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A Global Opportunity to Combat Preventable Disease

How to Use Covid-19 Infrastructure to Transform Public Health Worldwide

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Idea in Brief

The Covid-19 pandemic showed both what is possible in global public health and what to do to make it better in instances where international cooperation fell woefully short. Learning from this experience, we have an opportunity to create an adult-vaccination programme with transformative potential for the world. This will require a new partnership between the Global South and the Global North, underpinned by global health institutions.

Executive Summary

Over the coming years there will be a range of new vaccines not only for pathogens like Covid-19, but also for tuberculosis, malaria, HIV/AIDS, dengue and other diseases. Given recent advancements in the development of therapeutics, we should also push the traditional definition of a vaccine to include preventative injectables for conditions including HIV, cardiometabolic disease and common cancers.

At least 10 million deaths per year are attributable to diseases with existing or forthcoming adult vaccines and preventative injectable therapies – deaths that could also be reduced through a system of adult public-health interventions.

But Covid-19 has exposed some chronic deficiencies in the global architecture for delivering such a huge programme. Though vaccine production to fight the virus proceeded at a pace remarkable in comparison to conventional vaccine development, the world still paid a heavy price for not accelerating it further. The distribution of vaccines has been plainly inequitable. And some countries have been unable to absorb the vaccines received. We will squander the public-health opportunity presented by new vaccines and therapeutics unless we find a better way to develop, manufacture and distribute them in the future.

The potential economic benefits are also compelling. In this paper, we have rethought the traditional investment case for vaccines by assessing them together as part of a structured programme; further, by considering the impact of preventing the next pandemic, modelling conducted exclusively for this paper suggests that such a programme could have more than \$3.4 trillion in value for the global economy, including \$1 trillion for developing countries. Should a future pandemic affect younger, less vulnerable, working-age populations, this value could be above \$7 trillion.

This paper sets out how – through a global adult-vaccination programme underpinned by strong Global South input and leadership – this goal can be achieved. By strengthening Global South leadership in this effort, the world can achieve improved global population health, economic benefits and increased autonomy for developing countries.

- An endeavour of this magnitude will require a partnership with mutual responsibilities for both Global North and South so that such a programme can be fully effective, and we set out the following recommendations for achieving this:
- Multilateral organisations including Gavi, the Vaccine Alliance; the World Health Organisation (WHO); the Global Fund; the Coalition for Epidemic Preparedness Innovations (CEPI); the World Bank and others, and donors such as the Bill & Melinda Gates Foundation, should mobilise resources, infrastructure and expertise, building on lessons learned, to either take on or support the development of this programme. Regional organisations in the Global South, potentially including the Africa Centres for Disease Control and Prevention (Africa CDC), the Pan American Health Organisation (PAHO) and the Association of Southeast Asian Nations (ASEAN), should drive Global South leadership by coordinating supply and demand, allocating financial resources and harmonising regulations.
- Governments receiving support should agree to make the preparations for the demand that will be driven by the approval of new life-saving vaccines and injectables, and should sustain and develop their Covid-19 vaccine-deployment and manufacturing infrastructure for long-term use. They should also invest in scalable digital infrastructure to support registration, distribution and the collection of real-world evidence.
- Scientific experts should collaborate to develop global eligibility and dosing guidelines for an adult-vaccination programme.
- The private sector should ensure availability and affordability of vaccines for developing countries as they come to market through appropriate pricing schemes and intellectual-property arrangements.
- There should be an oversight body comprising the key partners in conjunction with scientific experts to ensure that the obligations of the parties are fulfilled in terms of the supply of vaccines and injectables, the best protocols for dosing and the necessary infrastructure in participating countries to allow effective use of supply.

This programme will only work based on mutual responsibility. Wealthier countries must provide the resources, the private sector the intellectual property. And every country has a responsibility to make the changes in infrastructure and policy that would allow the resources to be used effectively. All of this must be overseen in an objective way by key stakeholders and experts.

Building a permanent adult-vaccination programme as a positive legacy of the Covid-19 crisis will have a profound impact on global public health and prevent the premature deaths of millions of people each year.



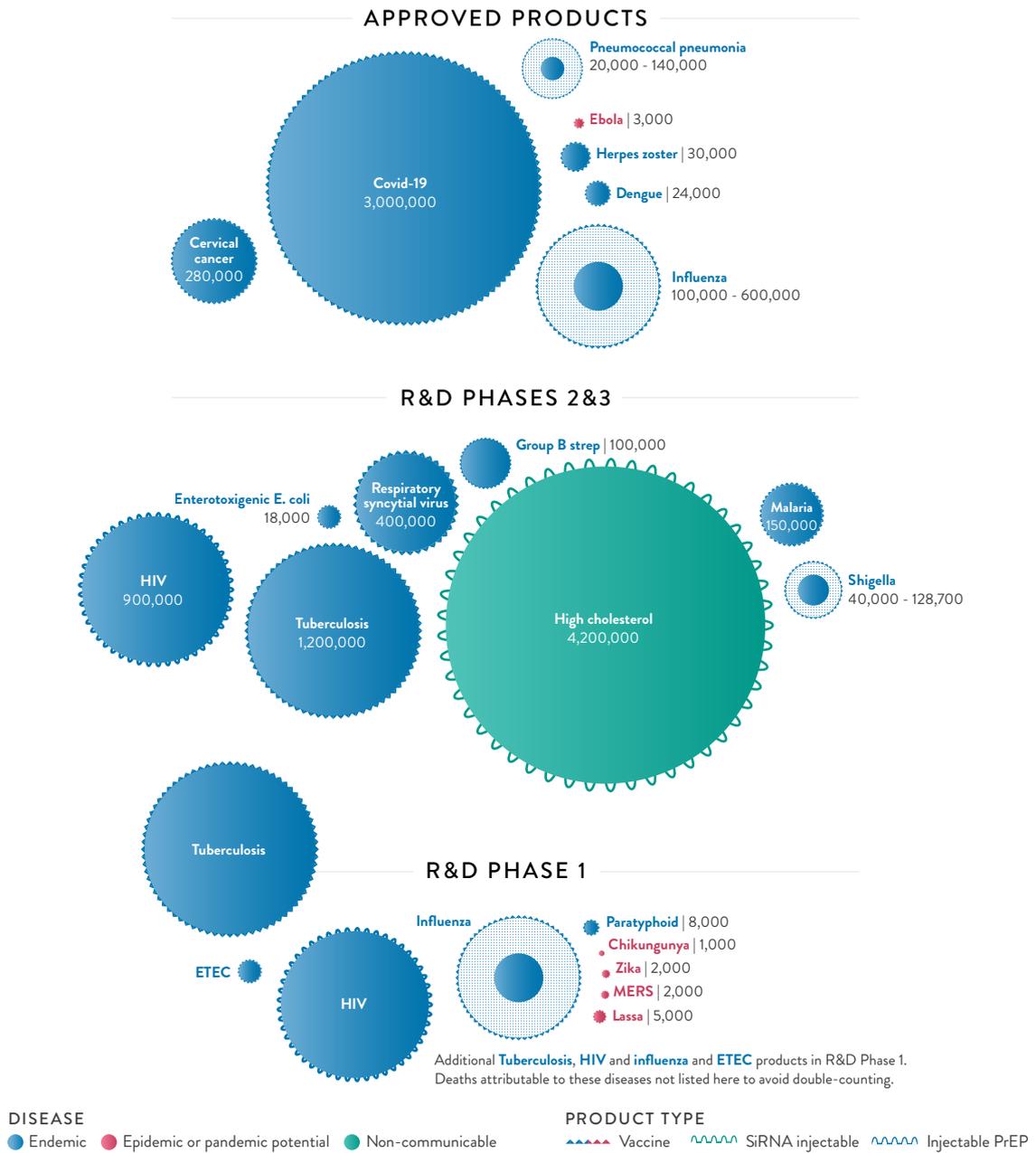
A Post-Covid Opportunity for Public Health

The Covid-19 pandemic has exposed fundamental weaknesses within public health – including a lack of strong global coordination and baseline manufacturing capacity that was inadequate for the scale and speed of vaccine production needed. They have exacerbated existing inequalities, and extended the crisis by allowing new variants to emerge and spread. These failures have risked undermining the exceptional achievements of scientists, regulators and industry in creating and scaling safe and effective vaccines. Furthermore, the rate at which new pathogens are emerging is increasing, due to expanded human contact with wild animals and the effects of climate change. Thus, once-in-a-century infectious-disease outbreaks may well become more frequent, with far-reaching global consequences.¹ New crises, perhaps on a bigger scale, are inevitable without remedial action.²

But alongside these challenges, strides have been made. The response to Covid-19 has accelerated advances in vaccine development, forced countries to ramp up their manufacturing capabilities and led to improvements in vaccine-deployment infrastructure, while helping to bridge the gaps between science, government and industry. This progress means that a global adult-vaccination programme, analogous to the [Essential Programme on Immunization](#) that led the effort to vaccinate the world's children against preventable illnesses, is possible for the first time: we can leverage this new understanding and lessons learned from Covid-19 for the future of global health, initiating a vaccination programme aimed at reducing high-burden infectious diseases and building population-level immunity against respiratory diseases such as influenza and pneumonia. The programme should also go beyond the traditional definition of a vaccine to include preventative and therapeutic injectables for conditions including HIV, cardiometabolic disease, common cancers and others.

Figure 1

AT LEAST 10 MILLION DEATHS PER YEAR ARE ATTRIBUTABLE TO DISEASES WITH EXISTING OR FORTHCOMING ADULT VACCINE



*Adult vaccines include vaccines and select preventative injectables

Note: a summary schematic of some of the current and promising vaccines that would avert millions of deaths each year. This figure is drawn from estimates based on OWID,³ IHME Global Burden of Disease metrics for 2019,⁴ systematic reviews^{5,6} and WHO health data.⁷ Deaths are all of adult populations, except for Group B strep where neonatal deaths are measured but vaccination is given to the mother. Herpes zoster, pneumococcal and RSV are estimated for eligible adults (>60 years). Pneumococcal and RSV are representative of an equal split of the total lower-respiratory-tract infections in the >65 age group (roughly 1.2 million), of which they are the most common. Shigella and ETEC deaths are for adults >70 as these were the only available data sets and so are likely to be higher.⁸ Covid-19 deaths represent those that occurred after the first vaccine rollouts began.

Source: GHSC

At least 10 million deaths per year are attributable to diseases with existing or forthcoming adult vaccines and preventative injectable therapies – deaths that could also be reduced through a system of adult public-health interventions. A global adult-vaccination programme, with a coordinated manufacturing and delivery infrastructure that deploys routine adult vaccines and can be rapidly mobilised in response to another pandemic, would provide immeasurable global benefit and ultimately transform global-health infrastructure from reactive to preventative.⁹

What It Will Take to Realise This Opportunity

Manufacturing and distribution capacity have grown as a result of Covid-19, and the world must ensure that this infrastructure is maintained and used in sustainable and cost-effective ways into the future, through the next phases of this pandemic and beyond. Advancements in the development of preventative injectables and vaccines for a number of diseases mean that consistently maintained infrastructure can be used productively during non-pandemic times. A global adult-vaccination programme would ensure stable and predictable demand for these vaccines and injectable therapies, and could help offset the costs of investing in increased manufacturing capacity. Conversely, if the systems are not kept operational after Covid-19, much of that work and investment will have been squandered.

Individual- and country-level needs will drive demand, but the essential components – outlined in this chapter – remain the same for both pandemic preparedness and preventative health care.

VACCINE AND PREVENTATIVE INJECTABLES SELECTION

In a revolution that began well before Covid-19, vaccine technology has progressed dramatically. New programmable platforms [such as RNA and adenovirus](#) have made it much easier to create new vaccines; meanwhile, the evolution of adjuvants (ingredients added to certain vaccines to trigger a stronger immune response in recipients, such as AS01, which is used in tuberculosis vaccines) and lipid nanoparticles means that the next generation of powerful products will soon be available to tackle many of the world's major pathogens.

Emerging technologies, along with established vaccines, can form the basis for a global adult-vaccination programme. The global community should begin by addressing the present need for Covid-19 vaccines and regular boosters, build on that framework with other existing vaccines and then add

promising new candidates over time. Some existing vaccines and long-acting, injectable preventative therapies, or those that are in human trials, will be considered briefly here and in more comprehensive detail in the chapter entitled Technical Deep Dive 1: Vaccine Candidates and Eligible Populations later in the paper.

Beyond Covid-19 vaccination, the World Health Organisation (WHO) has a recommended list of routine vaccines for adults.¹⁰ In high-income countries, such as the United States and the United Kingdom, guidelines already exist for the use of these available vaccines,^{11,12} but global consensus regarding access to these important interventions has not been achieved.¹³ This would be a key consideration in developing the global adult-vaccination programme.

Looking ahead, a number of game-changing vaccines are in the pipeline, including a vaccine for respiratory syncytial virus (RSV), with a candidate from Pfizer currently in a phase III trial. Prevention of malaria, HIV and tuberculosis are all within reach as a number of candidates have reached phase I-III clinical trials in adults. These will also be detailed in the aforementioned Technical Deep Dive 1: Vaccine Candidates and Eligible Populations; this deep dive will also include an examination of **predictive vaccination** (which could make it possible within our lifetime to use [multivalent vaccines](#) – vaccines that protect against multiple pathogens or multiple strains of the same pathogen – to pre-empt pandemic risks by providing exposure to highly pathogenic influenza antigens as some of the multivalent epitopes in seasonal flu vaccines¹⁴), as well as further details on **preventative injectables** and why we recommend including them in the global adult-vaccination programme.

INCREASED MANUFACTURING CAPACITY, PARTICULARLY IN THE GLOBAL SOUTH

To deliver vaccines to the world's population and to be able to manage the manufacture of new types of vaccines, including viral vectors, RNA, virus-like particles (VLPs) and a wide range of novel adjuvants, it has been necessary to greatly expand vaccine-manufacturing capacity. A hard lesson learned from this pandemic was that our baseline global manufacturing capacity was inadequate for the scale of Covid-19 and controlled by a small number of commercial companies with competing interests.¹⁵ Very few countries had facilities capable of providing a sovereign supply of vaccines.

Developed economies have rapidly enhanced their ability to be self-sufficient since the start of the pandemic and, increasingly, capacity has been expanding in developing economies. Vaccine-manufacturing and drug-development capabilities in Africa are now becoming a reality, with the Africa Centres for Disease Control and Prevention (Africa CDC) and WHO supporting several endeavours. The biggest manufacturer in the world is the Serum Institute of India, which will soon be producing up to 200 million doses of Covishield per month. This growth in manufacturing supply is a massive boost to global vaccine production and the new infrastructure created will remain in place after Covid-19.

As vaccine production increasingly focuses on a smaller number of platforms, this new manufacturing infrastructure should offer a solid basis upon which a range of new vaccines can be produced and supplied to regions across the world. An adult-vaccination programme would sustain this additional manufacturing capacity with ongoing demand and in the event of another pandemic, these facilities can be rapidly repurposed to manage new global threats.

When governments fund new facilities (in part or wholly), they will need to consider walk-in rights¹⁶ and think collectively about how to support regulators to maintain good manufacturing-practice standards across the globe. Ideally, countries will cooperate to build a long-term manufacturing network optimised to meet demand, without creating redundant facilities.

Building a global manufacturing footprint for adult vaccines that is standardised and efficient but also versatile should reduce production costs worldwide and improve the investment case for an ambitious adult-vaccination programme.

FINANCING AND PRICING MODELS

The need for currently available vaccines and those that are in the pipeline is most acute in developing countries. New pricing models will be needed, with the possibility of tiered pricing to meet global demand in low-to middle-income countries (LMICs).

Industry and governments must work together to incentivise the production of these vaccines at scale. For example, donors and governments can use advance market commitments (AMCs) – which guarantee the minimum purchase of a vaccine once it receives regulatory approval, while it is still in the research and development (R&D) phase – to incentivise R&D

investments. Industry will need to fit price and supply to the budgets available in order to drive sustainable business practices that also deliver the public good of global pandemic preparedness. AMCs and other market-shaping tools that de-risk investment for industry could justify lower industry margins and maintain favourable economic conditions for both parties.

IMPROVED SERVICE DELIVERY AND DIGITAL INFRASTRUCTURE

We need a more systematic approach to vaccine deployment in all nations. Particularly in the poorest countries, this requires capacity in health-care systems to identify the individuals to be vaccinated, recall them and ensure that the appropriate number of doses and boosters are given, in line with the chosen national approach. In some cases, unconstrained supply is necessary, but in others, demand will be determined according to the specific local context.

Such structures will be relatively bespoke to most health systems, but all have required elements in common, such as strong IT infrastructure, the ability to create personal identifiers and health-system databases that can be kept secure, and a well-trained workforce.¹⁷ There are a wide range of use cases for digital applications to support vaccine rollout, including registration of patients, ensuring adherence to multidose vaccine regimens, collection of real-world evidence on side effects and therapeutic outcomes, tracking vaccine inventory, and monitoring vaccine rollout to increase resourcing in geographic areas facing challenges. This digital infrastructure will enable efficient identification of vaccine need and distribution, while real-world evidence provides relevant local data to overcome vaccine hesitancy and loss.

Countries are already building new infrastructure to support Covid-19 vaccination and, once created, these should be leveraged to roll out other adult vaccines and injectable therapeutics. Unless this sort of infrastructure is put to different use, it may lie fallow and public health may revert back to its pre-pandemic state. (A detailed framework for how countries can improve their absorption capacity is set out in [a previous paper from the Global Health Security Consortium](#).)

Consolidating, reinforcing and adding to existing and developing infrastructure will prevent fragmentation in our response to global public-health crises.

BUILDING VACCINE CONFIDENCE

A lack of global support for adult vaccines before the Covid-19 pandemic means that most people, particularly in LMICs, were not accustomed to the idea of vaccines in adulthood. Together with real-time data on side effects being published in the mainstream media and the serious impact of misinformation, vaccine hesitancy continues to be a significant barrier to ending the current pandemic. A global effort is needed, together with in-country support, to develop a strategic communication framework that can be leveraged to build trust in vaccinations and support for an adult-vaccination campaign. Real-world evidence collected through the digital infrastructure described above will contribute directly to this effort by both highlighting areas where hesitancy may exist and providing a locally relevant set of data for use in any communication strategy.

A number of methods to achieve this have been described in [the previously mentioned Global Health Security Consortium paper on absorption capacity](#), along with a more detailed description of all the necessary components of vaccine absorption.¹⁸

GLOBAL EPIDEMIOLOGICAL MONITORING

Public-health monitoring has improved considerably because of Covid-19 but it must become better still.

Major expansion of local population-level epidemiological monitoring, real-world data collection and genomic-sequencing capacity is needed to monitor vaccine effectiveness and disease flare-ups, and to identify new variants and novel threats. These tools need to be accessible to developing economies with limited infrastructure, and high-income countries (HICs) have started funding programmes in this space. The technology is rapidly evolving, with both input from major sequencing suppliers and software products such as the Global Pathogen Analysis System (GPAS),¹⁹ meaning a standardised global solution for pathogen identification and tracking is likely to soon emerge.

Enhanced biological-monitoring capacities, of course, will have major implications for a range of pathogens beyond Covid-19. Novel approaches, such as conducting biological monitoring in the event of a zoonotic-disease outbreak to assess the spread among the humans who made the initial contact with animals, are also now possible.²⁰ The rapid diagnosis and identification of drug-resistant forms of *Mycobacterium tuberculosis*, for example, will impact the control of that disease. But the ability to track and manage variation and, more broadly, antimicrobial resistance in other

infections such as HIV, dengue fever and malaria would be a major dividend of the wider application of a sequence-driven pathogen-identification system emerging from the Covid-19 crisis.

GLOBAL GOVERNANCE AND LEADERSHIP

A definitive position on governance will develop as stakeholders are engaged and a commitment to support this programme has been established. It will require collaboration between multilateral and regional organisations, governments, scientific experts and the private sector. A full list of recommendations for each stakeholder are listed below in the Conclusions and Action Plan.

However, based on three unique considerations – all of which are trends accelerated by Covid-19 with implications for global public health – we believe as an overarching principle that Global South input, decision-making and leadership are critical to a global adult-vaccination programme:

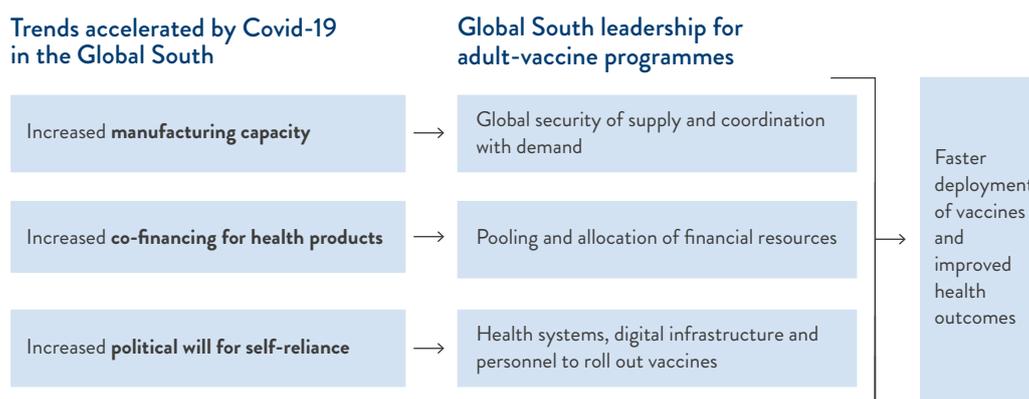
1. A global adult-vaccination programme must optimise novel manufacturing capacity, with an emphasis on building this capacity in the Global South.
2. There are opportunities for the co-financing of vaccine programmes by the Global South.
3. There is increased political will for self-reliance in the Global South.

The failure of the Global North to share significant numbers of vaccine doses early in the pandemic, and the Global South's reliance on manufacturing capacity primarily based in the United States, Europe, India and China, has created a renewed call for self-reliance in global health and international development among LMICs. The two aforementioned opportunities regarding manufacturing capacity and financing from the Global South reinforce this call and reflect broader political will for self-reliance.

The governance structure for a global adult-vaccination programme should reflect this and should also include a scientific oversight committee comprising the key partners in conjunction with scientific experts; this oversight body would ensure that the obligations of the parties are fulfilled in terms of the supply of vaccines and injectables, the best protocols for dosing and the necessary infrastructure in participating countries to allow effective use of supply.

Figure 2

**A GLOBAL SOUTH-LED ADULT-VACCINATION PROGRAMME REPRESENTS
A HISTORIC OPPORTUNITY FOR GLOBAL HEALTH**



Source: GHSC

Given these unique considerations (outlined in further detail in the Technical Deep Dive 2: Global Governance and Leadership, later in this paper), a global adult-vaccination programme represents a historic opportunity for a major global-health programme with strong Global South leadership.

Further details on the governance and leadership of the adult-vaccination programme – including recommended multilateral partnerships and the scientific oversight committee – are detailed in the aforementioned Technical Deep Dive 2.

The Investment Case

The economic case for a global adult-vaccination programme is compelling. The International Monetary Fund (IMF) has noted that accelerating the end of the Covid-19 pandemic could yield economic returns of some \$9 trillion from 2020 to 2025.²¹ In addition to the IMF's estimates, the GHSC has conducted exclusive modelling – calculating the economic benefit that would have resulted from accelerated vaccine rollout during the first 21 months of the pandemic – which shows that an adult-vaccination programme is likely to have strong economic benefits. Our modelling suggests that in the event of another outbreak similar to Covid-19, a faster vaccination programme that allows the world to normalise more quickly than current timelines could save \$3.4 trillion in lost economic activity, and more than \$1 trillion for developing economies, over 21 months.

To assess the investment case for a global adult-vaccination programme, we considered two different approaches: first is the Health-Economic Approach, a literature review of classic health-economic analyses regarding the cost effectiveness of adult vaccines that have been launched or are in development; second is the Pandemic-Preparedness Case, a novel approach to estimating the economic benefit of pandemic preparedness, which includes our exclusive modelling.

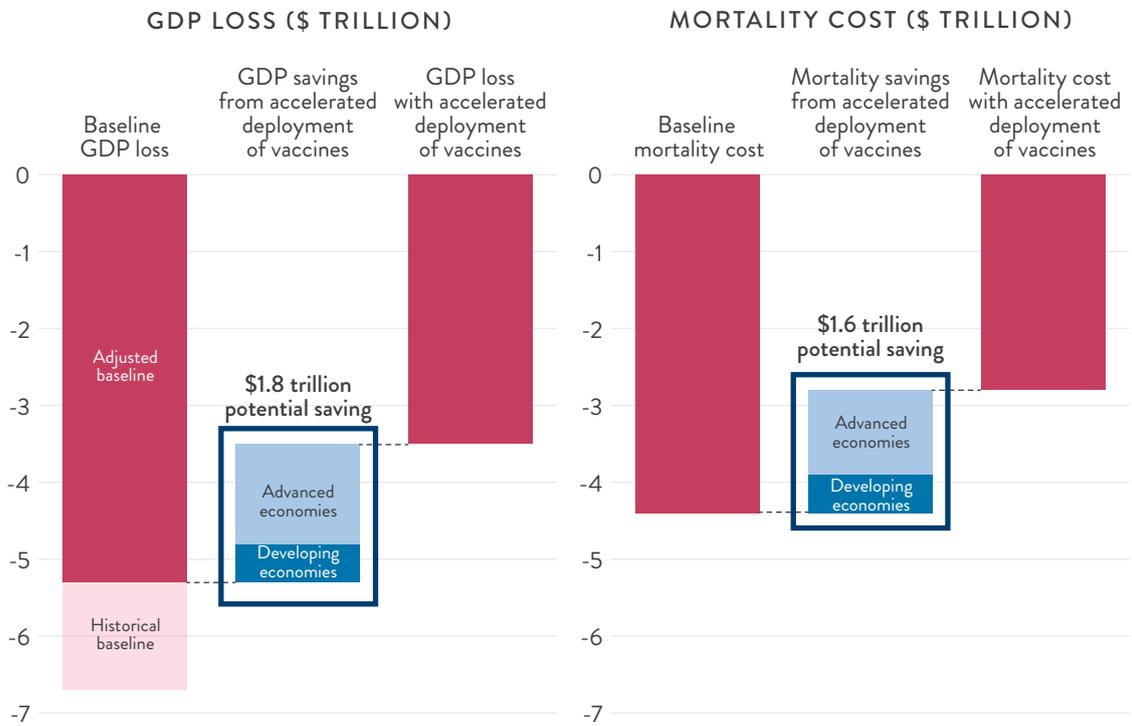
Both approaches are explored in full in the Technical Deep Dive 3: The Investment Case but our key takeaways are:

1. There is a strong health-investment case for rolling out adult vaccines currently in development, including HIV vaccines. However, given differences in target populations and dosing regimens, delivering these vaccines would require a robust primary-care delivery infrastructure.
2. We also estimate that a global adult-vaccination programme could have a global economic value of \$3.4 trillion (see Figure 3).

- More robust methodologies must be developed for estimating the macroeconomic value of pandemic-preparedness measures, including global vaccination manufacturing and service-delivery readiness.

Figure 3

DURING A FUTURE PANDEMIC, A GLOBAL ADULT-VACCINATION PROGRAMME COULD SAVE THE WORLD \$3.4 TRILLION, INCLUDING \$1 TRILLION IN DEVELOPING ECONOMIES



Source: Our World in Data, the Economist's excess Covid-19 deaths database, United Nations population data, OECD Economic Outlook statistics

Conclusion and Action Plan

An adult-vaccination programme will bring significant health benefits in terms of morbidity and mortality, and help to reduce inequalities across the globe. Further analysis will be required to define the investment case within a new economic framework and bearing in mind recommendations for vaccine candidates and injectable therapeutics. We will need to scope the potential manufacturing technologies and platforms along with production capacity and consideration of the core design components of the campaign. Now is the time to call for health leaders, scientists and economists to come together and drive forward this idea with the wider stakeholder community.

ACTION PLAN TO END PREVENTABLE DISEASE:

Recommendations for Multilateral and Regional Organisations

Multilateral organisations and donors can support the creation of a global adult-vaccination programme in the following ways:

- Organisations with existing expertise, resources and infrastructure, such as Gavi or the Global Fund, should consider taking the lead on establishing or supporting this programme, incorporating strong Global South leadership.
- The programme should be guided by lessons learned, in particular from Gavi's past and present vaccine programmes, as well as from the recent development of COVAX. By mobilising expertise and resources to support the global planning and development of the programme and individual countries in their implementation, these learnings will be imperative.
- Regional organisations in the Global South, potentially including the Africa Centres for Disease Control and Prevention (Africa CDC), the Pan American Health Organisation (PAHO) and the Association of

Southeast Asian Nations (ASEAN), should drive Global South leadership by coordinating supply and demand, allocating financial resources and harmonising regulations.

- Global health institutions should help by defining a portfolio of adult vaccines and other preventative and therapeutic injectables with strong economic and population-health return-on-investment for this programme.

Recommendations for Governments

An opportunity exists not just at a regional level but at a national level. Governments have a unique chance to learn lessons from the Covid-19 pandemic by creating and sustaining the right infrastructure to deliver vaccinations at speed. They should begin to prepare for participation in this programme in the following ways:

Awareness

Understanding the impact that new vaccines will have on disease prevention in their local context and the demand that will be driven by their populations once these become available.

Opportunity

Capitalising on the unique opportunity to leverage the investment governments have made in Covid-19 infrastructure to create a framework to administer new vaccine and therapeutic candidates in the pipeline to their populations – and deliver this at scale.

Planning for Sustainability:

- Planning for the implementation of a scalable digital solution for vaccine registration, monitoring, pharmacovigilance and other use cases.
- Investing wisely in vaccination delivery and primary-care infrastructure, with a specific focus on sustainability within the local public-health framework and building on existing vaccination programmes.
- Identifying in-country champions and management structures to drive this forward.
- Harmonising and strengthening existing regulatory approaches to approve vaccines and manufacturing sites, or planning for this should these regulatory bodies not yet exist in-country.

Recommendations for Scientific Experts

Experts can assist in this process by:

- Ensuring the adult-vaccination programme forms part of the agenda of global expert groups (for instance, the WHO scientific advisory group of experts on immunizations), as well as regional expert groups.
- Working to develop a global-consensus framework for eligibility and timing of doses.
- Contributing expertise to the scientific oversight committee that will ensure obligations are met and best practice is maintained.

Recommendations for the Private Sector and Civil Society

The private sector and civil society can accelerate this process by:

- Innovating pharmaceutical-manufacturing technologies and processes, and clinical-development approaches.
 - Building digital infrastructure to support delivery of adult vaccinations, and collection and analysis of real-world evidence.
 - Ensuring availability and affordability of vaccines and preventative and therapeutic injectables for developing countries as they come to market through appropriate pricing schemes and intellectual-property arrangements.
 - Advocating for a global adult-vaccination programmes to generate demand among country governments and citizens.
-

Technical Deep Dive 1: Vaccine Candidates and Eligible Populations

Emerging technologies, along with established vaccines, can form the basis for a global vaccination programme. Here we consider in more detail and greater number the existing vaccines and long-acting, injectable preventative therapies or those that are in human trials, following on from the earlier chapter including details of Vaccine and Preventative Injectables Selection. No pre-clinical candidates are described.

Eligible populations will also need to be considered and defined; this is challenging, and as we have seen with Covid-19, a matter of debate.

KEY MESSAGES

- Scientific developments are leading to a robust pipeline of adult vaccines and preventative injectables.
- The global community should begin by addressing the present need for Covid-19 vaccines and regular boosters, build on that framework with other existing vaccines, and then add promising new candidates over time.
- Individual and geographical needs will drive demand.

CURRENT AND IMMINENT VACCINE CANDIDATES

A number of effective adult vaccines already in existence have not yet been widely distributed:

Influenza vaccination: Vaccination rates vary globally and may be as low as 1 per cent in some regions that drive influenza-related deaths, which in 2017 for example were estimated at 290,000 to 650,000 from respiratory causes alone.^{22,23} In the future, new platforms will likely allow us to move away from the slow and cumbersome traditional approach to production

of the influenza vaccine ([where the virus is incubated in chicken eggs](#)). Following the extensive rollout of their Covid-19 vaccine, Pfizer and BioNTech have already entered into another collaboration, building upon their existing RNA technology to produce more effective and targeted flu vaccines.²⁴ As the trend of adapting a form of vaccine technology to treat more than one disease continues, it is likely we will also see the development of single vaccines that provide cover for a full range of respiratory viruses.

Pneumonia and herpes zoster: Vaccines to prevent pneumococcal pneumonia and herpes zoster virus are already recommended for older adults (aged 65+). For this same vulnerable age group, Pfizer has launched a phase III clinical trial for a vaccine to prevent RSV,²⁵ which accounts for more than 177,000 hospitalisations and 14,000 deaths annually in the United States alone.

Human papillomavirus: Human papillomavirus (HPV) variants 16 and 18 are the primary cause of cervical cancer worldwide.²⁶ There are several HPV vaccines available that have proven highly protective against HPV infection and cervical cancer, but while they have been available for about a decade, many LMICs face challenges with introduction and immunisation rates. Only 22 per cent of low-income and 30 per cent of lower-middle-income countries include HPV vaccines in their national immunisation schedules.²⁷ While a rollout of the HPV vaccine as part of our recommended programme would need to primarily target adolescents, its inclusion would help to make it a priority global immunisation and also support any ongoing rollout efforts worldwide.

Hepatitis B: Despite a hepatitis B vaccine first being approved in 1981, there were 26,634 adult deaths due to acute hepatitis B infection in 2019, with 9,092 of those reported in LMICs.²⁸

Cholera: Since 2013, cholera vaccine doses have been available for emergency and endemic control through a global stockpile. A systematic decrease in cholera risk is noted for each step-increase in vaccine coverage, from 5.54 cases per 1,000 placebo recipients in areas with the lowest coverage (<25 per cent) to 1.93 cases per 1,000 placebo recipients among those with the highest coverage (>34 per cent).²⁹ Creating a global framework for adult vaccination would mean that vaccine rollout could be more consistent in endemic areas.

Ebola: It is also worth considering viruses that are not widespread but have extremely high mortality rates, such as Ebola. As recently as February 2021, two new outbreaks of Ebola were declared in the Democratic Republic of the

Congo and the Republic of Guinea. Two vaccines have been approved for the prevention of Ebola (rVSV-ZEBOV, a single-dose vaccine, made by Merck; and the two-dose Ad26.ZEBOV/MVA-BN-Filo, made by Janssen), but the current approach has focused on “ring vaccination”: quickly identifying and vaccinating contacts, as well as contacts of contacts, and health-care and other frontline workers. However, this is dependent on efficient contact tracing, and its concept has been challenged by local communities that struggle to accept this limited-eligibility model. More widespread routine, targeted-population and geographic vaccination campaigns have been called for.³⁰

Vaccine bundles: In specific contexts, adults may require more than one vaccination and so the demand may extend to a bundle of vaccines for each individual.

In particular, this broader framework for adult vaccination could support the additional vaccination needs for pregnant women, particularly in LMICs.

This would also be the case for high-risk individuals, travellers and those with high levels of occupational risk, for whom there are a number of approved vaccines available. These include vaccines to prevent yellow fever, typhoid fever, meningococcal meningitis, haemophilus influenzae type B, hepatitis, tetanus and cholera.

Existing efforts: In some cases, efforts are already underway to enable access to these vaccines. Gavi, Unitaïd and the Global Fund have together committed nearly \$70 million to support malaria vaccination efforts after the recent approval of the malaria vaccine by the WHO.

Gavi has run successful vaccination programmes for cholera, with ongoing efforts to keep South Sudan cholera-free, and Ebola, where strong public-private partnerships created an enabling environment that led to an increase in the number of vaccine manufacturers from five in 2001 to 17 in 2019.

Since the inception of Gavi’s HPV programme in 2012, 3.9 million people have been protected against cervical cancer. In 2016 this programme was accelerated with the aim to protect 40 million people and avert 900,000 deaths; however, due to surging demand and supply shortages this goal has been reduced to 14 million protected and 300,000 deaths averted. An adult-vaccination programme, leveraging such platforms, would strengthen efforts and ensure supply could meet demand.

Future prospects: Looking ahead, a number of game-changing vaccines are in the pipeline, in addition to the **RSV vaccine** already mentioned:

- **Malaria:** The recent success of the R21 malaria vaccine for children³¹ has prompted renewed interest in ongoing trials for adults, with Sanaria launching its first large clinical trial of its PfSPZ malaria vaccine in those aged 2 to 50 years old.³²
- **Tuberculosis:** The large-scale trial of the M72/AS01 tuberculosis vaccine has generated efficacy data.³³
- **Group B streptococcus:** A number of phase II clinical trials are underway by Novartis, Pfizer and MinervaX to develop a vaccine for group B streptococcus (GBS), which the WHO has made a priority for administering to pregnant women.³⁴ Although predominantly used to prevent infant mortality, this has the dual impact of preventing excess maternal morbidity.
- **HIV:** Phase I HIV vaccine studies have been launched by Moderna and the University of Oxford.^{35 36}
- **Zika, Lassa and MERS:** CEPI has announced funding for early-stage studies of vaccines for Zika virus, Lassa virus, Middle East Respiratory Syndrome (MERS) and Chikungunya virus.³⁷
- **Dengue:** Approximately five additional dengue vaccine candidates are in clinical development, with two candidates (developed by NIH/Butantan and Takeda) now in phase III trials.³⁸
- **Staphylococcus aureus:** GSK has entered phase I and II trials for a new candidate vaccine for Staphylococcus aureus.³⁹
- **Paratyphoid:** Human models for paratyphoid disease understanding and vaccine testing are currently being undertaken by the University of Oxford, with funding by the European Vaccine Initiative and the Bill & Melinda Gates Foundation.⁴⁰
- **Shigella:** A new Shigella vaccine has entered phase II clinical trials.⁴¹
- **E coli:** A number of vaccines, in the phase I and II stage, are being investigated for Enterotoxigenic Escherichia coli.⁴²

These developments offer promising preventative measures for a number of conditions that cause significant morbidity and mortality.

PREDICTIVE VACCINATION

Although in its early stages, research in pandemic science is taking us into new territories. It may be possible within our lifetime to use [multivalent vaccines](#) – vaccines that can protect against multiple pathogens or multiple strains of the same pathogen – to pre-empt pandemic risks by including exposure to highly pathogenic influenza antigens as some of the multivalent epitopes in seasonal flu vaccines.⁴³

Highly pathogenic flu strains that circulate in birds but have not yet acquired the ability to transmit between humans remain a looming threat. Should they acquire human-transmission capacity, they could produce rapid and devastating future pandemics in an immunologically naïve population. Providing pre-emptive exposure to highly pathogenic influenza antigens is a novel concept, but worth exploration as a whole new approach to managing future pandemic risks in the context of a new adult-vaccine campaign.

There is evidence to suggest that new strains of influenza carry case-fatality rates of up to 50 per cent and might target young rather than older populations. A robust adult-vaccination framework would require flexibility based on pandemic evolution.

PREVENTATIVE INJECTABLES

Not all threats to public health are from infectious diseases. An epidemic of chronic diseases accounts for more deaths than the major infections worldwide.⁴⁴ Public-health responses to these threats are inconsistent and difficult to apply at scale due to challenges with compliance and the unreliable nature of prevention tools that rely on behaviour change. The conditions associated with cardiometabolic disease, including obesity, hypertension, lipid abnormalities, diabetes and cardiovascular disease, account for many of the total premature deaths globally in low-, middle- and high-income countries.⁴⁵

Long-acting injectable preventative therapies, encompassing candidates beyond the bounds of monoclonal antibodies, are now becoming available for these disorders. For example, an annual injection of the medication inclisiran, based on small interfering RNA (siRNA) technology, could reduce cholesterol. Similar siRNA compounds could be used to manage hypertension with an annual injection. There are other long-acting, preventative injectable drugs available, such as the pre-exposure prophylactic cabotegravir for HIV – which has been shown to be more effective than its oral counterpart.⁴⁶ These interventions are preventative, just as vaccines are, and could be delivered by the same infrastructure used for Covid-19.

Technical Deep Dive 2: Global Governance and Leadership

KEY MESSAGES

- A global adult-vaccination programme represents a historic opportunity for a major global-health programme with strong Global South leadership.
- Global South countries, including those represented on the G20, can partner with Global South multilaterals, other multilaterals (such as Gavi and CEPI), and other countries to launch this initiative.

GLOBAL GOVERNANCE

Global-health programming, especially when it involves novel sources of financing, requires a global structure that can perform the following governance and financing functions:^{47,48}

- **Resource mobilisation:** Raising funds from various sources.
- **Pooling resources:** Bringing funds together for a common purpose.
- **Allocating and channelling resources:** Determining where and how to use funds in order to meet strategic, policy, programmatic, public-health and/or economic objectives, and transferring these funds to other entities, including governments, non-governmental organisations and the private sector.
- **Implementation, monitoring and evaluation:** The role of the organisation executing the work will vary depending on its relationship between any global or multilateral bodies.

Many successful multilateral organisations – including Gavi, the Global Fund and Unitaid – fulfil these functions and provide a useful blueprint for how to govern a global adult-vaccination programme and may be best placed to take on or support such a programme

However, there are three unique considerations to bear in mind for a global adult-vaccination programme:

1. A global adult-vaccination programme must optimise novel manufacturing capacity, with an emphasis on building this capacity in the Global South

Many nations in the Global South are planning to build – or are at least considering building – manufacturing capacity for mRNA and other vaccines, as well as biologic drugs. Given the challenges faced after the initial launch of Covid-19 vaccines of hoarding, vaccine nationalism and the inability to repurpose private-sector plants for urgent manufacturing, it is likely that governance of these new facilities will involve mechanisms for rapid repurposing in the event of surging demand during an outbreak. Ensuring that these facilities meet global demand for vaccines and biologics, both between and during outbreaks, will require significant coordination across countries. Because each facility will be governed by the laws of the sovereign nation where it resides, and specific ownership terms and structures, any multilateral entity focused on global adult vaccinations must have the authority and capacity to coordinate with these manufacturing facilities and the countries that host them.

2. There are opportunities for co-financing by the Global South

Co-financing mechanisms, where countries in the Global South at least partially contribute to public-health programmes supported by international donors, are becoming increasingly common and are critical for the sustainability of global health.^{49,50} Launching any novel effort on global adult-vaccination programmes with an explicit co-financing component will help ensure its sustainability and provide the opportunity to develop novel financing instruments. Thus, the governance for the initiative should reflect this opportunity.

3. There is increased political will for self-reliance in the Global South

The failure of the Global North to share significant numbers of vaccine doses early in the pandemic, and the Global South's reliance on manufacturing capacity primarily based in the United States, Europe, India and China, has created a renewed call for self-reliance in global health and international

development among LMICs. The two aforementioned opportunities regarding manufacturing capacity and financing from the Global South reinforce this call and reflect broader political will for self-reliance. The governance structure for a global adult-vaccination programme should reflect this.

Beyond these three considerations, any novel governance structure for a global adult-vaccine programme should reflect best practices from other global initiatives, including the power of pooled financing and the importance of multisectoral representation (including civil society, marginalised populations and the private sector) in leadership and decision-making bodies.

Given these unique considerations, we propose that the coordinating structure ensures strong Global South leadership. Important mechanisms for input include pooling, allocating and channelling resources, overseeing implementation and machinery and equipment, and coordinating with donors and manufacturing facilities.

Regional organisations in the Global South, potentially including the Africa CDC, PAHO and ASEAN, should drive Global South leadership by coordinating supply and demand, allocating financial resources and harmonising regulations.

To launch this initiative, Global South countries represented at the G20 should partner with leading multilateral organisations, especially Gavi and CEPI, and the other G20 countries.



Technical Deep Dive 3: The Investment Case (Two Approaches)

KEY MESSAGE

- There is a strong health-investment case for rolling out adult vaccines currently in development, including HIV vaccines. However, given differences in target populations and dosing regimens, delivering these vaccines would require a robust primary-care delivery infrastructure.
- We also estimate that a global adult-vaccination programme could have a global economic value of \$3.4 trillion.
- More robust methodologies must be developed for estimating the macroeconomic value of pandemic-preparedness measures, including global vaccination manufacturing and service-delivery readiness.

Diseases that are vaccine-preventable (or could be in the future) comprise a significant total burden of disease and are costly for national economies. In 2016, 15.6 million excess deaths occurred in LMICs compared to HICs across 61 conditions, with at least 7 million of those deaths from preventable conditions.⁵¹ See Figure 1 earlier in the paper for examples of diseases currently or potentially vaccine-preventable and the associated estimated deaths.

To assess the investment case for a global adult-vaccination programme, we considered two different approaches: a literature review of classic health-economic analyses regarding the cost-effectiveness of adult vaccines that have been launched or are in development, and a novel approach to estimating the economic benefit of pandemic preparedness.

Finally, consideration is given to the market-shaping mechanisms and pricing models needed to ensure sufficient innovation incentives, global access and sustainable demand for these products.

HEALTH-ECONOMIC APPROACH

Deploying adult vaccines beyond Covid-19 in LMICs is generally not considered cost-effective today, with the exception of the HPV vaccine. The cost-effectiveness of several vaccines, as determined by various studies, is outlined below (along with the limitations of said studies).

These vaccines could potentially be made more cost-effective through inclusion in an adult-vaccination programme. If vaccines are bundled and delivered together, this could reduce per-vaccine service-delivery costs. Offering research and development incentives to improve vaccine efficacy would also increase cost-effectiveness.

Influenza: Modelling results indicate that in upper-middle-income countries (UMICs), primarily in South America, seasonal influenza vaccination can be cost-effective when targeted at the elderly, children with high-risk conditions, health-care workers, and chronic obstructive pulmonary disease (COPD) patients.⁵²

Pneumococcal pneumonia: Modelling results indicate that in UMICs, primarily in South America, pneumococcal pneumonia vaccination can be cost-saving and/or cost-effective when targeting adults aged over 50.⁵³

However, these studies are limited because:

- They were primarily funded by industry manufacturers with a vested interest in demonstrating the cost effectiveness of adult pneumococcal vaccination.
- It is possible that childhood vaccination provides sufficient protection through to adulthood, so expanding childhood immunisation programmes may be more cost-effective.

Pertussis (one component of DTaP vaccine): Modelling using parameters from Brazil, Nigeria and Bangladesh indicates that acellular maternal vaccination against pertussis (aP), also known as whooping cough, is only cost-effective at low or moderate levels of infant vaccination, and when infant vaccination exceeds 90 to 95 per cent, maternal vaccination is no longer cost-effective.⁵⁴

Herpes zoster: Based on a systematic review of studies:⁵⁵

- 60 per cent of studies from HICs find that herpes-zoster vaccination in the 50+ population is cost-effective.

- At current prices (typically \$100 to \$250), vaccination is unlikely to be cost-effective in LMICs.
- Implementing a price-reduction strategy through pooled demand could help increase cost-effectiveness in LMICs, although herpes zoster is still unlikely to be a priority among other cost-effective vaccines.

HPV:

- There is wide consensus that HPV vaccination is cost-effective in LMICs. However, vaccination coverage in LMICs remains low, at 12 to 16 per cent as of 2019.
- One of the major drivers of slow uptake of HPV vaccines is limited supply, although that may ease with time.⁵⁶ Building out robust adult-vaccination infrastructure could significantly accelerate HPV vaccination rates. Health-management information systems in particular will be critical to tracking vaccination statuses.

Future adult vaccinations have the potential to be highly cost-effective (if certain price expectations can be met by manufacturers).

These vaccines include:

HIV: Modelling indicates that an HIV vaccine would be cost-effective at \$20 per regimen in low-income countries even if it achieved only 30 per cent efficacy, and it would be highly cost-effective at 60 per cent efficacy or above. Vaccines of all efficacy and cost levels were considered cost-effective in middle-income countries.⁵⁷

Respiratory syncytial virus (RSV): While acknowledging significant epidemiological uncertainties, modelling indicates that a vaccine prevention strategy in Gavi-eligible countries could be cost-effective, but this is highly dependent on the price and efficacy of potential interventions.⁵⁸

Group B streptococcus: Modelling indicates that a maternal GBS vaccine would have similar cost-effectiveness to other vaccines introduced as part of global-health programmes in the past ten years, assuming 70 per cent efficacy and a cost of \$7 per dose.⁵⁹

Tuberculosis: Modelling indicates that a TB vaccine would be cost-effective at \$4, \$9 and \$20 per dose in LICs, LMICs and UMICs respectively.⁶⁰

Case Study: The Joint United Nations Programme on HIV/AIDS

In 2011 and 2013, the Joint United Nations Programme on HIV/AIDS (UNAIDS) published the Investment Framework (IF) and Investment Framework Enhanced (IFE) reports to map high-value strategies for the prevention and treatment of HIV/AIDS.^{61,62} The IF report underscored the critical role of new prevention technologies, citing evidence that the impact of existing prevention and treatment programmes is levelling off, even when countries maintain these programmes well.

Subsequently, UNAIDS called for an increase in research to speed up the development of an HIV vaccine. In response, one study developed an epidemiological model to examine the impact of a future HIV vaccine in conjunction with the existing prevention and treatment options detailed in UNAIDS' Investment Frameworks.⁶³ Sensitivity analyses, varying the characteristics and costs of a potential future vaccine, evaluated the relative reductions in HIV incidence and cost-effectiveness under three IFE scenarios:

1. Current trends scenario
2. 50 per cent scale-up of IFE targets
3. Full scale-up of IFE targets

The study found that all scenarios are cost-effective in LICs under both full scale-up and 50 per cent scale-up of IFE. Furthermore, at a base cost of \$20 per regimen, the vaccine would be cost-effective under all efficacy sensitivity scenarios (30 to 90 per cent). The vaccine would be highly cost-effective if it demonstrated 60 per cent efficacy or more. Under the very-high-price scenario (\$65 per regimen), the vaccine must be 60 per cent efficacious to be considered cost-effective. Finally, vaccines of all efficacy and cost levels were cost-effective in MICs, with most being highly cost-effective.

The modelling is promising, and while the HIV vaccine is not yet a reality, recent advances in vaccine development offer hope to susceptible populations. A new candidate, HIVconsvX, for example, has recently entered a phase I trial to evaluate its safety, tolerability and immunogenicity.⁶⁴

Meanwhile, an adult-vaccination campaign not only sets the foundation for the future delivery of an HIV vaccine but also expands the global capacity for conducting efficacy trials.

NOVEL PANDEMIC-PREPAREDNESS CASE

An adult-vaccination programme is also likely to be highly cost-effective in the context of a future global pandemic. Our modelling suggests that in the event of another outbreak similar to Covid-19, a faster vaccination programme that allows the world to normalise more quickly than current timelines could save \$3.4 trillion in lost economic activity, and more than \$1 trillion for developing economies.

In line with existing literature, our model calculates costs associated with a future pandemic across two main areas: a contraction in overall output as a result of enforcing economic restrictions and a reduction in long-run economic activity from lives lost. While both parameters inevitably depend on the disease profile of a future pathogen – impossible to predict in advance – we can use historical data from the current pandemic to create a stylised forecast of what the potential savings might plausibly look like.

Benchmarking historical Covid costs against a scenario of more rapid vaccination rollout and faster economic normalisation, we find that a global vaccination programme could potentially save \$1.8 trillion in lost GDP over the first 21 months of a future pandemic, as well as \$1.6 trillion in economic damage from deaths averted. About \$500 billion savings each from lost GDP and deaths averted would accrue to developing countries, resulting in a combined \$1 trillion saving. In essence, this modelling shows the potential saving of maintaining vaccination-absorption capacity at the highest 2021 levels going into a future pandemic that is similar to Covid-19. (See Figure 3 earlier in this paper.)

More detail on our scenarios is presented below.

- Historical baseline:** We value the historical cost of Covid based on the difference between the latest available and pre-pandemic OECD GDP forecasts, using a seven-quarter period from March 2020 to November 2021. Our calculations are made at the World Bank income-group level (across high-income, upper- and lower-middle-income, and low-income countries). We calculate total lives lost using data from the *Economist's* global excess-deaths model, the best-available estimate of the true mortality cost of the pandemic, correcting for potential unrecorded Covid deaths as well as the secondary impact of the pandemic on health systems. To attach a cost figure to lives lost, we use the method of Robinson and Hammitt et al (2019):⁶⁵ we calculate a “value of statistical life” figure (VSL) for Covid-related deaths for each World Bank region, adjusting for varying life expectancy across countries conditional on the average age of Covid-related death.

- **Adjusted baseline:** Our historical baseline is modified to reflect the fact that during a future pandemic, we would be able to use the knowledge we have gained from Covid to keep economies running despite social-distancing measures without the extreme economic damage incurred in the second quarter of 2020. The hit from an initial economic shutdown for each World Bank region is therefore approximated as the average of subsequent quarters during the Covid pandemic before mass vaccination begins (i.e., the average hit from the adjusted baseline from the third quarter of 2020 to the start of mass vaccination). Since the speed of vaccination remains unchanged, the economic hit in subsequent quarters remains the same as in the historical baseline. The savings reported in Figure 3 are calculated against the adjusted baseline.
- **Accelerated global-vaccination scenario:** We then model how much sooner economic normalisation could occur with a faster global-vaccination rollout compared to current timelines. We use the observed relationship between the recovery in GDP growth over the past two years and population Covid-vaccination levels to simulate a fast-forward of the global recovery, with full economic normalisation occurring once a global region reaches 70 per cent adult-vaccination coverage. Accelerated rollout speeds are calculated as the fastest monthly 2021 vaccination rates for each region. Vaccination is assumed to begin six months after the start of the outbreak, reflecting best-prevailing estimates of the time needed to update existing vaccines to combat a new pathogen. Faster vaccination also reduces baseline deaths by about 50 per cent: baseline deaths are calculated as the 2020 average monthly excess deaths for each region, reduced proportionately based on the population being fully vaccinated over time, assuming vaccines are 90 per cent effective against mortality.

The disease burden of a future pandemic naturally changes the outcome of the modelling substantially. Importantly, if a future pathogen inflicts high mortality on younger, working-age demographics, as opposed to Covid which has disproportionately affected the elderly and vulnerable, then the potential impact in terms of statistical life-years lost would be significantly larger. This may increase the saving of a rapid global vaccination programme to more than \$7 trillion over a 21-month period. Holding deaths at baseline Covid levels, with a 100-day timeframe to develop and roll out a vaccine – in line with Pfizer’s claim that mRNA vaccines can be updated more quickly than six months⁶⁶ – could also raise the potential global saving to more than \$4.6 trillion.

TECHNICAL APPENDIX: FULL METHODOLOGY ON THE MODELLING

Historical Baseline: To estimate the global GDP cost of Covid-19 over the past two years, we compare the OECD's latest and last pre-pandemic GDP forecasts. This allows us to estimate the difference between where the global economy could have been if Covid had never occurred and where we are today. Our pre-pandemic forecasts are taken from the November 2019 OECD Economic Outlook, aggregated to the World Bank income-group level.

As the OECD does not produce forecasts for each country, for advanced economies and upper- and lower-middle-income countries, we use an average of OECD forecasts for those countries in each group, weighted by GDP level in 2019. For low-income countries, since the OECD does not produce any forecasts, we use the OECD forecast for all emerging economies. Our estimates cover a 21-month period to capture the full-time series of Covid costs to date, up to the latest complete quarter. Unlike other estimates in existing literature, our estimates are therefore not based on forward projections for the global economy for 2022 and beyond.

To estimate the cost of lives lost due to Covid, we use the *Economist's* excess deaths database. We use this resource as the best-prevailing estimate of the true death toll of the pandemic, correcting for potential unrecorded Covid deaths as well as the secondary impact of Covid on health-care systems. Total excess deaths from March 2020 to November 2021 are calculated by aggregating individual-country death tolls over time in the raw data to the World Bank income-group level.

To attach a cost figure to lives lost, we use the method proposed by a group of researchers at the Harvard T H Chan School of Public Health in 2019. This [paper](#) was the conclusion of a project initiated by the Bill & Melinda Gates Foundation in 2016 to provide reference case guidance on how to conduct cost-benefit analysis to determine the economic value of mortality-reducing public-health interventions. Following the paper's method, we convert a given statistical value of life lost (VSL) for the United States – \$9.4 million – into VSL figures for each of the four World Bank country-income groups. This is achieved by adjusting the United States-estimate based on the ratio of GNI per capita in the US to the average 2020 GNI per capita in each World Bank group, exponentiated to the power of 1.5 to capture an income elasticity factor. If this value is less than 20 times the GNI per capita of the World Bank group, this second value is used instead.

Given that these VSL figures reflect the average statistical value of life across the population, we then adjust these estimates to reflect the fact that Covid deaths have disproportionately been among those of advanced age, who are mostly no longer economically fully active. This is calculated through a “value of statistical life per year” calculation. First, we calculate the value of statistical life per year remaining by dividing the VSL figures by the average outstanding life expectancy in each World Bank region (i.e., $VSL / (\text{average life expectancy conditional on average age} - \text{average age in population})$). Next, we multiply this by the average years remaining in the population conditional on average age of Covid death (i.e., $\text{average life expectancy conditional on average of Covid death} - \text{average of Covid death}$). Inputs for these values are taken from relevant United Nations population data sets, except for the average of Covid death estimates, which are regional averages taken from an [open-source database](#) of Covid deaths and cases by age, maintained by the Max Planck Institute for Demographic Research in Germany. These age-adjusted VSL figures are then multiplied by the excess deaths in each World Bank region to arrive at baseline economic mortality costs.

Adjusted Baseline: Our historical baseline is modified to reflect the fact that during a future pandemic, we would be able to use the knowledge we have gained from Covid to keep economies running despite social-distancing measures, without the extreme economic damage incurred in the second quarter of 2020. The initial hit from an economic shutdown for each World Bank region is therefore approximated as the average of subsequent quarters during the Covid pandemic before mass vaccination begins (i.e., the average hit from the adjusted baseline from the third quarter of 2020 to the start of mass vaccination). But since the speed of vaccination remains unchanged, the economic hit in subsequent quarters remains the same as in the historical baseline. Covid-related deaths remain unchanged from the historical baseline.

Accelerated Global-Vaccination Scenario: We then model how much sooner economic normalisation could occur with a faster global-vaccination rollout compared to current timelines. We use the observed relationship between the recovery in GDP growth over the past two years and population Covid vaccination levels to simulate a fast forward of the global recovery, with full economic normalisation occurring once a global region reaches 70 per cent adult-vaccination coverage. Essentially, we assume that the reduction is brought forward in line with the acceleration in the vaccine schedule. For advanced economies, this involves bringing forward the recovery by three-quarters in the 180-day scenario and four-quarters in the 100-day scenario. For upper-middle-income economies, the recovery is

brought forward by one-and-a-half and three-quarters in the two scenarios respectively. For lower-middle-income and low-income economies, since the vaccine rollout is still incomplete, we assume that recovery occurs at the same pace as in advanced economies under the baseline scenario, once mass vaccination begins.

Accelerated vaccination rollout speeds are calculated as the calendar month during 2021 when each World Bank region had the fastest average daily-vaccination-rollout speed. Implicitly, our model therefore estimates the possible saving if vaccination production and absorption levels are maintained at the highest 2021 levels going into a future pandemic. According to Our World in Data, 7.9 million doses were delivered per day in high-income countries during June 2021, 23.8 million doses per day in upper-middle-income countries during June 2021, and 15.2 million doses per day in lower-middle-income countries during September 2021. The vaccination-rollout speed for low-income countries is calculated as the equivalent per capita daily vaccination rate as in lower-middle-income countries, which equates to around 890,000 doses delivered per day. This reflects a modelled vaccination-absorption capacity scale-up for low-income countries to bring this region into line with other emerging economies.

Vaccination is assumed to be two-dose, with the second doses administered 28 days after the first. Booster doses are not modelled. The vaccination rollout continues until 70 per cent of the total population are fully vaccinated, broadly reflecting the coverage level reached in many high-income countries to date.

To model the effect of faster vaccination on reducing pandemic-related deaths, we assume that vaccines are 90 per cent effective against mortality after the second dose. We do not assume any immunity waning during the modelled 21-month period. Deaths in the months after vaccination begins are consequently reduced based on the proportion of the total population vaccinated. Baseline deaths are calculated as the 2020 historical average monthly excess Covid-related deaths for each World Bank region. The 2020 average was chosen to capture Covid mortality trends averaging across seasonality effects between March and December, and the different timing of Covid waves in various parts of the world. The 2021 data were not included to avoid confounding due to the start of the vaccine rollout in high-income countries from January onwards. Implicitly, this baseline therefore assumes that whatever non-pharmaceutical Covid mitigation strategies are used during a future pandemic are about as effective as reducing deaths as the average effectiveness of strategies used during 2020 across World Bank

regions. We do not model scenarios where death rates change through different non-pharmaceutical interventions. Similarly, the model assumes that a future pandemic has similar mortality rates across demographics as Covid did during 2020.

Finally, as baseline deaths remain constant throughout the modelled period absent vaccination effects, we essentially assume constant pathogen transmission rates and that herd immunity is not attained through natural infection by 21 months post-outbreak. The estimate that a pandemic affecting younger populations could result in an accelerated vaccination valuation of above \$7 trillion is taken by multiplying historical and scenario Covid-related deaths by the average population VSL, rather than the age-adjusted one.



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