria but have not been taken up in treatment for hypertension and cardio-vascular disease. Polypills are cost effective, as they are cheaper than taking separate medication, and adherence to treatment is much higher. Several pills have been developed, especially where costs can be kept down by using generic drugs. For example, 'polycap' is one version, developed in India for a domestic market. Current research is focused on the effectiveness of different combinations, and especially in determining risks and benefits for different populations with different combination pills.

Costs of R&D into developing the polypill for market: The research costs are estimated at approximately $10m per year. This is a low figure for new drug development because there has already been so much progress and there are some polypill drugs in this field which are either ready or almost ready for distribution. Additional R&D is not needed for the early stages of drug development.

Size of problem: According to World Health Organization (WHO) figures, raised blood pressure accounts for loss of 57 million DALYs[118]

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 benefit of intervention: Depending on a range of factors, such as timescales, affordability and distribution, this may reduce the impact of hypertension on DALYs 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.

Distribution of polypill for hypertension and cardiovascular disease

R&D into distribution of polypill for treating hypertension and cardiovascular disease. The target audience 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 is necessary.

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).

118 WHO. Global Health Observatory Data, Raised Blood Pressure. Available online at: http://www.who.int/gho/ncd/risk_factors/blood_pressure_prevalence_text/en/ (Accessed on 07 April 2017).

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 treatment for asthma

R&D into a cheap and easy to distribute treatment for asthma. Asthma is largely under control in richer developed countries, but the medication commonly available (inhalers) is expensive and is generally unaffordable in developing countries. Research is needed into an affordable and easy to use medication that would be accessible to people with both asthma and other chronic respiratory conditions.

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

Size of problem: From the Global Burden of Disease, the estimated annual DALYs for asthma in low to middle income countries is 20m.

Estimated cost of problem: US$3,000 X 20 million DALYs = approximately US$60bn per year

Estimated potential benefit of R&D: There is evidence from Brazil that integrated programs focusing on preventative care and distribution of inhalers can have significant effects (79% reduction) on asthma related hospitalizations in a developing country setting[119]. That said, there is limited evidence of its applicability in other resource settings. We, therefore, assume a wide range of possibilities for this R&D. It may reduce the impact of asthma by between 0.1% ($60m) and 10% ($6bn).

BCR: An order of magnitude estimate gives a BCR of approximately 6 to 600.

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 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 that 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

119 Lasmar L, Fontes MJ, Mohallen MT, Fonseca AC, Camargos P.(2009) "Wheezy Child Program. The Experience of the Belo Hoizonte Pediatric Asthma Management Program." World Allergy Organization Journal December, 2009. Vol(2):289–95. Available online at: https://link.springer.com/article/10.1097/WOX.0b013e3181c6c8cb

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 the 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 cardio-vascular 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 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: Tuberculosis

Improved diagnostics for tuberculosis

Research and development is required into cheap diagnostic tools that are more sensitive to TB and can be used cheaply and accurately with target populations in different countries. Currently, diagnostics 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 depend 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; and 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

System to tackle mis-invoicing in trade transactions

Trade mis-invoicing appears to be by far the largest problem in illicit financial flows – albeit estimates using national-level data are inevitably subject to highuncertainty. 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 that 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. In addition, such an assessment would allow for substantially greater confidence in the actual scale of the phenomenon. 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 1% (US$1bn) of losses.

BCR: An order of magnitude estimate gives a BCR of approximately 100.

Nutrition

Improving implementation of nutrition interventions

There has been great progress in identifying nutrition needs and solutions, and current challenges are now centred on implementation and on ensuring that these solutions reach people in the most effective 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 and group sessions. 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[120] estimate that globally 23% children under-5 are stunted, which is 156 million children. A single cohort is 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 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.

120 UNICEF Data: Monitoring the Situation of Children and Women. Available online at: https://data.unicef.org/topic/nutrition/malnutrition/ (Accessed on 07 April 2017).

Assume that the costs of an unhealthy lifestyle lead to the equivalent loss of 2 DALYs per person[121] 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 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

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, research should investigate 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, in Vietnam where 15% of the population are different ethnic minorities, research should focus on groups which are being left behind, or are unable to access the benefits of urbanization and education and identify 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

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 potentially the UK), there are nevertheless beneficial trading opportunities for developing countries, and in particular between natural resource-rich Africa and natural resource-poor Asia. The impact such inter-regional trade potentially could have on African and Asian economies has been

121 May, AM et al (2015) "The impact of a healthy lifestyle on Disability-Adjusted Life Year: a prospective cohort study." BMC Medicine. Available online at: https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-015-0287-6

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 both within and between 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[122] 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, the estimated benefits are approximately US$330 trillion to 2100. Estimating the potential impact on improved trade between Africa and Asia is:

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

Urban infrastructure

Research is needed into city planning and infrastructure development associated with the 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. It is clear that even more is going to be spent in the future. There are no existing relevant models of city development to inform current growth patterns. Research and development is needed to understand new forms of urban growth and to develop options for city planning and more specifically for effective infrastructure investment and maintenance. One specific issue is to research and assess ways to better manage and integrate private water and energy supplies with public supplies to ensure reliable services. Many of the benefits will relate to the efficiency gains made on existing investments into urbanization. (Additional closely related issues raised include research into improving policy and regulations supporting urban development, better understanding of the advantages and disadvantages of urban living and how to mitigate the disadvantages, improving sanitation infrastructure)

Costs of R&D: The research costs are estimated at US$100m per year.

Cost of problem: Estimated US$57 trillion[123] 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.

122 Figures are from World Trade Organization statistical report (2015). Available online at: https://www.wto.org/english/res_e/statis_e/its2015_e/its2015_e.pdf. (Accessed on 07 April 2017).

123 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 at: http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/infrastructure-productivity (Accessed on 07 April 2017).

WASH

Promoting and maintaining hand washing

Research is needed into how to introduce hand washing as a social norm and support its sustained use. Changing behaviour is challenging, and even when changes are successfully introduced, maintaining and normalizing the new practice is critical to maintaining the benefits. Hand washing is important especially in preventing the spread of certain infectious diseases, and in particular diarrheal disease and respiratory infection[124].

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

Size of problem: Assume that the main impact is on reducing diarrheal disease. The number of deaths per year is 1.3 million, 72 million DALYs (Global Burden of Disease, 2015).

Estimated cost of problem: US$3,000 X 72 million DALYs = approximately US$216bn

Estimated potential benefit of R&D: Hand washing, when promoted effectively, has the potential to reduce diarrheal disease by approximately 42 to 47%[125]. If the research is successful in improving the impact of hand washing on reducing disease by 0.1% to 1%, this means approximately US$86m to $860m in health benefits, or 520 to 5,200 fewer deaths per year.

BCR: An order of magnitude estimate gives a BCR of approximately 10 to 100.

124 Curtis V, and Cairncross S. (2003). "Effect of washing hands with soap on diarrhoea risk in the community: a systematic review." The Lancet. Infectious Diseases. 2003 May; 3(5):275-81. Available online at: https://www.ncbi.nlm.nih.gov/pubmed/12726975 (Accessed on 07 April, 2017).

125 Abstract: 'On current evidence, washing hands with soap can reduce the risk of diarrheal diseases by 42-47% and interventions to promote hand washing might save a million lives.' Curtis V, and Cairncross S. (2003). "Effect of washing hands with soap on diarrhoea risk in the community: a systematic review." The Lancet. Infectious Diseases. 2003 May; 3(5):275-81. Available online at: https://www.ncbi.nlm.nih.gov/pubmed/12726975 (Accessed on 07 April, 2017).

Appendix B: List of Contributing Economists and Experts

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Kym Anderson
Professor of Economics, University of Adelaide and Australian National University

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Emmanuelle Auriol
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Jere Behrman
W.R. Kenan, Jr. Professor of Economics and Sociology, Population Studies Center, University of Pennsylvania

Luke Brander
Environmental Economist, Institute for Environmental Studies (IVM)

Zulfiqar Bhutta
Professor, Department of Nutritional Science, University of Toronto

Charles Cadwell
Director, Center on International Development and Governance, Urban Institute
Irma Clots-Figueras, Associate Professor Economics - Carlos III University

Alex Cobham
Chief Executive, Tax Justice Network

Günther Fink
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Harvard School of Public Health

Steven Forsythe
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Hellen Gelband
Associate Director for Policy, The Center for Disease Dynamics, Economics & Policy

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Professor of Economics , Department of Applied Economics, University of Minnesota

Alexei Lee Gonzáles Fanfalone
Doctoral Candidate, Toulouse School of Economics - University of Toulouse

Lorna Guinness
Independent Economist and Consultant

Anke Hoefler, D. Phil
Research officer at the Centre for the Study of African Economies, University of Oxford

Mary Hildebrand
Distinguished Practitioner in Residence and Senior Lecturer - George H.W. Bush School of Government and Public Service, Texas A&M University and Center for International Development, Harvard University

Susan Horton
CIGI Chair in Global Health Economics, University of Waterloo, Canada

Guy Hutton
Senior Advisor, WASH, UNICEF

Prabhat Jha
Professor of Economics, Canada Research Chair of Health and Development at the University of Toronto; founding director of the Centre for Global Health Research, St. Michael's Hospital

Valerie Kozel
Associate Adjunct Professor, La Follette School of Public Affairs, University of Wisconsin-Madison

Bjorn Larsen
Economist and Consultant

Anil Markandya
Professor of Economics, University of Bath; Scientific Director of the Basque Centre for Climate Change in the Basque Country

Claire Melamed
Global Partnership for Sustainable Development Data

Adele C. Morris
Senior Fellow and Policy Director for Climate and Energy Economics Project, Brookings Institution

Rachel Nugent
Vice President, Non-communicable Diseases, RTI International and Affiliate Associate Professor, UW Department of Global Health

George Psacharopoulos
Economics Expert, former London School of Economics and the World Bank

Neha Raykar
Lead Economist, Public Health Foundation of India

Mark Rosegrant
Division Director of the Environment and Production Technology Division, International Food Policy Research Institute

Grant Scobie
Principal Advisor at New Zealand Treasury

Appendix C: Additional R&D Ideas

The economists we spoke with identified between 70 and 100 ideas that could be a focus for R&D investments. Given the scope of this study, we were not able to elaborate on or perform calculations for many of those ideas. In some cases the issue is complex, or the research proposal is not yet focused, and even a quick 'back of the envelope' calculation was not possible. These ideas are nevertheless relevant, and worthwhile considering within a more in-depth review and cost benefit analysis of R&D in international development.

Biodiversity

Global Data Bank

Improved collation and coordination of environmental and ecosystem data globally is needed. So far there have been one off short-term efforts which then endAfter 3 or 4 years attempts to pool knowledge stagnate and the data is soon out of date. Improved data would support more accurate needs assessment, better targeting of resources and improved implementation of the right interventions. The benefit would be the more effective spending of existing investments.

Conflict & Violence

Teenagers

Teenagers are especially vulnerable to violence, and 15-19 year olds in particular experience high levels of abuse. As well as the direct impact on the people involved in terms of health, education, and workforce participation, such formative experiences can set up future negative patterns, exacerbating the potential costs. Research is needed to better understand patterns of abuse and violence and what interventions can help in what circumstances.

Violence against children

Violence against children is not considered unacceptable in many countries and is often prevalent, yet the high cost to individuals and to societies is increasingly recognized. There is some limited evidence on the effectiveness of programs tackling violence against children in developed countries, but research is needed to identify which interventions are most effective and affordable in developing countries.

Impacts of experiences of violence in post-conflict and displaced populations

Research is needed into the relationship between experiences of violence over extended periods and mental health, in particular in conflict and post-conflict situations, among displaced populations, and in refugee communities. For example, the numbers of people fleeing conflict have increased in the past few years and have now reached 65 million people (UNHCR). Better understanding is needed of the issues facing displaced communities and ways in which the experience of violence plays out in their lives.

Drug and crime related violence

Research is needed into different forms of community support for men who are exposed to or participate in violence connected with criminal activities and in particular drug trafficking. Patterns of drug related crime and violence are especially apparent in communities in Latin America.

Education:

Quality of education

Drawing on PISA data and score, research should examine what constitutes good quality secondary education and identify key indicators to support monitoring and planning within national education policy frameworks. Research could include testing and comparing to what extent indicators can be developed and applied within countries and globally. The benefits would include better targeting of resources and prioritization.

Teacher contracts and incentives

R&D is needed into what incentives and contracts lead to improvements in teacher quality, attendance and retention. In many countries teacher absentee rates are as high as 20-30% and improving the selection and motivation of teachers could significantly impact on educational outcomes. Research would focus on identifying a range of alternative ideas and carrying out systematic research into them.

Use of communication technology

There is little understanding of what impact IT can have on education, especially given how widespread and accessible it is in most places. How can you encourage teachers to use tech in the best way – even if they are reluctant or unfamiliar with the technology?

Vocational training

Given the large scale investments currently made into vocational training, research should focus on how to improve the benefits of vocational training to make it more efficient, for example, through the development of new vocational training models and programmes.

Impact of private tutoring on public education

Private tutoring makes a large contribution to secondary education in many countries, including in Africa and Asia. For example in Vietnam, while there are very few private schools, there is a big industry in private tutoring. At present, there is no understanding of whether this is a contributes to learning in a positive way, whether it is cost effective either in public or private terms, or if it provides no net benefit at all. The system seems to support wealthy families from within the public system, potentially providing perverse incentives for teachers who work in public schools to also provide private tutoring to those who can afford it. In

South Korea, 1% of GDP is spent on private tutoring. Research is needed into the relationship between private and public sector funding in education and how different approaches can bring about increased educational effectiveness for more people.

Energy

Technology to grow 'lab' meat for developing country markets

Research and development into laboratory grown meat, sometimes referred to as 'clean meat', has advanced rapidly over the past five years. It has the potential to add affordable, nutritious, safe animal protein to people's diets, and in particular for people who otherwise cannot afford or do not have access to animal products. In addition, the production of 'lab' meat and related products (including dairy) would reduce environmental impacts in terms of energy, land use, and emissions.

Grid integration of renewables

R&D is needed into improving energy storage and distribution to minimize intermittency of renewables and encourage the efficiency and usage of renewable energy sources. The benefits would be in the reduction of carbon emission from fossil fuels, as well as improved energy access where there is currently energy poverty.

Carbon tax protocols/implementation

Policy research is needed into how best to implement and manage carbon taxes. Carbon taxes tend to be applied at 'choke points' such as imports, coal mines, refineries and storage facilities. These are large scale, easily identified and can be a focus for regulation and monitoring. Given these conditions, carbon taxes are potentially a very efficient form of revenue for governments. This helps to tackle environmental issues and create reliable and predictable revenue streams for government - one of the main challenges to government managed national development in low to middle income countries.

Negative emissions technologies

There is a longer term ambition to develop technologies that are carbon neutral or even negative. This type of research requires long term investment, with perhaps a 50 year time horizon.

Women's Health

Potential for targeting women as part of the National Rural Employment Guarantee Program in India

Pilot studies are proposed into how best to target the existing government mandated scheme in India (NREGP) to women. In its present form, the scheme has resulted in increased employment in rural areas and there is potential to adapt this approach to target women more specifically. Conducting research as a pilot project to evaluate its impact on women's labour market participation along with the impact on household relationships.

Gender

Evaluation of quota systems to support political empowerment for women

Policy research is needed into how quota systems can be used most effectively to encourage women's political participation. Quotas are the most used and researched intervention supporting political engagement, but there is often a mixed response from the electorate, at times leading to a backlash. Research could help to identify how best to use quotas and could test whether quotas might work better as part of a package or series of interventions. The potential benefits of more women in politics are high, as female politicians tend to support more investment in education and health, as well as providing role models for girls as leaders and decision makers in society.

Governance

Support governance capacities by incorporating into infrastructure support

Direct support for improving governance has not always been successful and research and development is needed into more indirect forms of support. Research would focus on the development of models, regulations and incentives for better integrating governance capacity support through specific infrastructure initiatives, for example in health or education. Such governance capacity models could become part of large-scale investments in infrastructure development from multi-lateral agencies, such as the World Bank, to individual countries.

National level data collection systems

National governments need reliable, consistent and regularly collected data in order to plan and prioritize health, education and infrastructure development and to monitor and evaluate policies. For some developing countries, and especially where there is relatively rapid economic growth, there are opportunities to research, evaluate and develop new data systems and regulatory frameworks such as data privacy and security, for example through government statistical offices.

Models of cross-border cooperation

Research and development is needed into solutions for cross-border cooperation on issues including security, water, trade, climate change and energy distribution.

Infrastructure

Potential for Internet Exchange Points in country

Internet Exchange Points (IXPs) provide a country with local internet management systems. This provides improved internet performance, reduced latency and local data. It encourages in-country development, and may act as a spur to economic development. Research is needed to improve understanding and development of interventions that support IXP development, the opportunities they bring and what policies support them.

Public-private partnerships (PPP) to support internet infrastructure

Policy research is needed into what forms of PPPs are most suited to supporting the development of internet broadband and wireless infrastructure in low income countries.

Infrastructure

Regulatory framework to support infrastructure investment and development

Basic infrastructure is still almost completely lacking in some of the poorest countries and rural areas, yet access to reliable and affordable electricity and water are basic needs in terms of future development. Research is needed into the differing roles of government such as initiating, implementing, regulating, managing and maintaining large scale infrastructure developments. This would provide the necessary utilities to people so that they can improve their lives and contribute to the economic development of their country. In much development the central contribution of government has taken a secondary place in relation to the private sector, and while the private sector has made significant progress in areas such as mobile technology access, there are areas where more state action is needed and greater understanding is required on how to make that happen effectively. R&D is needed into policy and regulatory frameworks, especially in relation to how international agencies such as the World Bank can work more effectively with national governments on such projects.

Malaria

Drug treatment for vivax

In recent years, most attention on tackling malaria has been focused on treating and controlling the more fatal form, p. falciparum, in particular across Sub Saharan Africa. However, vivax, while not as deadly, is very serious and does in some cases lead to fatalities. In addition, there is concern that successes in tackling falciparum may lead to an increase in vivax. There needs to be more research and development specifically into drug treatments for vivax, in order to both treat the condition and also to anticipate its potential spread.

Pilot projects to demonstrate the elimination of malaria

Research and development is needed into creating a template for how malaria could be eliminated from a community. This is likely to involve public awareness campaigns which would support en masse drug treatment once or twice a year over 2 to 3 years. By creating successful examples and models of elimination for defined geographical communities, this could help create momentum behind more ambitious campaigns to eliminate malaria across larger areas.

Management of 'mosaic' or multiple approaches to drug treatments

Malaria cannot be effectively managed and treated using just one approach, but models of how to use mixed approaches are not well developed. The effectiveness of varying insecticide use in agriculture has been demonstrated as a 'mosaic' approach to avoid the development of pesticide resistance. Similarly, models of drug treatments show that the effectiveness of drugs is improved if different drug and drug combinations are used within a geographical area. Research and development is needed into models of how this could be implemented, managed and monitored in practice.

Test for G6PD deficiency

G6PD is an enzyme deficiency found most commonly in people in Africa. It is associated with some resistance to malaria, especially the more fatal form of malaria, p. falciparum, which is also found primarily in Africa. However, a G6PD deficiency means that people cannot safely take existing drug treatments, and in particular for the vivax form of malaria. Research and development is needed into a fast, cheap and accurate point of care test for G6PD so that people are not given treatments that are potentially dangerous and so that they are treated appropriately for the vivax form of malaria.

Maternal Health

Menstrual hygiene management

Research is needed into menstrual hygiene habits, especially among adolescents, to better plan and maintain current investment in infrastructure development and promote correct use of the facilities provided. The benefits would be in the more efficient use of existing public expenditure.

Impact of agricultural policy on diet and health

There is disconnect between agricultural policy and health care/nutrition policy. The impact on diet and nutrition and the potential reduction in dietary diversity following the move towards cash crops and away from traditional crops in some places is not well understood. The role of locally grown agricultural crops in diet, and any causal links between agricultural policy, diet, nutrition and health should be researched.

Task sharing and task shifting in health systems

Research is needed into how best to structure health care systems in developing countries in terms of task sharing and task shifting.

Tuberculosis

Modelling impact of interventions in different high burden countries

The pattern of tuberculosis infection looks different in different countries, and at risk groups may exhibit different behaviours and risk factors. Modelling how different interventions could be implemented in different settings in order to help maximize the impact, and in particular where there is a high burden of tuberculosis. This would help identify how to prioritize interventions in a more county or region specific way.

Population

Scaling up nutrition interventions for under-5s

India has large numbers of undernourished children, as well as a large pool of schooled capable women in rural areas. Current RCT research focused on interventions working with local women to provide community based support in the form of nutritional education, home visits and group sessions is showing positive impacts. Follow up R&D is needed, focused on scaling up the model to expand across India and to test its feasibility in other countries in South and South East Asia.

Improving effectiveness of existing nutrition programs in India

Research is needed into how to improve the reach and effectiveness of existing government nutrition programs in India that provide nutrition programs at preschool, reaching potentially around 100m 3-5 years olds. Current evidence on the performance of these programs is mixed, and R&D into refining and improving their effectiveness is likely to be very cost effective given the large population of children in India and the potential cost effectiveness of improving existing programmes rather than introduce new projects.

Adapting and developing models for nutrition and early childhood stimulation interventions in Africa

Existing programmes with educated rural women in India to deliver training and support to families and care givers to improve early childhood stimulation is showing potential and could have relevance in other countries. However, in many parts of Africa, education levels are lower among rural women and R&D is needed on how to adapt and develop a model of delivery that is effective in African countries.

Fertility reduction/ Family planning

Conduct R&D into improved and affordable options for women in Sub-Saharan Africa to control fertility and reproductive health.

Poverty

Role of education in providing the right skills for globalization and technology development in the workplace

Research is needed globally into what forms of education will equip people in the longer term for dealing positively with the changing nature of work. Currently, education focus is either too academic for many, or provides vocational skills for workplaces which will soon to be redundant. In particular, there is a need to focus on the transition from secondary school to high school, providing students with relevant skills which will support their lives and labour market participation as urbanization and technology development change the nature of work opportunities in low to middle income countries, as well as in higher income countries.

WASH

Wastewater treatment technology

Conduct R&D into developing new technologies that can suck up sludge from sceptic tanks, and turn it into energy neutralising products, perhaps compost or fertiliser.

Recycle wastewater

Research is needed into further opportunities and the technologies and policies to support the roll out of innovations that have taken place in cities that treat water and recycle it for use by industry (eg Durban, Madras).

Policy Exchange

Investing in R&D is one of the most cost-effective types of international development, and one of the best ways for a Global Britain to help tackle global challenges.

The UK is already a world leader in development research, but there is considerable potential to go still further, become more strategic and better integrate with the Government's innovation-led Industrial Strategy

In order to better understand where additional resources on R&D could be spent, we asked the Copenhagen Consensus Center to use its network of the world's top economists to identify the best R&D options available to meet the UN's 17 Sustainable Development Goals: air pollution, biodiversity, conflict & violence, education, energy, food security, gender, governance, health, illicit financial flows, nutrition, population, poverty, trade, urbanization and WASH.

In this report, we look at three key questions:

Why spend more on R&D in development?

- **Many of today's technologies are not good or cost effective enough to meet future challenges, while substantial research gaps still exist in large parts of our evidence base.**
- **What are the most important targets for R&D?**
- **We present the details of 40 potential R&D projects with quantified benefit cost ratios, the vast majority of which look to be highly cost effective.**
- **How can development R&D be integrated with the Government's new Industrial Strategy?**
- **The current Global Challenges Research Fund should be made more strategic, with the creation of a new Innovation Challenge Agency and a series of new Advanced Market Commitments to bring in the expertise of the private sector.**

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