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IMF STAFF DISCUSSION NOTE

A Proposal to End the COVID-19 Pandemic

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A Proposal to End the COVID-19 Pandemic

Prepared by Ruchir Agarwal and Gita Gopinath*

Authorized for distribution by Gita Gopinath

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Urgent steps are needed to arrest the rising human toll and economic strain from the COVID-19 pandemic that are exacerbating already-diverging recoveries. Pandemic policy is also economic policy as there is no durable end to the economic crisis without an end to the health crisis. Building on existing initiatives, this paper proposes pragmatic actions at the national and multilateral level to expeditiously defeat the pandemic. The proposal targets: (1) vaccinating at least 40 percent of the population in all countries by the end of 2021 and at least 60 percent by the first half of 2022, (2) tracking and insuring against downside risks, and (3) ensuring widespread testing and tracing, maintaining adequate stocks of therapeutics, and enforcing public health measures in places where vaccine coverage is low. The benefits of such measures at about $9 trillion far outweigh the costs which are estimated to be around $50 billion—of which $35 billion should be paid by grants from donors and the residual by national governments potentially with the support of concessional financing from bilateral and multilateral agencies. The grant funding gap identified by the Access to COVID-19 Tools (ACT) Accelerator amounts to about $22 billion, which the G20 recognizes as important to address. This leaves an estimated $13 billion in additional grant contributions needed to finance our proposal. Importantly, the strategy requires global cooperation to secure upfront financing, upfront vaccine donations, and at-risk investment to insure against downside risks for the world.

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EXECUTIVE SUMMARY

It is over a year into the COVID-19 pandemic, and new cases worldwide are higher than during any previous phase of the pandemic. Urgent steps are needed to arrest the rising human toll and economic strain from the pandemic that is exacerbating already diverging recoveries. Ending the pandemic is a solvable problem but one that requires further coordinated global action.

Many organizations and initiatives have led the effort in the fight against the pandemic, including the Access to COVID-19 Tools (ACT) Accelerator, Coalition for Epidemic Preparedness Innovation, Gates Foundation, GAVI, Global Fund, World Bank, World Health Organization, and World Trade Organization. The proposal in this paper seeks to build on and complement these important efforts.

It is well understood that there is no durable end to the economic crisis without an end to the health crisis. Pandemic policy is thus economic policy. Ending the health crisis is critical for global macro and financial stability, which makes it of fundamental importance to the IMF and other economic institutions.

Consequently, this paper analyzes multiple dimensions of the fight against the pandemic, including projecting global and cross-country vaccination rates under alternative scenarios. The projections point to highly unequal health prospects well into 2022, which poses severe risks for the world. As public health officials have noted numerous times, "the pandemic is not over anywhere until it is over everywhere."

We propose pragmatic actions at the national and multilateral level to expeditiously tackle the global health crisis. The proposal targets (1) vaccinating at least 40 percent of the population in all countries by the end of 2021 and at least 60 percent by the first half of 2022, (2) while tracking and insuring against downside risks, and (3) ensuring widespread testing and tracing, maintaining adequate stocks of therapeutics, and enforcing public health measures in places where vaccine coverage is low.

Building on the budgeting of the ACT Accelerator, we estimate the cost of this proposal to be around $50 billion, which is small compared to the potential benefits of a faster end to the pandemic, estimated at around $9 trillion. Moreover, advanced economies stand to gain around $1 trillion in additional tax revenues, which means that funding this proposal may possibly be the highest-return public investment ever.

Given that ending the pandemic in a timely manner is a global public good, of the $50 billion total cost of this proposal, there is a strong case for grant financing of at least $35 billion from public, private, and multilateral donors and the remainder by national governments potentially supported by concessional financing from multilateral agencies.

The grant funding gap identified by the ACT Accelerator amounts to about $22 billion, which the G20 and other governments recognize as important to address. In addition, at least $15 billion is available from COVID-19 financing facilities created by multilateral development banks. This leaves an estimated $13 billion in additional grant contributions needed to get to the $50 billion identified by our proposal. This additional amount is mainly for raising COVID-19 Vaccines Global Access (COVAX) coverage to 30 percent, procuring additional COVID-19 tests, and expanding at-risk production capacity to insure against downside risks.

Importantly, the proposal requires not commitments but *upfront* financing, *upfront* vaccine donations, and *at-risk* investment for the world. It is essential that all necessary financing is available immediately. The key proposed steps (see table below) include:

Achieving the vaccination targets

1. *Provide additional upfront grants to COVAX of at least $4 billion to increase their vaccine coverage goal from 20 percent to 30 percent for 91 low- and middle-income countries (LMICs)*: This will help finalize their orders, and activate unutilized vaccine capacity.

2. *Ensure free cross-border flows of raw materials and finished vaccines:* Such restrictions are jeopardizing vaccine access for billions of people in the developing world.

3. *Donate surplus vaccines*: We project that at least 500 million vaccines courses (equivalent to around 1 billion doses) can be donated in 2021, even if countries prioritize their own populations. Donations, including for delivery costs, should be done through COVAX so that vaccines are shared equitably and on the basis of public health principles.

Insuring against downside risks

4. *Make at-risk investments* to diversify and increase vaccine production capacity by 1 billion doses in early 2022 to handle downside risks, including from new variants that require booster shots. *[$8 billion]*

5. *Scale up genomic surveillance and systemic supply chain surveillance* with concrete contingency plans in place to handle mutation scenarios or shocks to the supply chain. This should be prepared with the participation of multilateral agencies, vaccine developers and manufacturers, and key national governments. [*$3 billion*]

Managing the interim period when vaccine supply is limited

6. *Ensure widespread testing, sufficient therapeutics, and adequate public health measures, and prepare for vaccine deployment.* [*$30 billion*]

7. *Urgently evaluate and implement (where approved) dose stretching strategies to expand effective supply.* [*$2 billion*]

Additional needed measures account for $3 billion. According to our projections, the measures identified in steps 1–3 may be sufficient to achieve the 40 percent vaccination target by the end of 2021 and the 60 percent target by the first half of 2022, if no downside risks materialize. At the same time, steps 4–7 are needed to insure against downside risks and to mitigate the health consequences of the pandemic in the interim period. Nearly all the financing for steps 4, 5, and 7 and the majority of financing for step 6 should take the form of grants to the various arms of ACT Accelerator.

This analysis has benefited greatly from the work of the aforementioned organizations and from engagement with a number of experts in several fields. The proposal focuses on what is needed to bring the current pandemic under control. This complements the work of the G20 High Level Independent Panel, the G-7 Pandemic Preparedness Partnership group, and the Report of the Independent Panel for Pandemic Preparedness and Response, which primarily focus on addressing future pandemics. We also note that there is considerable uncertainty around any such analysis given the shifting vaccine and virus landscape. That said, we hope this proposal contributes toward the ongoing global effort to tackle the central health and economic problem of our times.

In the absence of urgent actions, many emerging and developing economies may have to wait until the end of 2022 or later to bring the pandemic under control. That will be too late not just for those countries but also for the world. We are all in this together.

Core Elements of the COVID-19 Pandemic Proposal

Actor	Measures	2021			2022				Financing Gap for LMICs and Global Public Goods (Billions $)		
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Total (A + B)	Of which Grants (A)	of which Concessional Financing (B)
National Authorities	Maintain social distancing, masking, and other public health measure; Encourage rapid uptake of tests, therapeutics, and PPE								4	2	2
	Procure adequate supply of tests, treatments, and PPE; Expand hospital capacity for COVID-19 patients								20	15	5
	Prepare to scale up vaccine deliveries and uptake (incl. storage, and transportation issues, prepare systems for prioritized vaccines, fight disinformation on social media, and fast track emergency use authorization)								6	2	4
	Invest in and maintain genomic surveillance for Sars-COV-2 variants								3	2	1
Governments with Manufacturing Capacity	Facilitate cross-border voluntary licensing and technology transfers with the aim of creating regional manufacturing capacity around the world								1	–	1
	Undertake surveillance of systemic supply chain risks to ensure availability of critical raw materials and supplies (in collaboration with multilateral agencies, other countries, and vaccine manufacturers)								< 1	–	< 1
	Prepare and regularly update contingency plans to shift production capacity between vaccine candidates if downside risks materialize										
Vaccine Developers / Regulatory Authorities	Conduct trials to evaluate efficacy against new strains, potentially financed by donor grants								2	1	1
	Develop booster or multivalent shots to protect against possible new variants (if needed)										
	Urgently evaluate and where approved implement dose stretching strategies, potentially financed by donor grants										
Multilateral Agencies	Scale up utilization of existing pandemic lending facilities; convert grant pledges to up front cash contribution								< 1	< 1	–
	Conduct global surveillance of systemic supply chain risks in vaccine production; prepare contingency plans based on scenario planning										
	Ensure LMIC vaccination will not be crowded out due to new HIC needs (e.g. booster doses, youth vaccination, etc.)										
G20 / Donor Countries	Provide upfront cash grant of $4 billion to COVAX; Plus additional grant and concessional financing for vaccine procurement as needed								6	5	1
	Make at-risk investment to expand vaccine manufacturing capacity to address downside risks and/or long-term needs of LMICs								8	8	–
	Donate at least 500 million courses (or, equivalent to 1 billion doses) of surplus vaccines in 2021 *								–	–	–
	Commit to maintaining free export of vaccine supplies and final products								–	–	–
Total Needs									**≈ 50**	**≈ 35**	**≈ 15**
Unutilized Lending Facilities and Donor Pledges Under Consideration *										**22**	**15**
Additional Needs										**13**	**–**

Notes: Darker cells correspond to greater importance of the measure in the given quarter. While our budgeting exercise attributes a zero additional cost for in-kind donations of surplus vaccinations since much of the procurement is sunk cost, there is a strong case to count donations to the COVAX-AMC facility as official development assistance (ODA). The unutilized financing from lending facilities is based on the World Bank and Asian Development Bank pandemic lending facilities. The grant funding gap identified by the Access to COVID-19 Tools (ACT) Accelerator amounts to about $22 billion, which the G20 recognizes as important to address. See Annex VI for details.

THE GLOBAL RACE AGAINST THE COVID-19 VIRUS

It is over a year into the COVID-19 pandemic, and new cases worldwide are higher than in any previous phase of the pandemic. The measured worldwide cumulative death toll exceeds 3 million, and daily death tolls are close to record highs. The actual death toll is estimated to be several times higher. This worsening of the pandemic is being fueled by a potent mix of factors including virus mutations that are more transmittable, highly unequal vaccine coverage across countries, and erosion of public health measures because of complacency and fatigue.

The April 2021 World Economic Outlook (IMF, 2021a) projected a dangerous divergence in prospects across countries with emerging and developing economies (excluding China) expected to have slower recoveries and greater scarring. This was despite the fact that the pandemic had on average hit the advanced economies harder and that several developing countries with weak health systems had been spared the worst of the pandemic. However, the ongoing catastrophic second wave in India, following a terrible wave in Brazil, is a sign the worst may be yet to come in the developing world. While India's health system held up fairly well in the first wave, this time around its health system is so overwhelmed that many are dying because of a lack of medical supplies like oxygen, hospital beds, and medical care. India is a warning of possible events in other low- and middle-income countries (LMICs) that so far have seemingly escaped the pandemic, including in Africa.

These developments represent not a country or regional problem but a global problem. As public health officials have noted numerous times, "the pandemic is not over anywhere until it is over everywhere." Further unchecked transmission of the virus can give rise to new variants, some of which may render existing vaccines ineffective, putting the world back to the starting line in the race against the virus. Several organizations and initiatives including the ACT Accelerator, Coalition for Epidemic Preparedness Innovation, Gates Foundation, GAVI, Global Fund, World Bank, World Health Organization, and World Trade Organization have led the effort in the fight against the pandemic. The proposal in this paper seeks to build on and complement these important efforts.

Pandemic policy is economic policy, as there is no durable end to the economic crisis without an end to the health crisis. It is critical for global macro and financial stability, which makes it of fundamental importance to the IMF and other economic institutions. Indeed, IMF economic projections and policy recommendations for the global economy rely crucially on the relative success of the race against the virus. To make this assessment, this paper analyzes multiple dimensions of the fight against the pandemic including projecting global and cross-country vaccination rates under alternative scenarios. The projections point to highly unequal health prospects well into 2022, which poses

severe risks for the world. To contain the rising global costs of the COVID-19 pandemic, urgent steps are needed to bring the virus under control in every corner of the world.

This proposal involves pragmatic actions at the national and multilateral levels, as outlined in Table 1, to help expeditiously tackle the global health crisis. The proposal targets (1) vaccinating at least 40 percent of the population in all countries by the end of 2021 and at least 60 percent by the first half of 2022, (2) while tracking and insuring against downside risks, and (3) ensuring widespread testing and tracing, maintaining adequate stocks of therapeutics, and enforcing public health measures in places where vaccine coverage is low. The strategy is one not of *commitments* but of *upfront* financing, *upfront* vaccine donations, and *at-risk* investment for the world.

Building on the budgeting of the ACT Accelerator (WHO, 2021b) and prior work on gaps in vaccine coverage in LMICs (Agarwal and Reed, 2021), we estimate the overall cost of this proposal to be around $50 billion.[1,2] IMF research (IMF, 2021b) estimates that the cumulative gain to the world from greater success on all aspects of the fight against the virus—including vaccinations, diagnostics, and therapeutics—is around 9 trillion dollars by 2025, with over 40 percent of this gain going to advanced economies as stronger recoveries in the rest of the world raises demand for their goods, and through stronger confidence effects at home as the pandemic ends durably. This translates into a cumulative gain of $1 trillion dollars in additional tax revenue for advanced economies, which means that funding this proposal may possibly be the highest-return public investment ever (IMF 2021c). The window for realizing these gains, however, is closing quickly, and action is needed now.

Given that ending the pandemic in a timely manner is a global public good, of the $50 billion total cost of this proposal, there is a strong case for grant financing of at least $35 billion from public, private, and multilateral donors and the remainder by national governments potentially supported by concessional financing from multilateral agencies. The grant funding gap identified by the ACT Accelerator amounts to about $22 billion, which the G20 and other governments recognize as important to address. In addition, at least $15 billion is available from COVID-19 financing facilities created by multilateral development banks. This leaves an estimated $13 billion in additional grant

[1] Since April 2020, the ACT Accelerator partnership, launched by WHO and partners, has supported the global effort to fight the COVID-19 pandemic, including by efforts to deploy tests, treatments, and vaccines the world needs. The ACT-A is a framework for collaboration that was set up in response to a call from G20 leaders in March 2020. Our work builds on the ACT-A budgeting exercise presented in WHO (2021b).

[2] Agarwal and Reed (2021) study the demand and supply of vaccines and find a procurement gap of about 350 million vaccine courses to reach 60 percent vaccine coverage in low- and lower-middle income countries. Our work expands on this exercise, including by analyzing how the global distribution of vaccine coverage would change under different scenarios, designing and quantifying the need for at-risk investments, budgeting for and highlighting the role of treatments and diagnostics, and identifying data gaps in global pandemic and supply-chain surveillance.

contributions needed to get to the $50 billion identified by our proposal. This additional amount is mainly for raising the COVAX vaccine coverage to 30 percent, procuring additional COVID-19 tests, and expanding vaccine production capacity to insure against downside risks. We emphasize the need for grant financing since the identified needs are largely on behalf of low- and lower-middle income countries.

The proposal focuses on what is needed to bring the current pandemic under control. This complements the work of the G20 High Level Independent Panel, the G-7 Pandemic Preparedness Partnership group, and the Report of the Independent Panel for Pandemic Preparedness and Response (G20, 2021; G7, 2021; and IPPP, 2021), which primarily focus on addressing future pandemics.

The following sections outline the opportunities and the challenges and discuss possible solutions. We also note that there is considerable uncertainty around the projections given the shifting vaccine and virus landscape, and the lack of sufficient transparency in vaccine contracts.

ACCELERATING GLOBAL VACCINE COVERAGE

Opportunities

A) Vaccines work: Vaccine discovery has been hugely successful (Agarwal and Gaule, 2021), and so far the evidence from multiple countries like Israel, the UK, and the US provide real-world reinforcement that vaccines are effective and can help bring the virus under control (Burn-Murdoch, 2021; Rossman and others 2021). Further, there is growing evidence that different vaccines in the existing vaccine portfolio retain an effectiveness of 50 percent or greater against most variants of concern or interest—especially in preventing hospitalization and deaths (see Table 2).

B) Vaccine supply in the pipeline for 2021 is sizable: More than 1.1 billion vaccine doses had been administered globally by the end of April 2021. Further, the International Federation of Pharmaceutical Manufacturers & Associations (IFPMA), which represents pharmaceutical companies around the world, projects an accelerating supply of vaccines. IFPMA stated on April 23, 2021, that "current projections to produce close to 10 billion doses by the end of 2021 is thought to be feasible." (IFPMA, 2021; Airfinity, 2021).

⇒ While these estimates remain subject to significant downside risks due to the fragility of the supply chain, the pace of global vaccination reached 20 million doses per day as of the end of April 2021 (as per data consolidated by Our World in Data). This is equivalent to 0.25 per

100 people in the world. Even at this pace, under the baseline we should expect conservatively at least 6 billion vaccine doses produced and administered worldwide by the end of 2021. For our business-as-usual projections of vaccine coverage by the end of 2021, we take this conservative estimate of 6 billion doses and treat the industry baseline of 10 billion doses as a potential upside scenario (discussed below).

⇒ Accounting for single-dose shots, the 6 billion doses would translate to about 3.5 billion vaccine courses (that is, would vaccinate 3.5 billion people) and will be sufficient to cover about 45 percent of the world's population by the end of 2021.

C) Vaccinating the high-risk population provides significant benefits: If vaccine prioritization is followed in line with guidance from the WHO to first vaccinate priority populations (WHO 2020a), the 6 billion doses would allow for universal coverage for the worldwide high-risk population (that is, older adults plus those with underlying health conditions that account for about 22 percent of world population) (Clark and others 2020).

⇒ The evidence from countries ahead on the vaccination drive is that vaccinating the high-risk population (for example, those in nursing homes and older individuals) can significantly ease the severity of the pandemic as health systems are not overwhelmed. So even before reaching anywhere close to herd immunity, significant benefits from vaccinations can be realized if coupled with sensible public health measures.

Challenges

A) Vaccine access is highly unequal: The access to vaccines remains deeply unequal across countries with the 1.1 billion doses already administered concentrated in a few countries. As of the end of April 2021, less than 2 percent of Africa's population had been vaccinated. By contrast, more than 40 percent of the population in the US and more than 20 percent in Europe had received at least one dose of the vaccine (Figure 1).

⇒ The inequality in vaccine access is expected to persist. Based on the estimate of 6 billion doses under the business-as-usual scenario, our projections show that the inequality in vaccine access is likely to persist until the end of 2021 and beyond—significantly jeopardizing global health prospects (Figure 2). This scenario does not include in-kind vaccine donations from donor countries, as stockpiled vaccines will simply go unused in the near-term in the absence of donations. To evaluate the degree of inequality in vaccine access, it is useful to split the LMICs (excluding China and India) into a group of 91 countries that require explicit global support and the rest. The first group is referred to as AMC91 (given their eligibility to access the grant-

financed COVID-19 Vaccines Advance Market Commitment, or COVAX AMC, facility) containing LMICs with a combined population of about 2.5 billion, and the rest contains 35 upper-middle-income countries with a population of about 1.1 billion (see Annexes I and II).

⇒ Under the business-as-usual scenario, the vaccine coverage in AMC91 countries is expected to remain below 30 percent by the end of 2021, whereas coverage in India is expected to reach under 35 percent (Figure 3). Other LMICs and high-income countries are expected to have a coverage of around 50 percent and 70 percent, respectively.

B) Several downside risks exacerbate this inequality: We describe three downside scenarios in which even the conservative estimate of 6 billion doses do not materialize by the end of 2021. Our projections show that in all three scenarios, LMICs are disproportionately impacted, worsening inequality (Figure 3 and Annex IV):

⇒ *Scenario 1: Persistent shortage of raw materials and export restrictions lead to longer delays.* Vaccine manufactures are aiming to produce this year around three times the annual global supply of vaccines in a normal year. Such rapid scaling up is posing substantial supply chain challenges with shortages of raw materials shared among multiple vaccine candidates. Already, various manufacturers including the Serum Institute of India (licensed to manufacture Novavax and AstraZeneca) have experienced substantial delays. Some of these delays can be attributed to ongoing export restrictions placed by the US as part of the Defense Production Act to secure its own vaccine supply chain. In addition, India has delayed most of its vaccine exports to prioritize vaccinations at home. Such delays disproportionately impact developing countries—for instance, the Serum Institute is contracted to supply about 85 percent of the supplies to the COVAX AMC facility, and persistent shortage of raw materials and export restrictions can reduce access to vaccines for 4 billion people in 91 developing countries plus India relying on this facility.

⇒ *Scenario 2: Safety concerns in a class of vaccines.* Concerns about safety—genuine or otherwise—of the AstraZeneca and Johnson & Johnson (J&J) vaccines have led to temporary halts in various jurisdictions. There is growing evidence that such halts have contributed to vaccine hesitancy. The developing world is heavily relying on adenovirus-based vaccines, with more than 80 percent of currently contracted vaccine courses in the group of AMC91 LMICs and India expected to come from three developers: AstraZeneca, J&J, or Sputnik V. All three share the same platform technology and are thus exposed to similar risks. Thus, safety concerns in this class of vaccines could significantly impact vaccine rollout and exacerbate the cross-country inequality in vaccine access. To demonstrate the distributional impact of such a scenario, Figure 3 depicts

a case in which 30 percent of global vaccine supply in 2021 is compromised due to a shock to the adenovirus-based vaccines (reducing the vaccine supply from 3.5 billion courses to 2.5 billion courses). Under this scenario, vaccine coverage for AMC91 countries and India by the end of 2021 will decline by more than half—from about 26 percent and 33 percent to 10 percent and 12 percent, respectively.

⇒ *Scenario 3*: *Vaccinations of children and booster doses administered in high-income countries due to reduced vaccine efficacy against new escape variants*. New mutations can render a class of vaccines less effective as is already the case with the B.1.351 variant (originally found in South Africa), although so far most vaccines remain highly effective in preventing severe illness and death. If existing or new variants of concern were to seriously compromise vaccine efficacy it could impact the global vaccination path in two ways:

i) First, it will raise demand for booster shots, which will require existing manufacturing capacity to be repurposed. This will divert capacity away from the unvaccinated world to the already-vaccinated people in high-income countries.
ii) Second, we have already seen that some vaccines that are so far available to developing countries—in particular AstraZeneca—have been associated with significant reduction in efficacy against the B.1.351 variant discovered in South Africa (Madhi and others 2021). Thus, the rise of further escape variants is likely to create a two-class system of vaccine portfolios under current capacity constraints—with high-income countries having access to relatively more effective vaccines supplemented by boosters.
iii) This scenario additionally assumes rapid vaccination of children in high-income countries in line with current development plans of leading vaccine developers (for example, Pfizer). Under this scenario, about 85 percent of the population in high-income countries will be vaccinated by the end of 2021, in addition to all vaccinated adults in high-income countries receiving a booster shot. This results in a reallocation of about 425 million vaccine courses from AMC91 countries to high-income countries, leading to the vaccine coverage of AMC91 countries and India falling to around 10 percent.
iv) Overall, these channels will leave LMICs with fewer and less-effective vaccines. Figure 3 quantifies such a scenario (see Annex IV for details) in which the coverage of AMC 91 countries and India may fall to around 10 percent at the end of 2021.

Proposed Solutions

I. Achieving the Vaccination Targets

To bring the pandemic substantially under control the goal should be to vaccinate at least 40 percent of the population in all countries by the end of 2021 and at least 60 percent by the first half of 2022. The 60 percent vaccination target is also consistent with the African Union's target of vaccinating 60 percent of the continent's 1.3 billion people. Reaching this target in developing countries and especially in Africa (where about 40 percent of the population is below age 15), may require near-universal vaccine coverage among adults or lowering the approved minimum age of vaccines (for example, from age 16 to age 12 as is being currently evaluated by regulatory authorities).

Prior work and evidence from the immunization campaign in Israel shows that, as long as vaccines provide protection, this immunization threshold could be sufficient to end the acute phase of the pandemic and enable substantial normalization in social and economic activity (Rossman and others 2021). The required immunization threshold for infections is sensitive to the particular vaccine being administered. However, real-world data demonstrate substantial gains in reducing severe disease, hospitalization, and death at 60 percent coverage in all cases, thus enabling a return to substantial normalcy.

Table 1 outlines the key elements of the proposal and financing required to help achieve this proposal for the AMC countries, with budgeting details for each item provided in Annex VI. Most high-income countries and upper-middle-income countries are already on track to attain the goal. The required actions are the following:

A) Provide additional upfront financing for COVAX. Additional up-front cash contributions (not commitments) of at least $4 billion are needed for the COVAX AMC facility, which is a global initiative aimed at equitable access to COVID-19 vaccines. This will close the current financing deficit and enable COVAX to increase its vaccine coverage goals for 91 LMICs ("AMC91") from 20 percent to 30 percent.

⇒ With immediate up-front cash contributions, COVAX can finalize orders that are currently under active negotiation. This in turn will help activate the unutilized vaccine capacity. As per industry estimates, only a subset of the 2021 vaccine production capacity has been pre-purchased, suggesting that there may be room to bring marginal supplies online before end-2021 beyond the 6 billion doses assumed in our business-as-usual scenario.

⇒ Estimates suggest that current vaccine pre-purchases (either bilaterally, or through COVAX and the African Union) already provide a coverage of about 40-50 percent in most LMICs (Agarwal and Reed, 2021). Thus, allowing the COVAX AMC to increase its coverage will help ensure that vaccine coverage reaches 60 percent in most of the LMICs eligible to access its AMC facility by the first half of 2022.

⇒ Further, funding will be needed to assist LMICs in financing the costs of delivering the COVID-19 vaccines, including to cover costs for technical assistance, outreach and fixed site delivery costs, and upfront costs such as cold chain installation and training.

B) Countries with insufficient coverage should immediately place purchase orders for vaccines. Countries or regions that are relying on domestic vaccine manufacturing capacity or on executing option contracts in the future should consider immediately placing orders to achieve sufficient vaccine coverage.

⇒ For India, current bilateral purchases plus coverage from COVAX will cover about 25 percent of its population by the first half of 2022. To get to 60 percent coverage, India will need to immediately place sufficient vaccine orders of about 1 billion doses through contracts that incentivize investment in additional capacity and augmentation of the supply chain. In this context, the authorities' recently announced financing of about $600 million to the Serum Institute of India and Bharat Biotech to boost production capacity in the near term is a welcome step. Authorities estimate that 2 billion doses will be available by the end of 2021. Efforts should be made to ensure that the projected production capacity will materialize without delay, including through securing the supply chain for raw materials—supported by international efforts to eliminate export restrictions on all critical inputs.

⇒ The African Union has entered a deal with J&J for 220 million single-shot doses with an option to order an additional 180 million doses. Most of this supply is expected to be produced by Aspen Pharma in South Africa. This deal alone provides a vaccine coverage of 18-32 percent to African Union member countries. Efforts should be made to secure additional doses as needed (either through the existing J&J option or other vaccine producers). Further, given the reliance on the South Africa manufacturing facility, proactively monitoring and mitigating supply chain risks in the plant will be important.

(C) Ensure free cross-border flow of raw materials and finished vaccines. An urgent focus should be to eliminate constraints on cross-border exports of critical raw materials and finished vaccines. Free cross-border flow of vaccine inputs and supplies is essential for the world to achieve its vaccination

targets without delay. Governments are taking steps to relax such constraints on raw materials (for example, the recent pledge by the US to facilitate greater access of critical raw material to Indian manufacturers after severe shortages emerged). However, there is scope for greater multilateral action on this front, as significant constraints still remain. Greater access to critical raw materials—combined with a commitment by Indian authorities to maintain no restrictions on exports once near-term shortages ease—will also enable the Serum Institute of India (currently the chief supplier to COVAX) to meet its export commitments, which is important for the path to global vaccination.

D) Donate surplus vaccines. Countries ahead on vaccinations already have surpluses or will soon have surpluses even if they prioritize their own populations. They should share these vaccines equitably and based on standard public health principles and not for political or commercial reasons. Donating to COVAX is the best way to accomplish this (IPPP 2021). In addition, because COVAX has a "No Fault Compensation Program," donating countries are exempt from liability concerns. There is a need for greater urgency in donating surplus vaccines, which will not only help reduce vaccine inequity but also help mitigate the acute near-term shortages in vaccine supply. Securing an international agreement, perhaps led by the UN and its agencies, to share surplus vaccines with COVAX, would help raise the "diplomatic cost" of using vaccine surpluses for national purposes.

⇒ The number of vaccines pre-purchased by high-income countries far exceeds the number of people in these countries. For instance, the United States will have at least 350 million pre-purchased courses available in excess of 75 percent of its population before 2022, and that number rises to about 1 billion courses when considering a select set of eight high-income countries/regions (Figure 6). Further, the scenario analysis depicted in Figure 5 demonstrates even 50 percent of the 1 billion surplus vaccines were available and donated (that is, 500 million courses) would result in close to 40 percent vaccine coverage in all countries by the end of 2021.

⇒ *US case study*: Based on data of existing and projected vaccine supplies, the US has an estimated 80 million surplus vaccine doses available to donate as of April 2021, and this stockpile of surplus vaccines will grow to about 350 million doses by August 2021 (Table 3 and Annex V). These numbers correspond to finished products in vials, suggesting that the US has an opportunity to make a significant contribution to the world by rapidly making the surplus vaccines available to COVAX in the form of donations.

⇒ *Cross-country prioritization*: While the allocation rules between countries are subject to various ethical and health considerations, efforts should be made to prioritize donations to places where it would save the most lives (Emanuel and others 2020). The impact of COVID-19 varies tremendously across geographies, and accounting for that in the allocation of surplus vaccines

is likely to save lives. While the initial phase of COVAX allocation has proceeded according to proportional allocation, the COVAX allocation mechanism (WHO 2020c) allows for special consideration for countries that face major outbreaks or national disasters. Increasing and utilizing this special consideration buffer could be a way to achieve better prioritization. An additional step that can facilitate prioritization is a system of vaccine exchange, which could help get doses to places where they are most needed—if intertemporal trade is allowed. Such a mechanism, called the *COVAX Exchange,* has been under development, and efforts should be made to immediately make the exchange operational.

Figure 4 depicts the "Achieving the Vaccination Targets" scenario, which is based on an immediate implementation of measures (A)-(D) discussed above. Under this scenario, a combination of utilizing the surplus inventory in high-income countries and activating the production capacity through immediate pre-purchases by COVAX and India, could increase the global vaccine supply from 3.5 billion vaccine courses by the end of 2021 (as in the business-as-usual scenario) to about 4.25 billion vaccine courses—and also reduce inequity in vaccine access. This would facilitate vaccine coverage of more than 40 percent in all countries worldwide by the end of 2021. This is equivalent to about 7.5 billion vaccine doses and may still be conservative, given the capacity for 2021 estimated by industry experts. Further, under this scenario there would be an estimated 5.5 billion vaccine courses or more by April 2022, which will facilitate a minimum vaccine coverage of 60 percent in all countries (in line with the 60 percent target in the first half of 2022).

Even if the vaccination targets are secured by such measures, additional measures, described next, will be needed to insure against the downside risks described previously.

II. Insure against downside risks for vaccinations

E) Make at-risk investments to ensure sufficient production. Given the significant downside risks, what is needed is upfront investment to ensure coverage including in downside scenarios and also to potentially address future needs for LMICs (for example, vaccination of children, booster doses). In this context, private incentives to invest in capacity and scale up production in a timely manner may be weak, especially if they are likely to face limits on pricing during the pandemic (Ahuja and others 2021; Castillo and others 2021). Thus, there is scope for greater government support to create at-risk capacity as was done by the US as part of its Operation Warp Speed.

⇒ *Immediately enter contracts to secure an additional 1 billion doses by first half of 2022 to handle downside risks or longer-term needs of LMICs.* Increasing vaccine production capacity by 1 billion doses in 2022 will require additional financing of about $8 billion. This is needed to address the

type of downside risks discussed in Scenario 1 and Scenario 3. Noting the recently concluded deal between Moderna and COVAX, and previous supplies by Pfizer/BioNTech to COVAX, after careful evaluations, a subset of this capacity could possibly be directed toward mRNA vaccine candidates given their expanding production capacity and potential efficacy against new variants. It will be important to ensure equitable and public health driven access to this additional vaccine capacity, and thus COVAX could be a natural candidate to execute the at-risk investments. A major current bottleneck in vaccine production is raw material shortages, and this at-risk investment to increase capacity by 1 billion doses by early 2022 should include provisions that ensure capacity is increased for all parts of the supply chain. See Annex VII for further discussion on how one could design the at-risk investment.

⇒ *Additional efforts and financing to encourage voluntary licensing and cross-border transfer of technology:* There is scope to increase manufacturing capacity through voluntary licensing, and encouraging expansion of regional production capacity. In the near term, focus should be on encouraging more voluntary licensing (for example, AstraZeneca licensing deals in India, China, Brazil) and on encouraging cross-company and cross-border partnerships to increase their manufacturing capacity (such as the U.S. government's move to get J&J and Merck to collaborate on manufacturing capacity, or the Quad vaccine initiative to increase production capacity in India). Efforts to expand manufacturing capacity should be coordinated across countries (for example, through WHO, WTO, and COVAX) to avoid crowding out vaccine supplies that are needed in the immediate short term (WHO 2021c, IPPP 2021). The recently announced COVAX manufacturing taskforce can serve a key role from this perspective. These efforts are important for vaccine equity as crowding out of vaccine supplies has tended to be at the expense of poor nations. These efforts can proceed in parallel to the ongoing WTO negotiations on the sharing of intellectual property for COVID-19 vaccines.

⇒ *Enhance quality control:* Thus far, quality control problems have created a number of delays in production for multiple vaccines. Improvements in quality control needs to go hand in hand with capacity expansion and supply chain investments to make sure that vaccine production is reliable, and to mitigate the risk of further delays.

⇒ *Increase yield of existing capacity:* Efforts should be made to increase efficiency and yields of existing vaccine production (for example, ongoing work by Pfizer and others to increase the yield of their production process), which when possible should be allocated to increased near-term supplies for LMICs.

F) Scale up genomic surveillance and systemic supply chain surveillance. To ensure vaccines remain up to the task there is a need to prevent downside scenarios impacting the global vaccine portfolio or the vaccine supply chain.

⇒ To mitigate the risk of delays in vaccine production or the impact of new variants, greater global surveillance of SARS-CoV-2 variants and supply chain risks are needed with concrete contingency plans in place to handle the downside scenarios. The contingency plans should be regularly updated, and stress tested with the use of scenario planning—with the participation of multilateral agencies, vaccine developers, and key national governments. The plans should develop guidelines on how manufacturing capacity can be repurposed under different scenarios such as Scenario 2 above (including to handle lineages that evade immunity for certain class of vaccines), while preserving equitable access to vaccines.

⇒ On the supply chain risks, an initial step could involve developing a global database of critical raw materials and manufacturing capacity and utilization, perhaps coordinated by the WTO or World Bank. Further, establishing a centrally coordinated COVID-19 database, including on vaccine contracts and various aspects of diseases surveillance (cases, deaths, testing, etc.) will be important to bring about greater transparency (He and others 2021, Morgan and others 2021; see Annex VIII). In this regard, the World Bank initiative to establish a data base about vaccine orders is highly welcome.

Overall, there is a need for transparent, coordinated, open-access data on multiple aspects to enhance pandemic surveillance. Annex VIII presents a non-exhaustive indicative list of data gaps that need to be addressed to enhance pandemic surveillance. There is also a need to adopt vaccine strategies that will minimize health risks before adequate vaccine supply arrives (without severe lockdowns), especially in LMICs. These strategies are discussed below.

III. Managing the interim period when vaccine supply is limited

G) Invest in infrastructure to prioritize vaccination of high-risk population and address vaccine hesitancy. In countries where vaccine supplies are scarce the high-risk population should be prioritized in vaccination drives as recommended by the WHO (2020a). Real-world evidence from the prioritized vaccine rollout in the U.K. demonstrates that rates of COVID-19 cases, hospital admissions, and deaths have fallen faster among the elderly and other highly vaccinated groups. Further, in the UK, which implemented a strict prioritization of vaccine access by age, the likelihood of getting COVID-19 fell rapidly in each age group as they became eligible to get vaccinated (Burn-Murdoch 2021). Similarly, in the U.S., which prioritized vaccination among the vulnerable groups

and older individuals, there was a rapid decline in cases among those in nursing homes starting in January 2021, while COVID-19 cases surged in the overall population (Conley and others 2021). Given the high risk of death among the vulnerable populations, a strict, well-managed, and effective vaccine prioritization can save lives even when vaccine access is scarce.

⇒ *Given* the younger demographics in LMICs, the share of vulnerable population is typically in the range of 20-25 percent of the population. Further, only 7 percent of vaccine coverage of the full population will be needed to cover individuals over the age of 65 in LMICs. Recognizing limited state capacity to implement adequate vaccine prioritization, countries at nascent stages of vaccination should invest in the vaccine delivery infrastructure, prioritizing getting shot-in-arms of at-risk groups ahead of time. This requires investing in storage and transportation logistics to reach the vulnerable (WHO 2021a); public health messaging to address vaccine hesitancy; fighting disinformation on social media (Gounder 2021). Countries like Bhutan, which vaccinated most of its adult population within a week, demonstrate that with strategic planning and management a rapid vaccination campaign is possible in LMICs.

⇒ *Evaluate a broad range of vaccines for fast track emergency use authorization*. The group of countries that are included in the Stringent Regulatory Authority (SRA) list recognized by the WHO to guide medical procurement decisions globally is comprised of 34 high-income western countries plus Japan. Since most of these countries are thus far not planning to use vaccines developed by the rest of the world (for example, Chinese, Indian, or Russian vaccines), the SRAs have been relatively slow in evaluating non-Western vaccines. This may inadvertently delay adoption of these non-western vaccines by countries around the world—since multilateral financing for vaccine procurement and also regulatory approvals in LMICs are often linked to the regulatory approvals granted by the select group of SRAs. To ensure a broad portfolio of vaccines are available to each country, and to handle possible downside risks due to new variants, regulatory authorities should expedite evaluation of a greater number of vaccine candidates.

⇒ *Ensure vaccine uptake also by making it available free of cost to people. Vaccine hesitancy is a growing concern.* Vaccine uptake appears to slow considerably as early as 40–60 percent of population coverage. Overcoming vaccine hesitancy will be important to secure a durable exit from the crisis. From this perspective, the benefits of uptake are so large for countries that a zero price should be implemented for all people to maximize uptake and avoid within-country inequality in vaccine access and uptake. Existing multilateral pandemic facilities should be fully utilized to ensure financing is not an obstacle for these important steps.

H) Urgently evaluate and, where approved, implement dose stretching strategies to expand capacity, and support investment in products that ease vaccine delivery. With a growing global death burden, there is an urgent need for regulatory authorities to evaluate and implement dose stretching strategies where vaccine supply is low as advocated by Tabarrok (2021) and others and implemented in the U.K. and most recently in India. The feasibility of dose stretching will depend on the vaccine portfolio available to a given country, as preliminary real-world evidence suggests that some vaccines (for example, mRNA vaccines or AstraZeneca) may work better with such strategies than others.

⇒ *First Doses First:* The first option to consider is the "first doses first" approach that prioritizes first doses by delaying the second shot to 12 weeks or more. In the context of countries facing significant shortage of vaccine supplies, it would be useful to evaluate longer delays for the second shot (say 24 weeks) for the subset of highly effective vaccines, as this could substantially increase vaccination coverage in the immediate future when supply constraints are most binding. For instance, in clinical studies, Novavax, has an efficacy of about 83 percent as early as 14 days after the first shot, and Moderna and Pfizer/BioNTech have comparable efficacy after two weeks of the first shot. AstraZeneca also appears to offer protection of 70 percent or more after the first dose, and the UK government policy of stretching the interval between the two shots of the AstraZeneca vaccine appears to have worked (Iacobucci 2021). As vaccinations rates rise in high-income countries (such as Israel, U.K., and Qatar) more can be learned about the effectiveness of such strategies from real-world data.

⇒ *Fractional Dosing:* The second option to consider is the "fractional dosing" approach under which half-doses are administered (or a full dose followed by a half-dose). This strategy has been used effectively in previous epidemics when vaccine supplies were scarce (Guerin and others 2008). The relative benefit of these first two approaches in terms of relaxing the supply constraint will depend on where the bottlenecks in the supply chain currently exist (for example, glass vials vs. raw materials).

⇒ *Single dose for previously infected:* A third option worth considering is a "single dose for previously infected." A recent study found that the first dose of some vaccines combined with prior infections is as or more effective than two doses for those with no prior infections (Anichini and others 2021). Furthermore, the second dose may not be beneficial or be associated with side effects for those with prior infections. Thus, for countries with high seroprevalence due to prior infections, population level screening for antibodies can significantly reduce vaccine needs under this approach.

⇒ *Other strategies to facilitate faster vaccine delivery:* Other strategies/products that need urgent attention include the development of nasal or oral vaccine products to overcome needle hesitancy (which is a non-negligible concern in LMICs), and development of mRNA vaccine doses that have better cold-chain characteristics making them more suitable for LMICs.

⇒ While each of these approaches have some downsides, the current shortages in vaccine supply place a high urgency on evaluating the public health benefits of implementing them. Figure 5 shows how these strategies can significantly improve vaccine coverage and reduce vaccine inequality by the end of 2021. The figure demonstrates that dose stretching strategies could lead to an increase in the global supply of vaccines by 50 percent in 2021 relative to the business-as-usual scenario. Under such a scenario all countries in the world could reach the 60 percent vaccine coverage target by the end of 2021.

⇒ *Provide public support for urgently evaluating these strategies through clinical trials when necessary.* Learning about the effectiveness of such strategies is a global public good, with potentially huge social returns. The private sector may have weak incentives to prioritize such trials or products. Thus, there is an urgent need for public support to scale up such clinical trials and development plans with the aim of expanding existing vaccine capacity, increasing speed of vaccine delivery, and to prepare for downside risks.

⇒ Finally, there is also an urgent need for public support for clinical trials and lab studies that evaluate the efficacy of existing vaccines against new variants, and to support parallel progress on updating the vaccines (e.g., by developing multivalent shots) to prepare for mutation scenarios with vaccine escape.

DIAGNOSTICS, THERAPEUTICS, AND PUBLIC HEALTH MEASURES

Vaccinations need to be supported with essential complementary measures to minimize the loss of lives and morbidity from this pandemic. Many countries will have to maintain public health measures, build up supplies of therapeutics, and continue scaling up their diagnostic/testing and contact tracing efforts. Such measures can help prevent the emergence of new virus strains and ensure that vaccines are up to the task. A globally coordinated procurement for medical supplies as envisioned by the ACT Accelerator will prevent countries crowding out one another. These nonvaccine measures present both opportunities and challenges.

Opportunities

A) Social distancing and public health measures work: Maintaining physical distance, wearing masks, ensuring proper ventilation of indoor spaces, avoiding crowds, and proper hygiene can significantly reduce risk of infections. Such measures can be particularly effective in areas with poor ventilation. (WHO 2021b).

B) Treatments can reduce mortality risk: Improved treatment regimens have reduced probability of death among those infected. Researchers have identified various treatments—including dexamethasone—that bring about a reduction in mortality rates among COVID-19 patients (Wiersinga and others 2020).

C) Testing and contact tracing works: Scaling up testing—including in settings such as universities and schools—and isolating those who test positive can help contain the spread of the virus (Fetzer and Graeber 2020).

Challenges

A) Difficulty and reluctance in maintaining social distancing and public health measures. In developing countries enforcing social distancing comes at considerable cost to livelihoods and poses practical challenges in areas with dense populations. Further, countries who experienced milder first waves may have become complacent with respect to public health measures. Fatigue may also be setting in among those residing in countries with long-standing measures. Vaccine optimism may also be leading to complacency.

B) Testing remains low in LMICs. Testing capacity in many LMICs remain low, especially in rural areas, limiting the benefit of testing and tracing efforts in these countries. While daily testing rates are above 3 per 1000 in most high-income countries, most LMICs are testing far below 1 per 1000 daily.

Proposed Solutions

A) Invest in testing and tracing efforts. Testing measures are a relatively low-cost and effective option to contain the spread of the virus and can enable resumption of activity in select areas of the economy (Reed and others 2021; Cherif and Hasanov, 2020). With expanded access to Rapid Antigen Tests, which are relatively cheap, big advance purchases might make it possible to lower the cost to about $2-3 per test and get billions of these produced. Several countries, including the U.K., are already pursuing this strategy, with the government sending people a free box of tests. Where

feasible, rapid tests can be used at workplaces, hot spots, concerts, etc. Further, if people are encouraged to enter their data, they can even be used for tracking the virus. To support effective public health strategies to reduce COVID-19 prevalence and to enable treatment of those infected with the disease, LMICs will need to be supported in rapidly scaling up their testing capabilities, utilizing a range of different diagnostic tools (for example, AgRDTs, PCR auto/manual, genomic sequencing, self-tests) for a variety of purposes such as case management, test-trace-isolate, border control, health-worker protection, disease surveillance, and more. This will likely require WHO's accelerated approval of a broader set of tests satisfying stringent performance criteria, greater access to manufacturer volumes (for example, automated PCR tests), significant procurement funding, more frequently update guidance from WHO reflecting the evolving range of use cases, plus increased on the ground technical assistance to ensure effective implementation. Testing will remain critical as vaccines are deployed, not least to track the impact of vaccine rollout on transmission, but also to detect potential incidence of variants evading vaccine protection.

B) Expand global capacity and procurement of medical supplies and treatments. Capacity should be increased especially at the global level with the aim of ensuring sufficient and rapid access to any country in need. This should be conducted in line with the current procurement and distribution schemes envisioned in the ACT Accelerator strategy. Further, there is a need to accelerate uptake of therapeutics such as dexamethasone and oxygen in LMICs, including by stronger country engagement, technical assistance, and procurement support (ACT Accelerator, WHO 2021b). Further there may be a case for scaling up investment in personal protective equipment (PPE) for healthcare workers in LMICs (Risko and others 2020; WHO 2021b).

C) Maintain social distancing and public health measures. In line with guidance from public health experts, it is important to make public health measures (such as masking) a policy priority until the acute phase of the pandemic ends. In many countries this will require stepped up communication from top officials on the importance of these measures, increasing resources to fight misinformation on social media, and making use of effective public health communication measures (Abaluck and others 2021). Moreover, conducting regional surveillance of COVID-19 cases both within-country and cross-country based on risk projections can help (Malani and others 2021). Knowing where the virus will strike next can help save lives—by guiding behavior change, local public health measures, and allocation of scarce resources.

D) Maintain and strengthen the social safety net for the vulnerable. It is essential to maintain social protection measures—including in-kind and cash transfers to protect vulnerable households and support for viable firms—until the virus is brought under control. Adequate and broad-based

coverage will enable national authorities to maintain the necessary public health measures while mitigating the social and economic burden of such measures. A complete discussion of these issues, policy priorities, and associated fiscal costs is found in the IMF's *World Economic Outlook, Fiscal Monitor,* and *Global Financial Stability Report* (IMF, 2020a-c, 2021a-d) and not included here.

FINANCING

The total cost of the different measures in this proposal to add up to about $50 billion. (Annex VI provides details on the budgeting.) There is a strong case for grant financing of at least $35 billion—given that ending the pandemic in a timely manner is a global public good, and also to ensure that the AMC91 countries (which are mainly low- and lower-middle-income countries) are able to undertake the needed measures without being saddled with large debt burdens. Given the enormous social and economic cost of the pandemic, these grants are likely the highest social-return investments available today and can be made by advanced economies, multilateral agencies, or philanthropic individuals or institutions. From this perspective, there is scope for donor countries to increase the grant element of their international aid budget.

The grant funding gap identified by the ACT-Accelerator amounts to about $22 billion, which the G20 and other governments recognize as important to address. In addition, at least $15 billion is available from COVID-19 financing facilities created by multilateral development banks (World Bank and Asian Development Bank). This leaves an estimated $13 billion in additional grant contributions needed to get to the $50 billion identified by our proposal. This additional amount is mainly for raising the COVAX vaccine coverage to 30 percent, procuring additional COVID-19 tests, and expanding vaccine production capacity to insure against downside risks. Most importantly, all pledges need to be delivered on immediately.

With respect to the COVID-19 pandemic facilities from multilateral development banks, the World Bank has set aside $12 billion to help developing countries purchase and distribute vaccines, tests, and treatments (of which about $2 billion has been utilized as of end-April 2021), and the Asian Development Bank has made $9 billion in financing available for vaccine procurement and delivery in developing Asia. There is scope to scale up utilization of such facilities. Annex I provides additional details of the pandemic financing facilities.

The IMF can also play its role to help countries meet their financing needs—supporting countries' own efforts to create fiscal space and potentially acting as a third-resort line of finance. In this regard, the IMF could explore options, consistent with its lending mandate, to use our existing toolkit and

adapt as needed to support the surge for pandemic financing. For existing IMF-supported programs, based on each country's circumstance, there may be scope to flexibly approach the financing needed to support pandemic purchases.

Further, the IMF's Executive Board is considering a Special Drawing Right (SDR) allocation of $650 billion, which, once approved, would add substantial financial resources to all countries in these difficult times. Beyond that, the IMF is also exploring options to channel SDRs from countries with strong external positions to support global public policy goals.

CAVEATS AND UNCERTAINTIES

The analysis presented here is subject to several caveats, including due to incomplete information available in the public domain. First, regarding vaccine deals between countries/regions and vaccine developers, there are many contracts that remain unavailable in the public domain. Further, there are many contract negotiations that remain ongoing or contain option arrangements, hindering an adequate accounting of vaccine coverage. From this perspective, the coverage of vaccine contracts between countries and vaccine developers in China and Russia are relatively more likely to be undercounted.

Second, vaccine pricing estimates included here are based on existing assumptions and actual contractual prices reported by COVAX, African Union, and others based on the existing vaccine portfolios. However, the vaccine landscape remains subject to uncertainty, including due to potential issues with safety and/or efficacy, and the future portfolio of vaccines may shift relative to current projections. This is partially addressed by using a reference price of $12 per course (compared to the base price of $10.4 used by COVAX in its internal projections).

Third, similar uncertainty exists around other cost estimates such as costs for vaccine delivery and for the procurement costs and needs for diagnostics, therapeutics, and PPE. Some of these estimates included here are based on the work of various agencies and initiatives, which have carefully documented these uncertainties in their documents.

Fourth, although this proposal addresses a broad range of risks and uncertainties, the global COVID-19 landscape is particularly challenging given the possibility of several unknown unknowns relating to the biology of the virus, the psychology of the people, and the complexity of supply chains.

These caveats also highlight the need for greater data disclosure by country authorities and private sector participants, which will enhance global surveillance of risks and improve the effectiveness of

policy actions. We hope future work can build on our analysis as more data becomes available and there is lesser uncertainty about various elements of the exercise.

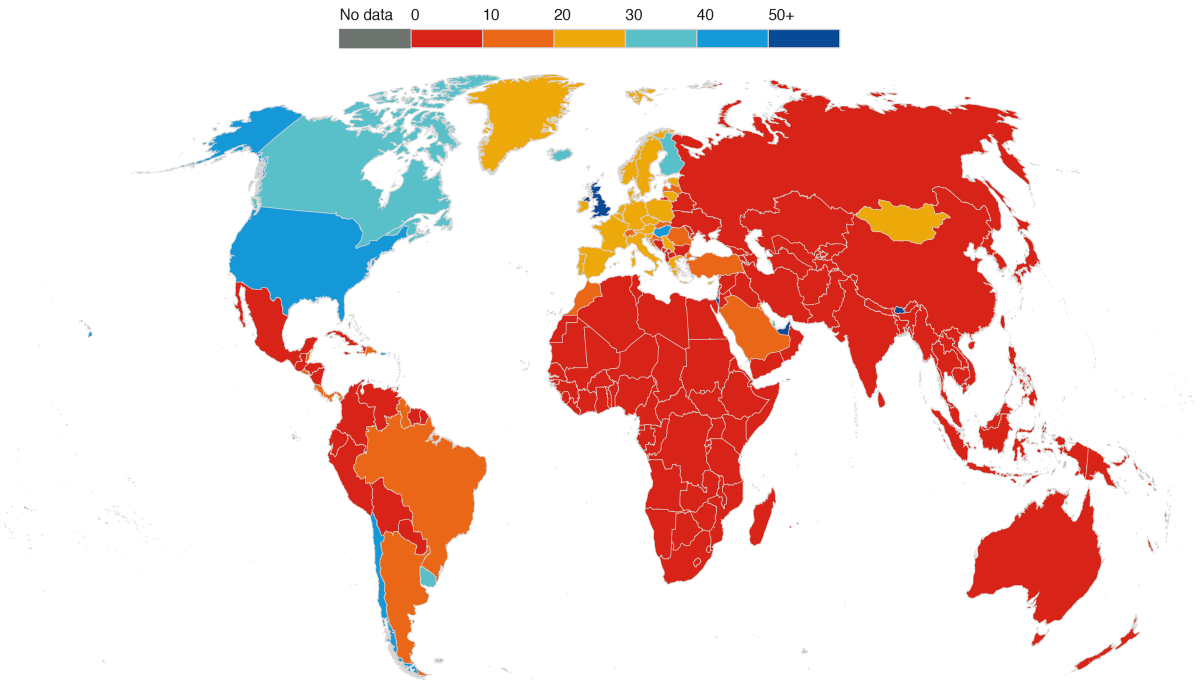
CONCLUSION

As described at the start, ending the pandemic is a solvable problem. Thanks to the ingenuity of the scientific community we have multiple successful vaccines, and in countries that are ahead in vaccinations life appears to be returning to normal. This is however a precarious normal. No country can return to normalcy until all countries can defeat the pandemic.

The record-high number of global COVID-19 cases in recent days makes this abundantly clear. Countries that had reopened substantially have gone back into lockdown to fight the new variants of concern. International travel remains highly restricted, and international shipping disruptions are creating shortages of goods and increasing production costs. The social and economic costs of the pandemic continue to rise and already diverging recoveries between rich and poor nations looks to worsen.

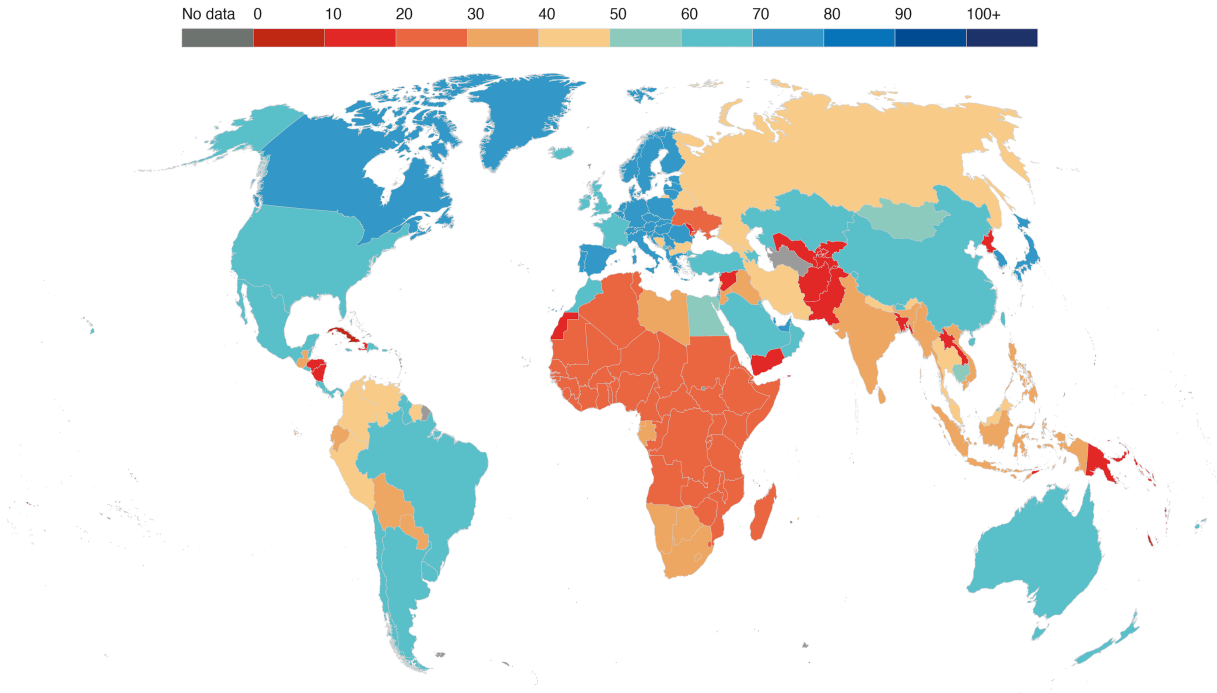
The world does not have to live through the pain of another surge of COVID-19 cases. If there is strong global action, which requires very little in terms of financing relative to the outsized benefits, much can be accomplished in the next twelve months to durably exit this health crisis.

Figure 1: Share of population vaccinated as of End-April 2021
(% of total population, at least one dose)



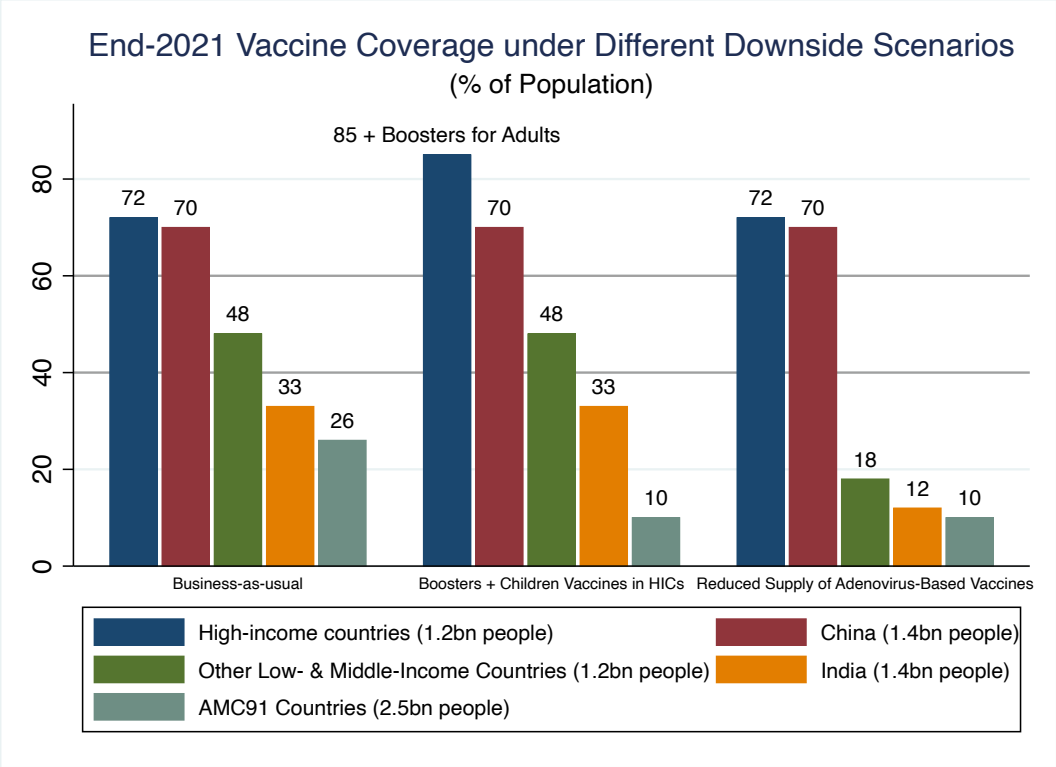
Source and Notes: Authors' calculations. See Annex III. Country borders or names do not necessarily reflect the IMF's official position.

Figure 2: Estimated share of population fully vaccinated as of End-2021 under a Business-as-Usual Scenario (% of total population)



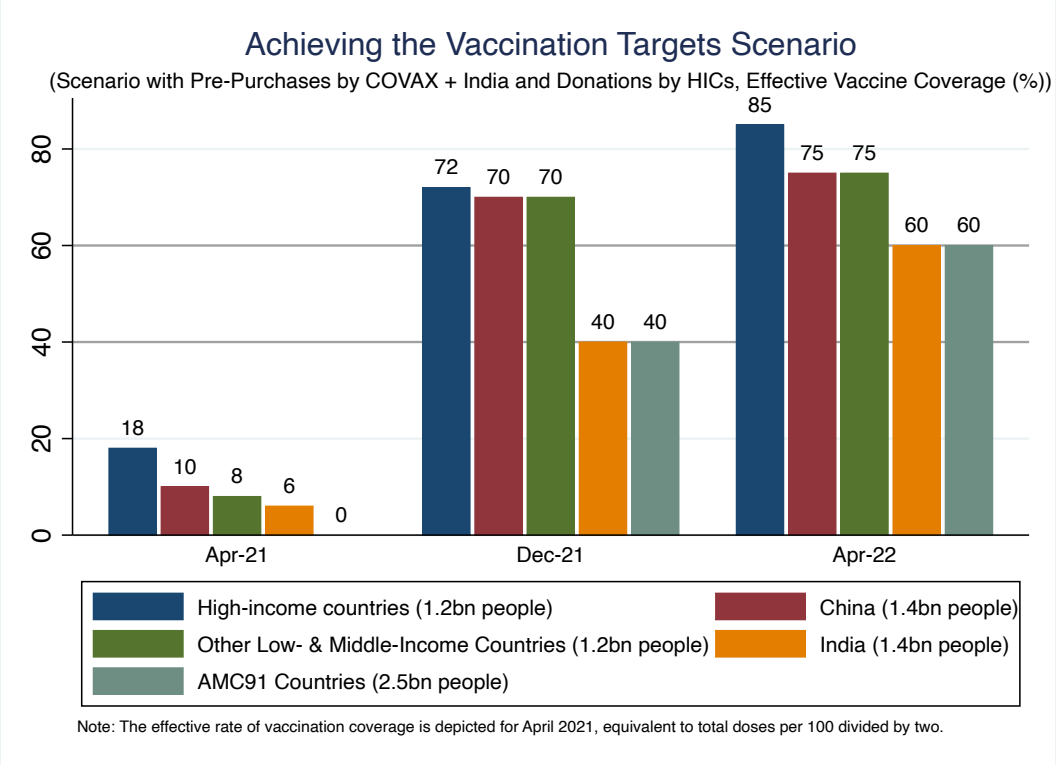
Source and Notes: Authors' calculations. See Annex III. Country borders or names do not necessarily reflect the IMF's official position.

Figure 3: Vaccination Coverage at End-2021 Under Downside Scenarios



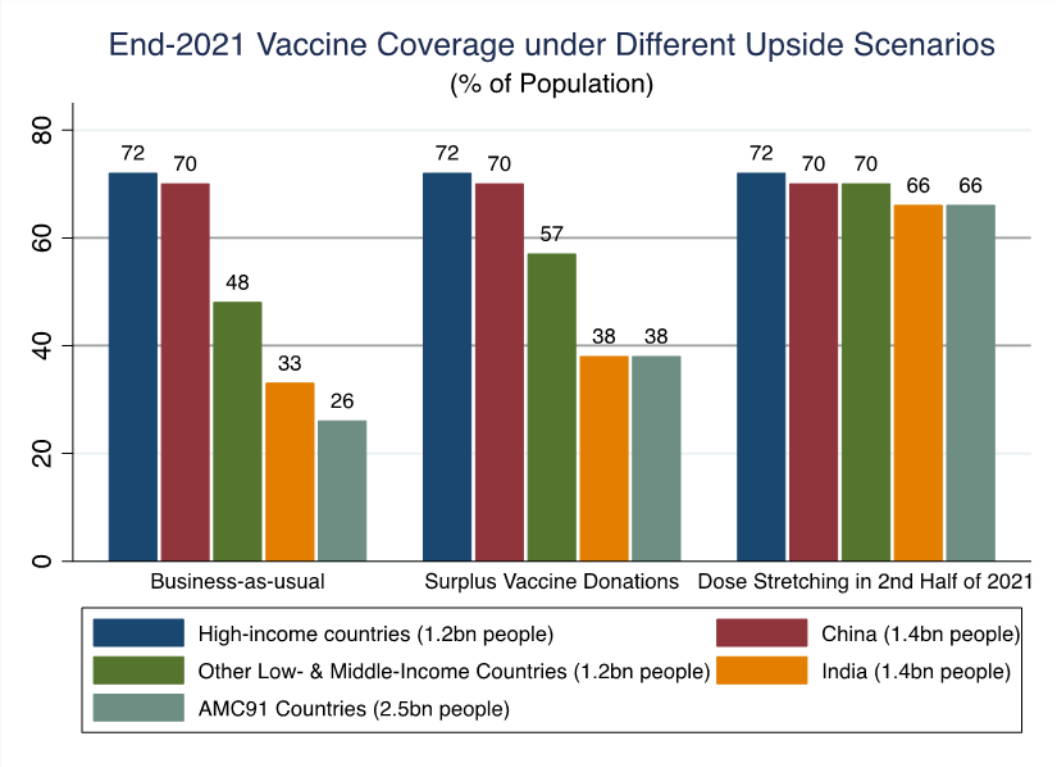
Source and Notes: Authors' calculations. See Annex IV. AMC91 stands for the group of 91 low- and middle-income countries (excl. India) that are eligible to access the COVAX AMC facility. Other LMIC refers to the group of low- and middle-income countries excluding India, China, and AMC91 countries. HIC refers to high-income countries as per World Bank income classifications. The bars report the fraction of population fully vaccinated within the country group, under different scenarios.

Figure 4: Achieving the Vaccination Targets Scenario



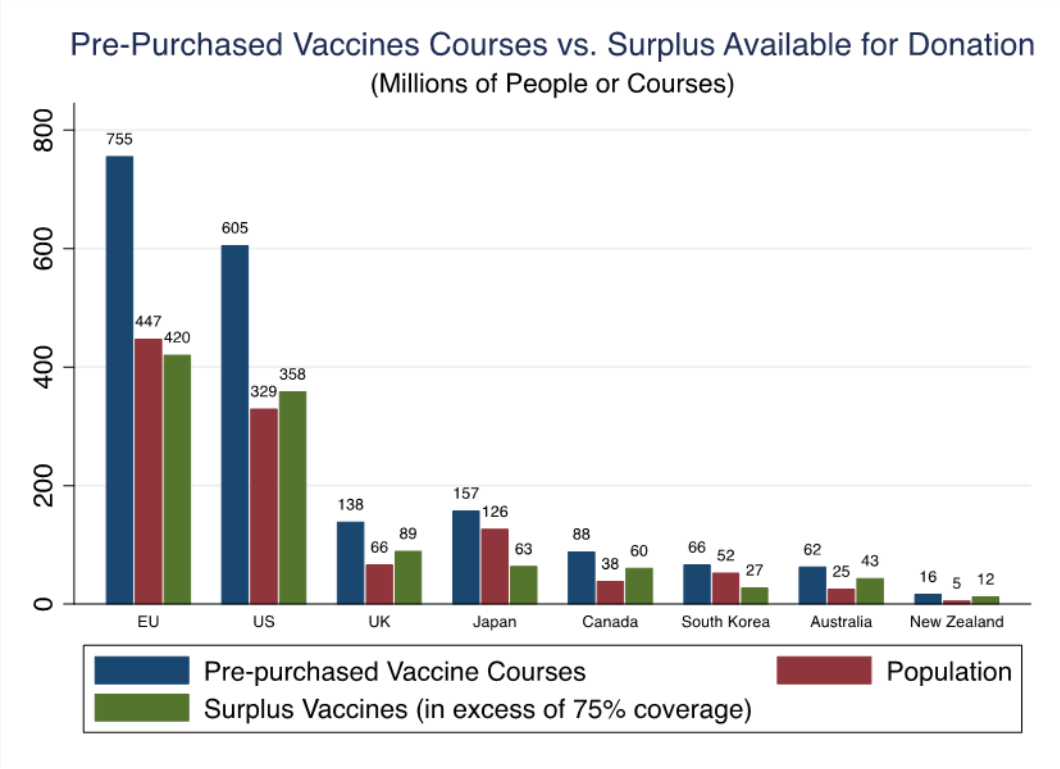
Source and Notes: Authors' calculations. See Annex IV. AMC91 stands for the group of 91 low- and middle-income countries (excl. India) that are eligible to access the COVAX AMC facility. Other LMIC refers to the group of low- and middle-income countries excluding India, China, and AMC91 countries. HIC refers to high-income countries as per World Bank income classifications. The bars report the fraction of population fully vaccinated within the country group, under different scenarios.

Figure 5: End-2021 Vaccine Coverage under Different Upside Scenarios



Source and Notes: Authors' calculations. See Annex IV. The bars report the fraction of population fully vaccinated within the country group, under different scenarios.

Figure 6: Pre-Purchased Vaccines Courses vs. Surplus Available for Donation



Source and Notes: Duke Global Health Innovation Center (2021); Authors' calculations.

Table 1: Core Elements of the Global COVID-19 Action Plan

Core Elements of the COVID-19 Pandemic Proposal

Actor	Measures	2021			2022				Financing Gap for LMICs and Global Public Goods (Billions $)		
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Total (A + B)	Of which Grants (A)	of which Concessional Financing (B)
National Authorities	Maintain social distancing, masking, and other public health measure; Encourage rapid uptake of tests, therapeutics, and PPE								4	2	2
	Procure adequate supply of tests, treatments, and PPE; Expand hospital capacity for COVID-19 patients								20	15	5
	Prepare to scale up vaccine deliveries and uptake (incl. storage, and transportation issues, prepare systems for prioritized vaccines, fight disinformation on social media, and fast track emergency use authorization)								6	2	4
	Invest in and maintain genomic surveillance for Sars-COV-2 variants								3	2	1
Governments with Manufacturing Capacity	Facilitate cross-border voluntary licensing and technology transfers with the aim of creating regional manufacturing capacity around the world								1	–	1
	Undertake surveillance of systemic supply chain risks to ensure availability of critical raw materials and supplies (in collaboration with multilateral agencies, other countries, and vaccine manufacturers)								< 1	–	< 1
	Prepare and regularly update contingency plans to shift production capacity between vaccine candidates if downside risks materialize										
Vaccine Developers / Regulatory Authorities	Conduct trials to evaluate efficacy against new strains, potentially financed by donor grants								2	1	1
	Develop booster or multivalent shots to protect against possible new variants (if needed)										
	Urgently evaluate and where approved implement dose stretching strategies, potentially financed by donor grants										
Multilateral Agencies	Scale up utilization of existing pandemic lending facilities; convert grant pledges to up front cash contribution								< 1	< 1	–
	Conduct global surveillance of systemic supply chain risks in vaccine production; prepare contingency plans based on scenario planning										
	Ensure LMIC vaccination will not be crowded out due to new HIC needs (e.g. booster doses, youth vaccination, etc.)										
G20 / Donor Countries	Provide upfront cash grant of $4 billion to COVAX; Plus additional grant and concessional financing for vaccine procurement as needed								6	5	1
	Make at-risk investment to expand vaccine manufacturing capacity to address downside risks and/or long-term needs of LMICs								8	8	–
	Donate at least 500 million courses (or, equivalent to 1 billion doses) of surplus vaccines in 2021 *								–	–	–
	Commit to maintaining free export of vaccine supplies and final products								–	–	–
Total Needs									**≈ 50**	**≈ 35**	**≈ 15**
Unutilized Lending Facilities and Donor Pledges Under Consideration *										**22**	**15**
Additional Needs										**13**	–

Notes: Darker cells correspond to greater importance of the measure in the given quarter. While our budgeting exercise attributes a zero additional cost for in-kind donations of surplus vaccinations since much of the procurement is sunk cost, there is a strong case to count donations to the COVAX-AMC facility as official development assistance (ODA). The unutilized financing from lending facilities is based on the World Bank and Asian Development Bank pandemic lending facilities. The grant funding gap identified by the Access to COVID-19 Tools (ACT) Accelerator amounts to about $22 billion, which the G20 recognizes as important to address. See Annex VI for details.

Table 2: Efficacy of COVID-19 Vaccines Against Different Variants

Efficacy of COVID-19 Vaccines Against Different Variants

Variant	Place first idenified	Vaccines	Lab Studies	Randomized Clinical Trials	Real World Evidence
B.1.1.7	U.K.	Novavax, Pfizer/BioNTech, Moderna, AstraZeneca	✓	✓	Israel, U.K., Qatar
B.1.351	South Africa	Novavax, J&J, Pfizer/BioNTech, Moderna	✓	✓	Qatar
P.1	Brazil	Sinovac, Sinopharm, Pfizer/BioNTech, Moderna	✓	✓	Chile, Brazil
B.1.526	New York	Pfizer/BioNTech, Moderna	✓	–	New York (CDC)
B.1.429	California	Pfizer/BioNTech, Moderna	✓	–	California, Colorado
B.1.617	India	Bharat, Pfizer/BioNTech, Moderna	✓	–	Israel

Source and Notes: Abdool Karim (2021), Abu-Karim (2021), Madhi (2021), and compiled by Eric Topol (2021), based on data available as of early May 2021. A check corresponds to efficacy of at least 50 percent in clinical trials.

Table 3: U.S. Vaccine Landscape and Estimated Surplus Doses for Donation

United States COVID-19 Vaccines Landscape and Estimated Surplus Doses for Donation
(Millions)

	Pre-Purchased Doses	Projected Use to Cover 85% of Population	Estimate of Surplus Doses	of which stockpiled and available for donations (based on current production forecasts)	
	(A)	(B)	(A - B)	As of April 2021	As of August 2021
AstraZeneca/Oxford	300	0	300	20	100
J&J	200	18	182	60	115
Novavax	100	0	100		50
Pfizer/BioNTech	300	286	14		14
Moderna	300	235	65		65
	1200	540	660	80	344

Sources and Notes: CDC, Authors' calculation, various company and media reports. See Annex III for details.

ANNEX I: EXISTING PANDEMIC FINANCING OPTIONS FOR LMICS

This annex describes some of the existing financing options and regional deals made available to LMICs for vaccine procurement and other needs in response to the pandemic.

Regional Advance Market Commitments (AMC) or Production Deals for COVID-19 Vaccines

COVAX AMC. Gavi is coordinating the implementation of the COVAX Facility. The COVAX Facility has been making investments across a broad portfolio of vaccines (including those being supported by CEPI) to make sure at-risk investment in manufacturing happens ahead of time. Further, Gavi is coordinating the development and implementation of the COVAX AMC, the financing instrument supporting the participation of 92 lower-middle and low-income economies in the COVAX Facility. The group of countries with access to COVAX is known as AMC92, or AMC91 + India. The COVAX AMC takes a tailored approach to India, given that India accounts for 17 percent of the world population (or about 35 percent of the total AMC92 countries' population). Correspondingly, the near-term aspiration of the COVAX AMC is to provide minimum vaccine coverage of 20 percent of the population in AMC91 countries, and about 7-9 percent coverage for India. Gavi is also working with Alliance partners UNICEF and WHO to ensure that the infrastructure is in place, and the technical support available, to make sure COVID-19 vaccines can be safely delivered to all those who need them. Gavi is also part of the health systems work of the ACT-Accelerator effort, focusing on areas where it has expertise and experience, such as cold chain. As of May 5, 2021, total donor pledges to the COVAX AMC amounted to $6.7 billion, plus nearly $1 billion in commitments for vaccine delivery and/or logistics. Further the United States has pledged to match other donors by pledging an additional $2 billion through 2021 and 2022, of which the first $500 million will be made available when existing donor pledges are fulfilled and initial doses are delivered to AMC countries.

African Union. In a COVID-19 vaccine procurement Agreement signed on 28 March 2021, all African Union Member States, through the African Vaccine Acquisition Trust (AVAT) set up in November 2020 will have access to 220 million doses of the Johnson & Johnson single-shot COVID-19 vaccine, with the potential to order an additional 180 million doses. The transaction was made possible through the $2 billion facility approved by the African Export-Import Bank (Afreximbank). On January 19, 2021, the Afreximbank approved a $2 billion financing facility for purchase of COVID-19 vaccines by African Union member states. Afreximbank will facilitate payments by providing advance procurement commitment guarantees of up to US$2 billion to the manufacturers on behalf of the Member States. This deal offers vaccine coverage of 18-32 percent to the roughly 1.25 billion people in the African Union.

Latin America – AstraZeneca deal. AstraZeneca has signed an agreement with Argentina, and Mexico for licensing agreements to manufacture the vaccine domestically and supply to Latin American countries (excluding Brazil). The Argentina and Mexico deal took place between AstraZeneca and the biotechnology firm mAbxience, with funding from the Carlos Slim Foundation. The deal is expected to produce approximately 150 million doses in 2021 and up to 250 million doses in 2022 to distribute across Latin America and the Caribbean. As part of the deal, the vaccines will be manufactured in Argentina with part of the fill-finish process conducted in Mexico.

Existing Financing Facilities for Procurement of COVID-19 Vaccines, Tests, & Treatments

World Bank. On October 13, 2020, The World Bank's Board of Executive Directors approved an envelope of $12 billion for developing countries to finance the purchase and distribution of COVID-19 vaccines, tests, and treatments for their citizens. As of April 20, 2021, about $2 billion of the $12 billion had been approved for 17 countries.

Asian Development Bank. On December 11, 2020, the Asian Development Bank (ADB) has launched a $9 billion vaccine initiative—the Asia Pacific Vaccine Access Facility (APVAX)—offering rapid and equitable support to its developing member countries for the procurement and effective delivery of COVID-19 vaccines.

Much of the existing pandemic lending facilities remain unutilized, suggesting scope to make adjustments to further scale up these facilities. In line with the limited uptake thus far, we have not called for additional lending facilities for vaccines, which can be considered if there is an increase in the utilization of the existing facilities.

Broader Financial Safety Net for General Financial Support (IMF, World Bank, MDBs)

Beyond the aforementioned vaccine-specific facilities that provide effective grant financing and concessional financing for the procurement of vaccines, the IMF, World Bank, and other multilateral development banks have rapidly deployed financing for budget support, balance of payment needs, and more generally to strengthen the global response to the pandemic (including through grants and concessional financing). A full review of these facilities is beyond the scope of this paper.

ANNEX II: UNIVERSE OF LMICS AND THEIR COVERAGE BY AFRICAN UNION OR COVAX AMC

In this annex we provide some details about our cross-country vaccine coverage calculations. It is useful to split the global population into the following groups: (i) members of the 91 LMICs that have access to the COVAX AMC (also called the AMC91 countries), (ii) members of the African Union that have access to the vaccines procured under AVAT, (iii) India (which also has access to the COVAX AMC and is included in the broader group AMC92), (iv) China, and (v) other upper middle-income countries (see table below). We discuss vaccine coverage for each of these groups in turn.

The COVAX AMC currently aspires to provide a minimum vaccine coverage to 20 percent of the population in AMC91 countries, and between 7-9 percent coverage to India (which has reduced access relative to other COVAX AMC countries due to its large size, with the allocations for India capped at 20 percent of total AMC allocations). Under our proposal and as per our calculations, additional grants of $4 billion for the COVAX AMC will be sufficient to raise the minimum vaccine coverage for COVAX AMC91 countries to 30 percent, and for India to about 14 percent (using existing Gavi rules for allocation).

Further, the existing J&J deal with AVAT, facilitated by financing from the Afreximbank, ensures a coverage of up to 32 percent of the population in African Union member countries. Of the 55 African Union member states, 46 also have access to the COVAX AMC, ensuring a minimum coverage of 60+ percent for this set of countries. The other 9 member countries are classified as high income or upper middle income, and some of them (e.g., South Africa) have sizable bilateral deals.

After accounting for coverage through African Union and the COVAX AMC as per our proposal, most AMC91 countries end up with a coverage over 60 percent. Some remaining countries will still need additional pre-purchases totaling about 100 million courses based on publicly available contract details. However, existing data sources (e.g., Airfinity or the Duke Global Health Innovation Center) as of now do not contain coverage of some sizable vaccine contracts (e.g., with Chinese vaccine developers and with Sputnik V) that suggest that residual needs are likely to be smaller. Nevertheless, to be conservative we allocate about $1 billion in grant funding to potentially cover these residual needs for AMC91 countries.

As for India, it continues to face production bottlenecks, including due to ongoing shortages of critical raw materials, suggesting the need for further relaxation of de facto export restrictions under the U.S. Defense Production Act. Despite such near-term constraints, as of mid-May 2021, the authorities estimate that over 2 billion doses will be available by the end of the year based on

company-level supply projections publicly shared by officials. Therefore, while current pre-purchases of vaccines plus coverage from the COVAX AMC remains around 25 percent, the authorities intend to meet the residual needs through the additional production. To reach a coverage of 60 percent of the population, India will need to order roughly 1 billion doses of additional vaccines (a small subset of which can be met by the increased COVAX AMC coverage under our plan). Given the authorities are expected to comfortably use domestic resources for meeting these residual needs and are not seeking external financing for these purposes, we do not allocate additional funds for India in our budgeting exercise. (The authorities are currently pursuing a strategy of procuring vaccines for those above 45 years of age by the central government, while enabling states to procure vaccines for those aged 18-44. Given the current vaccine pricing offered by domestic suppliers, and the estimated size of the younger population in India, the *additional* funding needs for the center for covering the 18-44 population is approximately 0.25 percent of GDP, suggesting that there is scope for the government to handle the entire procurement centrally.)

As for China, it has substantial domestic production capacity, despite limited formal supply contracts as per publicly available information. China's vaccination is proceeding at record speed as of mid-May, with China administering about 10 million doses daily (or 0.7 per 100 people). China is on track to vaccinate its adult population by end-2021, and has adequate domestic resources to meet residual vaccine costs.

This leaves the group of 35 countries that constitute other upper middle income countries. Among this group is Russia which has significantly larger domestic production capacity than existing pre-purchase orders, and Brazil that has vaccine coverage from pre-purchases exceeding its population. Overall, many of these countries have vaccine coverage of greater than 60 percent due to bilateral or other contracts. Based on publicly available data they need about 100 million additional courses to reach a minimum 60 percent coverage in each country. However, this does not account for several production deals such as the AstraZeneca-Latin America deal to deliver 150 million doses in 2021, or for hidden contracts. Further, given the upper income status of these countries, and given that most of these countries have not sought external financing for procuring vaccines we do not allocate additional funds for these countries in our pragmatic budgeting exercise. This choice is also justified by the low uptake of existing pandemic lending facilities made available by the World Bank and the ADB, which suggests that external financing needs for vaccine procurement beyond the AMC91 countries remain minimal.

Distribution of 6.5 Billion People in Low- and Middle-Income Countries based on Coverage by African Union or COVAX AMC

<table>
<tr><td>AMC91 countries but not Members of African Union (Pop. 1.3 bn)</td><td rowspan="3">AMC91 Countries also Members of African Union
(Pop. 1.2 bn)</td></tr>
<tr><td>India (Pop. 1.4 bn)
(also has access to the COVAX AMC)</td></tr>
<tr><td>China (Pop. 1.4 bn)</td></tr>
<tr><td>Other Upper Middle Income Countries (Pop. 1.1 bn)</td><td>AU but not AMC91 (0.08 bn)</td></tr>
</table>

AMC91 Only (45)	African Union Only (9)	AMC91 & African Union (46)	Other UMCs (35)
Afghanistan	Botswana	Algeria	Albania
Bangladesh	Equatorial Guinea	Angola	Argentina
Bhutan	Gabon	Benin	Armenia
Bolivia	Libya	Burkina Faso	Azerbaijan
Cambodia	Mauritius	Burundi	Belarus
Dominica	Namibia	Cabo Verde	Belize
El Salvador	Seychelles	Cameroon	Bosnia & Herzegovina
Fiji	South Africa	Central African Republic	Brazil
Grenada	Western Sahara	Chad	Bulgaria
Guyana		Comoros	Colombia
Haiti		Congo, Dem Rep	Costa Rica
Honduras		Congo, Rep	Cuba
Indonesia		Cote d'Ivoire	Dominican Republic
Kiribati		Djibouti	Ecuador
Korea, Dem People's Rep		Egypt, Arab Rep	Georgia
Kosovo		Eritrea	Guatemala
Kyrgyz Republic		Eswatini	Iran
Lao PDR		Ethiopia	Iraq
Maldives		Gambia, The	Jamaica
Marshall Islands		Ghana	Jordan
Micronesia, Fed Sts		Guinea	Kazakhstan
Moldova		Guinea-Bissau	Lebanon
Mongolia		Kenya	Malaysia
Myanmar		Lesotho	Mexico
Nepal		Liberia	Montenegro
Nicaragua		Madagascar	North Macedonia
Pakistan		Malawi	Paraguay
Papua New Guinea		Mali	Peru
Philippines		Mauritania	Russia
Samoa		Morocco	Serbia
Solomon Islands		Mozambique	Suriname
Sri Lanka		Niger	Thailand
St Lucia		Nigeria	Turkey
St Vincent and the Grenadines		Rwanda	Turkmenistan
Syrian Arab Republic		Sao Tome and Principe	Venezuela
Tajikistan		Senegal	
Timor-Leste		Sierra Leone	
Tonga		Somalia	
Tuvalu		South Sudan	
Ukraine		Sudan	
Uzbekistan		Tanzania	
Vanuatu		Togo	
Vietnam		Tunisia	
West Bank and Gaza		Uganda	
Yemen, Rep		Zambia	
		Zimbabwe	

Notes: The list includes all countries classified as low- and middle-income countries (LMICs) as per World Bank income classifications, plus two high-income countries (HICs) that are part of the African Union, Seychelles and Mauritius. In addition, Bulgaria, which is part of the European Union and therefore covered by its vaccine deals is listed here since it is classified as an upper middle-income country by the World Bank. The total population of LMICs is about 6.5 billion. India is eligible to access the COVAX AMC facility and COVAX includes it in their list of "AMC92" countries, but excludes it in the "AMC91" list due to special treatment and a lower vaccine coverage provided to India considering its size.

ANNEX III: CALCULATIONS FOR END-2021 VACCINATION COVERAGE UNDER BAU

The end-2021 vaccine coverage under the business-as-usual scenario is done using the following allocation assumptions. First, countries that already have vaccinated over 20 percent of their population as of end-April 2021, countries that have reached daily vaccination rates of 0.3 percent of the population as of end-April 2021, or high income countries are assumed to achieve 85 percent coverage for their eligible population. The 85 percent coverage threshold accounts for the 15 percent of surveyed adults who are currently unwilling to be vaccinated in select high income countries. The eligible population for each country corresponds to the 15+ population. Note variation in coverage among this group of countries is solely due to the difference in demographics with some countries having a greater share of older eligible individuals than others, leading to greater vaccine coverage as a share of the total population.

Second, the group of 91 low- and middle-income countries (excl. India) called "AMC91" that are eligible to access the COVAX AMC facility, are assumed to receive and administer 60 percent of the sum total of doses they are eligible to receive from either the COVAX AMC facility, African Union, or direct pre-purchases from vaccine developers. The 60 percent number is estimated based on current projected delays in vaccine deliveries. Note that 46 of the 55 African Union members are part of the AMC91 countries.

Finally, the remaining group of countries, are split into a small group of low-income countries not eligible for the COVAX AMC and middle-income countries. Given the relatively low pace of current vaccinations in these two groups, it is assumed that they will achieve a coverage of 25 percent and 55 percent of their eligible population respectively. The 25 and 55 percent numbers are calibrated based on the expected coverage for COVAX AMC countries (for the remaining low-income countries) and the relative speed of current vaccination in middle-income countries compared to the countries expected to that of high-income countries.

Overall, this bottom-up projection method suggests that about 3.5 billion vaccine courses would have been administered by end-2021. A two-dose vaccine equals one course, whereas a one-dose vaccine also equals one course. This bottom-up projection is consistent with our top-down projections based on daily global vaccinations. As of end-April 2021, about 1.1 billion vaccine doses had been administered. In addition, the daily vaccination rate had reached 20 million per day. Taking this current rate of daily vaccination as a conservative estimate, it would imply that total vaccines administered by end-2021 could reach about 6 billion doses (i.e. 1.1 billion doses + 245 days * 20 million daily doses = 6 billion doses). Further, taking the J&J estimate of producing 1 billion doses in 2021 we obtain 3.5 billion vaccine courses administered by end-2021, which is identical to our bottom up estimate.

ANNEX IV: END-2021 VACCINATION COVERAGE UNDER DIFFERENT SCENARIOS

The business-as-usual scenario presented in Figures 3 and 5 are based on the methodology presented in Annex I. As for the first downside scenario presented in Figure 3, labeled as 'reduced supply of adenovirus-based vaccines,' it is assumed that 30 percent of global vaccine supply under the baseline is compromised due to a shock to the adenovirus-based vaccines. The developing world is heavily relying on adenovirus-based vaccines, with over 80 percent of vaccine courses in low- and middle-income countries (outside China and India) expected to come from three developers: AstraZeneca, J&J, or Sputnik V. All three share the same platform technology and are thus exposed to similar risks. Further, the supplies of these vaccines are expected to scale up in the second half of 2021. Therefore, the 30 percent number is calibrated to account for the large exposure to adenovirus-vaccines in the global vaccine portfolio. Under this scenario it is assumed that high income countries and China, which have a diversified portfolio of vaccines with excess capacity are able to still meet their needs through alternate vaccine options, while the impact will be entirely borne by other low- and middle-income countries. In particular, it is assumed that India and the AMC91 countries will receive half of the supplies compared to the baseline (given their large exposure to the adenovirus-based vaccines), while the residual impact will be borne by other LMICs.

In the second downside scenario presented in Figure 3, labeled as 'booster doses in HICs crowd out vaccines for LMICs,' it is assumed that vaccine dose needs of high income countries (HICs) increase by 50 percent due to the need for a booster shot (i.e., they will effectively need three shots in 2021 compared to two shots under the baseline). In this scenario, the total vaccine supply is assumed to be unchanged compared to the baseline, and the scenario depicts a case in which the entire crowding out effect is borne by the AMC91 countries. In the dose stretching scenario depicted in Figure 5, it is assumed that total vaccine production increases by 50 percent in 2021, due to dose stretching strategies. The vaccine coverage would be similar if this increase was due to better-than-expected monthly production. Note that the latest projections by IFPMA suggest that we should expect 10 billion vaccine doses in 2021 under their baseline (or about 5.5 billion vaccine courses after adjusting for single-dose shots). By contrast, the dose stretching scenario presented in Figure 5 amounts is based on 5.25 billion vaccine courses in 2021, suggesting that based on industry estimates both the baseline and the upside scenarios are quite conservative. Finally, the donation scenario in Figure 5 assumes that of the estimated 1 billion courses that are available 50 percent of it will be produced and available for donations by end-2021. We assume that 80 percent of the surplus vaccines will go to the COVAX AMC facility (and allocated as per existing rules to AMC91 countries and India), and the remaining 20 percent surplus allocated to other LMICs, facilitated by COVAX in proportion to their population.

ANNEX V: CALCULATIONS FOR SURPLUS VACCINE DOSES IN THE U.S.

In this annex we describe the numbers presented in Table 2. The pre-purchased doses are based on Operation Warp Speed (OWS) contracts. For the U.S. we estimate an upper estimate of 85 percent of the population to be vaccinated even after allowing for the potential expanded use of vaccinations for those aged 12+. A population coverage of 85 percent allows for the possibility that there is roughly universal coverage for all aged 12 and above.

For AstraZeneca, the current stockpile is estimated to be 20 million doses based on media reports, and the U.S. government has announced that it expects to have 60 million AstraZeneca available for donations by June 2021. Projecting this rate of stockpiling forward we estimate as of end-August they could have up to 100 million doses warehoused and available for donations.

As for Pfizer/BioNTech, the company recently announced that it expects to finalize its contracted delivery of 300 million doses to the U.S. by July 2021. So far about 51 percent of U.S. vaccinations have been using Pfizer/BioNTech, compared to 42 percent using Moderna vaccines, and 7 percent using J&J vaccines. Using this share and projecting forward it is estimated there may not be excess stockpiles available for Pfizer/BioNTech and Moderna as of April 2021. However, once the U.S. has reached its vaccination target in the summer, it will make available about 14 million vaccine surplus doses of Pfizer/BioNTech and 65 million surplus vaccine doses of Moderna, which can be used for donation by August 2021. This is consistent with the recent announcement by the CEO of Pfizer, who indicated that all 300 million contracted doses should be delivered to the U.S. by July.

As for J&J, CDC data indicates that as of April 2021, 18 million vaccine doses had been delivered to U.S. states, of which only 8 million had been administered. As per our estimate the eventual needs of J&J should not exceed 18 million doses (i.e., roughly 7 percent of eventual needs), suggesting that all marginal production can be made available for donation. In this context, media reports suggest that Emergent BioSolutions has already produced more than 115 million doses worth of drug substance for the J&J vaccines, of which 60 million doses are already in vials. These two numbers inform our surplus vaccine estimates for J&J in April 2021 and August 2021 respectively.

Finally, for Novavax, company reports suggest that they have begun producing vaccines to meet their contractual obligation once they receive approval. All the contracted capacity should be available as surplus vaccines, and given limited information on this timing of manufacturing, we estimate half of the contracted 100 million should be available by August 2021.

ANNEX VI: BUDGETING OF THE PROPOSAL

This annex provides details on the budgeting of the action plan presented in Table 1. We use the group of AMC92 countries as a reference group for this exercise that have a population of about 4 billion people—of which about 2.5 billion are in AMC91 countries and about 1.4 billion in India (see Annex II for a list of countries). The motivation for focusing on this group is that most HICs and other upper middle income countries have already made adequate pre-purchases of vaccines to cover over 60 percent of their population, and have relatively greater fiscal resources to meet their domestic needs (as discussed in Annex II). Further, we have made efforts to align our budgeting exercise with the budgeting exercise undertaken by the ACT-A accelerator WHO (2021b), which aims to equitably scale and deliver essential COVID-19 tools to the global community while managing emerging viral risks. The original ACT-Accelerator investment case published in September 2020 outlined a total requirement of US$38.1 billion to fully fund its work. Based on the refreshed strategic priorities outlined above, the Pillars have adjusted their resource needs. Despite generous donor contributions amounting to US$11.0 billion to date, ACT-Accelerator continues to require an additional US$22 billion in 2021 to deliver on its full promise. About $3 billion is currently available as ACT-A pending allocation, leaving the residual funding need to be $19 billion. Ahead of the global health summit to be held in Rome on May 21, 2021, leaders of G20 nations are expected to make pledges to close this gap. We take this into account in our budgeting exercise.

Vaccine procurement. Under our plan we propose the vaccine coverage provided by COVAX to the AMC countries be raised from the current aspiration of 20 percent to 30 percent. This costing estimate builds on the numbers presented in Agarwal and Reed (2021). They quantify that $4 billion more in grant funding for the COVAX AMC (in addition to the existing donor commitment of $6.3 billion) would allow the COVAX AMC to raise its minimum vaccine coverage to about 30 percent of the population of these countries (See Annex II for further discussion). A marginal increase of COVAX coverage with the support of $4 billion in up-front cash contributions will be sufficient to achieve 60 percent vaccine coverage in most low- and middle-income countries. In this context, the United States has already offered to provide an additional $2 billion in grant funding to the COVAX AMC, or half the funds required for this proposal, though this will be released only when other donors have fulfilled their pledges. The details of the calculation are as follows. Gavi estimates for COVAX AMC assume that a vaccine course will cost them between $10-14 (i.e., $5-7 per dose for a two-dose vaccine) with $12 per course being the mid-point of this range. We use the mid-point for our projections. The current aspiration of the COVAX AMC is to achieve a vaccine coverage of 20 percent. Before countries achieve the 20 percent coverage, the cost to the COVAX AMC is assumed to be $12 per course, and $0 to the purchasing country. After the 20 percent coverage is achieved,

we apply a 20 percent cost sharing rule (in line with suggested cost-sharing rules of the AMC), which implies a cost of $9.6 to the AMC and $2.4 to the purchasing country. These pricing assumptions, which are in line with those used by Gavi, imply that an additional grant of $4 billion (beyond the approximately $6.7 billion they have as of early-May 2021) would be sufficient to raise the vaccine coverage to 30 percent. In addition, to help the AMC countries cover the 20 percent cost-sharing, we allocate $1 billion to the AMC countries in terms of concessional financing. Further, as discussed in Annex II, we have also allocated an additional $1 billion of concessional financing for residual needs of countries not accounted for here. If needed, the upfront commitment for donor countries can be reduced further by relying on the International Finance Facility for Immunization (IFFIm) to issue Vaccine Bonds against a long-term donor commitment (or instead by utilizing multilateral financing).

Vaccine delivery. A study by the WHO, Gavi, and UNICEF (2021a) estimate that total financing cost for vaccinating 20 percent of the AMC91 countries will cost about $2 billion or about $3.70 per person vaccinated. This estimate includes costs for technical assistance, outreach and fixed site delivery costs, and up-front costs such as cold chain installation and training. Using their estimates and adjusting for fixed up-front costs (which is about 28 percent of total costs), we arrive at delivery cost of $3 per fully vaccinated individual for the purposes of vaccinating 60 percent of the population. Then, adjusting for the already vaccinated population in these countries, we estimate the vaccine delivery cost of vaccinating 60 percent of the roughly 4 billion people in countries that need support ("AMC91" plus India) will require a *further* $6 billion. COVAX has received commitments from donor countries of about $1 billion for vaccine delivery and costs. In our costing assumptions we estimate that further support from donors in grant form of $2 billion will be needed to aid vaccination plans in low- and middle-income countries (i.e., one-third of estimated additional needs), and allocate concessional financing for the remaining $4 billion.

Procurement of Diagnostics, PPE, and Therapeutics. First, large-scale testing for COVID-19 is needed to monitor where the virus is circulating and the spread of new variants. This requires scaling up testing. At present LMICs are testing roughly 1 in 1,000 per day, while HICs are testing over 3 in 1,000 per day. Under our plan, the goal is to at least triple the rate of testing in LMICs, especially through the use of rapid antigen tests in workplaces, hotspots, etc. This step will enable some economic activity to resume without unduly jeopardizing the public health goals. For our exercise, we take the bulk procurement cost to be $3.5 per test. This pricing is in line with the goal of the ACT-Accelerator WHO (2021b) to expedite the introduction of antigen-detecting rapid diagnostic tests (Ag-RDTs) by reducing the cost to below $2.5 in 2021 (compared to the price ceiling of $5 targeted in 2020). Thus, using $3.5 as a reference price for tests, we estimate that grants of $10 billion should

enable an increase in daily testing from roughly 1 per 1,000 to 3 per thousand in the targeted group of LMIC countries for the 12 months (i.e., 365 days x 4 billion people x 2 / 1,000 * $3.5 ≈ $10 billion). Second, personal protective equipment procurement needs we rely on the ACT-A budgeted of about $6 billion. Third, on procurement needs for therapeutics and oxygen supplies we also rely on the ACT-A budgeted amount of about $3 billion to meet the goal of providing medical oxygen and corticosteroids (e.g., dexamethasone), for up to 12 million severe and critical patients, and introduce new therapies for 100 million treatment courses across all use cases WHO (2021b). Finally, we allow a buffer of $ 1 billion to account for administrative costs and other expenses that are not explicitly accounted for here. The sum total of these procurement costs amounts to $20 billion, for which we allocate $15 billion in grants that is already included in the financing gap calculations of ACT-A and allocate concessional financing for the remaining $5 billion.

Strengthening public health systems to ensure rapid uptake of tests, therapeutics, and PPE. In line with ACT-A we allocate about $2 billion in grants for this item, and supplement that with $2 billion of concessional financing to ensure adequate financing is available to LMICs.*Genomic surveillance.* Countries around the world are already scaling up efforts to improve genomic surveillance. For instance, in April 2021, the U.S. government announced that it plans to send $1.7 billion to the Centers for Disease Control and Prevention (CDC) and local and state governments and to improve the tracking of coronavirus variants, of which $1 billion is allocated for genomic surveillance, and the remainder for infrastructure and other costs. For our plan, given wide uncertainty in the financing required to globally scale up genomic surveillance, we are guided the by ACT-A budgeting exercise which allocates about $2 billion for genomic sequencing to procure sequencing tools and strengthen testing infrastructure in grants. Since the genomic sequencing needs are likely to be greater going forward given the risk of new variants, we allocation an additional $1 billion for this purpose in terms of concessional financing.

Conduct trials to examine dose stretching strategies and to efficacy against new variants. Learning about the effectiveness of such strategies is a global public good, with potentially huge social returns. The private sector may have weak incentives to prioritize such trials (including for fractional dosing, efficacy of single shot regimes for vaccines that are highly effective with two doses, etc.). Based on cost of prior trials, and the global public good nature of these measures, we allocate up to $1 billion for this step, financed by grants from the donor community, and an additional $1 billion in the form of concessional financing.

Voluntary licensing and sharing of intellectual property. Here we allocate about $1 billion, half of it in terms of grant financing, to encourage cross-border deals to increase regional capacity of vaccines in developing countries. This costing envisions more cross-border deals such as the U.S. government

plan to provide a concessional loan to Biological E in India to increase vaccine manufacturing capacity in India by 1 million doses in 2022.

In-kind donations of surplus vaccines. As per the OECD Secretariat's assessment on official development assistance (ODA), contributions to the Gavi COVAX AMC facility are ODA-eligible, since it is an Advance Market Commitment for the development and procurement of vaccines for the benefit of the developing countries (OECD, 2021). Therefore, while our budgeting exercise attributes a zero additional cost for in-kind donations of surplus vaccinations (since much of the procurement is sunk cost), there is a strong case to count donations to the COVAX-AMC facility as ODA—as the donor countries would be providing a major benefit to the developing countries and a significant global public good.

Expanded global manufacturing capacity to address downside scenarios and longer-term needs. Our investment for at-risk purposes and longer-term needs is based on an all-in cost of expanding capacity by 1 billion doses in the first half of 2022, at a total cost of $8 billion. Castillo et. al (2020) estimate that increasing the total supply of vaccine capacity available by 1 billion doses per year could generate nearly $1 trillion in social value. The full details of this costing exercise is provided in Annex VII below.

ANNEX VII: DESIGNING THE AT-RISK INVESTMENT IN VACCINE MANUFACTURING CAPACITY

This annex describes the budgeting and considerations underpinning our proposal of 1 billion doses of at-risk investment on behalf of low- and lower-middle income countries. In particular, our investment for at-risk purposes and longer term needs is based on five principles discussed below.

Equity. As per company-reported data aggregated by Airfinity, projected manufacturing capacity is expected to increase significantly in 2022 with a capacity of over 16 billion doses of COVID-19 vaccines when restricting attention to currently-approved vaccines (including due to expanded capacity in some large LMICs like India, Russia, China, Brazil, and South Africa). For instance, in early May, Pfizer recently raised their production target to 3 billion in 2021 (up from previous target of 2.5 billion doses), and to 4 billion doses in 2022 (up from the previous target of 3 billion doses). Overall global capacity is expected to increase further with additional vaccine candidates gaining approval or authorization in coming months. However, a key risk is that despite sufficient aggregate supply in 2022, we may see a continuation of inequity in access to vaccines with the supplies being made available first to high-income countries or upper-middle income countries. To avoid this risk (and a repeat of vaccine inequity witnessed in 2021) our at-risk investment focuses on preserving capacity for the group of 91 low and lower-middle-income countries (AMC91)—with a population of 2.5 billion—that are most likely to be hurt by ongoing inequity in vaccine access.

Insurance against aggregate risk. A second key question to answer is how much at-risk investments in vaccines do we need for AMC91 countries in 2022. Here we were guided by the size of aggregate shocks to global vaccine supplies in our downside scenarios, and potential longer-term needs of AMC91 countries. One source of longer-term needs is booster shots to address new variants or to enhance durability of immunity. However, it still remains unclear if and when booster doses will be needed. For instance, the U.K. is assessing the possible need for a third COVID-19 vaccine dose for the vulnerable and elderly population later in the Fall. Balancing the dual objective of being pragmatic in terms of seeking grant financing for at-risk investment and securing adequate insurance against downside risks and longer-term needs of AMC91 countries we propose an initial at-risk investment of 1 billion vaccine doses. This capacity will provide an *additional* 40 percent coverage to the AMC91 population (compared to our vaccination target of 60 percent by first half of 2022 under the baseline). Moreover, this capacity would be able to provide nearly double the quantity of booster doses needed for vulnerable or elderly population in AMC91 countries, if the need arises. Further, this investment will complement other efforts to increase country-level investments in vaccine manufacturing capacity.

Portfolio diversification. A third question is which vaccines should be included in the at-risk investments portfolio. As we have discussed in the context of downside risks the developing world

is heavily relying on adenovirus-based vaccines, with a dominant share of their vaccines expected to come from three developers: AstraZeneca, J&J, or Sputnik V. All three share the same platform technology and are thus exposed to similar risks. Thus, safety concerns in this class of vaccines could significantly impact vaccine rollout and exacerbate the cross-country inequality in vaccine access. Further, preliminary evidence suggests vaccines such as the mRNA vaccines (Pfizer/BioNTech and Moderna) and Novavax have high efficacy against several of the variants of concern. The decision for which vaccines to be included in the at-risk investments portfolio should internalize these risks and be guided by the growing scientific evidence on vaccine efficacy against new variants. Considering these factors, we have allocated 50 percent of our at-risk investment budget for the relatively higher-priced mRNA vaccines. Therefore, our pricing assumption is based on $6 per dose for half of the total capacity relying on vaccines such as Novavax (in line with current pricing for COVAX AMC), and a price of $10 per dose for mRNA vaccines (which is in line with their indicative lowest-tier pricing for LMICs). Given that expanding global vaccine manufacturing capacity is a global public good, we allocate 100 percent of this cost to be financed by grants by the donor community. Castillo et. al (2020) estimate that increasing the total supply of vaccine capacity available by 1 billion doses per year could generate nearly $1 trillion in social value.

Speed. It is important that the additional vaccine supplies under our at-risk investments are available in the first half of 2022. Given the estimated lag of up to 9 months to bring additional capacity online (e.g., as suggested by public statements by Moderna), and the potential for repurposing existing capacity (as in the case of the recently-announced joint venture deal on May 8, 2021 between BioNTech and Fosun Pharma to produce 1 billion doses of mRNA vaccines), the additional capacity of 1 billion doses for AMC91 countries could be brought online before the end of the first half of 2022 if contracted with such provisions immediately.

Supply Chain Fragility. Building on inputs from multiple experts, our investment for at-risk purposes and longer-term needs is based on an all-in cost of expanding capacity by 1 billion doses in the first half of 2022. We rely on an all-in cost estimate—instead of contracting solely on capacity with an option to buy doses in the future—both due to the simplicity of this approach and due to the potential increase in reluctance of companies to accept such option contracts as new global capacity comes online in 2022. Correspondingly, our costing is *greater* than the $3 per dose assumed by Ahuja and others. (2021). Moreover, the at-risk investment contracts may need provisions that require the vaccine manufacturers to demonstrate *additional* large-scale manufacturing capacity and augmentation of the supply chain ahead of time (to prevent the risk of delays due to manufacturing problems, supply chain bottlenecks, or raw material shortages).

ANNEX VIII: DATA GAPS IN PANDEMIC SURVEILLANCE

The table below presents a non-exhaustive list of data needs for effective pandemic surveillance (with coverage of several dimensions including disease surveillance, supply chains, financing, and economic aspects) and a preliminary assessment of where data gaps are high.

A Non-Exhaustive List of Data Needs for Pandemic Surveillance (Supply Chains, Genomic, Finance, and Economic)

Type	Unit of observation	Coverage	Suggested Frequency	Level of Detail	Some Existing Data Sources	Current Data Gaps
Vaccine/Therapeutics/PPE Deals						
Committed purchases of vaccines/therapuetics/PPE	Transaction-level data	Global	Daily	Prices, quantities, delivery dates, source and structure of financing, details about penalty or priority clauses, location and other details about manufacturing plants, etc.	Duke Global Health Innovation Center, Airfinity, COVAX	High
Optional Purchases of vaccines/therapuetics/PPE	Transaction-level data	Global	Daily			
Ongoing Negotiations of vaccines/therapuetics/PPE	Transaction-level data	Global	Weekly			
Vaccine Production and Supply Chain Data						
Installed production capacity	Production-stage-level data by location, over time	Global	Weekly	Quantity data (e.g. number of doses per month) by stages of production (e.g., fill-finish) and complementary products (e.g., syringes); intended destination of supplies; and financing information. The database on export restrictions could include types of restrictions by country/region; information on affected supply chains.	Duke Global Health Innovation Center, UNICEF Vaccine Market Dashboard, Airfinity, COVAX, International Trade Centre Market Access Map	High
Actual production	Production-stage-level data by location, over time	Global	Weekly			
Planned production capacity	Production-stage-level data by location, over time	Global	Weekly			
Repurposable capacity (contingency plans)	Production-stage-level data by location, over time	Global	Monthly			
World trade data on vaccines/therapeutics	Transaction-level data	Global	Weekly			
Export restrictions database	Therapeutics, PPE	Global	Weekly			
Vaccine/Diagnostic/Healthcare Delivery Systems						
Cold chain capacity, testing facilities, and healthcare delivery systems	By delivery platform/system and location	Global, regional	Monthly	Assessment of preparedness, information on capacity by delivery platform/systems	WHO, World Bank	Medium
Aggregation of Information and Risk Monitoring						
Systemic Supply Chain Surveillance Report	Critical Inputs (e.g., bags, filters), complementary products; capacity by stage	Global, regional	Weekly	The systemic supply chain surveillance report could contain monitoring of risks at micro- and aggregated-level, including based on scenario and geographic analysis	N.A.	High
Stockpiles and Donations Data						
Stockpiles	By vaccine/therapeutics/critical inputs, for each country and over time	Global	Weekly	Quantities, types of vaccines/therapeutics, source and destination information, date of dispatchment, planned vs. actual	National authorities	High
Product donations (vaccines, therapeutics, PPE, etc.)	By vaccine/therapeutics/critical inputs, for each country and over time	Global	Weekly			
Research & Development						
Clinical trials	Trial-level data	Global	Daily	In line with current reporting guidelines for scientific studies and patent databases. The database of approvals should contain information about type of regulatory approval, demographic coverage, safety/efficacy considerations, etc.	U.S. National Library of Medicine (clinicaltrials.gov), ICTRP, Chinese Clinical Trial Registry, EU Clinical Trials Register, WHO Landscape and Tracker of COVID-19 Vaccines, WHO Research Database, WHO C-TAP, WIPO IP Policy Tracker, Stanford Antiviral & Resistance Database, Metaevidence.org, MedsPaL	Low/Medium
Lab or other studies	Study-level data	Global	Daily			
Patents and intellectual property	Patent level data	Global	Weekly			
Database of approvals	Vaccine-level data by jurisdiction; planned and actual	Global	Daily			
Database of open questions	By topic	Global	Weekly			
Disease Surveillance						
Mortality rates, disease burden, and lab-confirmed cases	By geography over time	Global, sub-national	Daily	Confirmed cases, hospitalizations, ICU usage vs. capacity, deaths, variant types, type and purpose of tests (e.g., agRDT vs. molecular, border screening vs. workplace), etc.	National authorities, CRVS databases, WHO, JHU coronavirus resource center, Our World in Data, IHME, GISAID, CDC, Nextstrain.org, Malani et al., etc., FIND	High
Vaccine delivery	By geography over time	Global, sub-national	Daily	Rate of vaccination by types of vaccines, first vs. full vaccination, demographics		
Within-country and cross-country vulnerability index	By geography over time	Global, sub-national	Daily	Highlight risk of rising cases at local level using a predictive-approach to guide public health measures and allocation of scarce resources		
Genomic sequencing	By geography over time	Global, sub-national	Daily	For variants of concern and variants of interest; supplemented by clinical and epidemiological data incl. through partnership with commercial diagnostic labs, universities, etc.		
Donor Contributions, Grants, and Multilateral Financing						
Existing contributions	By donor/agency, over time	Global	Daily	Financing details, type of support, eligibility criteria, utilization of existing facilities, etc.	National authorities, WHO, COVAX, World Bank, ADB, IMF, Devex, etc.	Low/Medium
Financing Facilities	By donor/agency, over time	Global	Daily			
R&D/manufacturing	By country, type of support	Global	Weekly			
Residual Funding Needs	By donor/agency, over time	Global	Daily			
Economic, Social & Health Impact and Public Health Measures						
Database of fiscal, monetary, financial support	By geography over time	Global	Weekly	Types of measures/support/impact by date and location	IMF Policy Response Tracker, IMF Fiscal Policy Database, World Bank COVID-19 Dashboard, Oxford Govt. Response Tracker	Low/Medium
Household, poverty, and other impact	By geography over time	Global	Weekly			
Database of non-pharmaceutical interventions	By geography over time	Global	Weekly			

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