COVID-19 futures: a framework for exploring medium and long-term impacts

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Research in context

Evidence before this study

Although the trajectory of the COVID-19 pandemic cannot be predicted, it is likely that it will continue over several years. Long-term planning will therefore be critical. The initial response in policy and academia, however, has largely focused on building the scientific knowledge base for the short-term response. There has been little attention devoted to exploring the combined biological, social, behavioural and economic of COVID-19. We used PubMed to compare searches for [COVID + long-term -(long-term conditions)] (508 results) and [SARS-Cov-2 + long-term -(long-term conditions)] (337 results) with those for [COVID] (39,412 results) and [SARS-CoV-2] (23,295 results). Using these search criteria we found that only 1·3% (COVID) and 1·4% (SARS-CoV-2) of papers in PubMed considered long-term issues.

Added value of this study

We describe a framework to explore four possible biological 'futures' of the COVID-19 pandemic over the next five years, examining how each could combine with different social, political and geographical contexts. This framework will support and provoke others to take a longer-term view that moves us towards the global actions needed to reach equitable future outcomes, and to better prepare for future pandemics.

Implications of all the available evidence

These possible futures show that COVID-19 will be with us for a long time and will have multi-layered consequences. The futures highlight the importance of a strong global response to mitigate the profound, long-lasting and inequitable negative impacts on the world's health, economy, politics and societies.

Progress on vaccines and antivirals will be central to moderating the impact of COVID-19. To control and reduce the impact of COVID-19 it will be important to pool the costs and risks of high quality R&D and manufacturing capacity, as well as to deliver these products effectively and equitably to those who need them. Designing and implementing non-pharmaceutical interventions based on evidence from the social sciences will also be critical.

The futures emphasise that the ability to deliver public health interventions is a key factor in the effectiveness of the pandemic response. Regional, national and local approaches are essential to implement sustainable and locally-owned solutions that account for the strengths and fragilities of any given context, and must complement the global response.

Abstract

Background
Considering the possible trajectories of the COVID-19 pandemic is important to inform both short- and long-term responses and to prepare for pandemics of the future. We describe a framework to explore four possible futures of the COVID-19 pandemic over the next five years, examining how each could play out globally.

Methods
We have defined four futures based on the biology of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its human host, and the scientific responses to it. Rather than predictions, these futures represent plausible possibilities and are used as a framework to help explore what could happen. To investigate the impacts of these four futures in a global context we created five archetypal settings with different social, economic, and political characteristics. We overlaid the four futures across the five settings, taking into consideration how SARS-CoV-2 may spread, and behavioural, political and economic factors.

Findings
SARS-CoV-2 is not globally eradicated within five years in any of these futures, although community transmission could be eliminated within certain national boundaries. Some people and settings are disproportionately adversely affected due to existing and emerging vulnerabilities, but nowhere is unaffected, and all areas are susceptible to the arrival of new infections whilst there are ongoing outbreaks elsewhere. Countries face their own challenges and choices as the world learns to live with COVID-19, particularly in how vaccines, antivirals and non-pharmaceutical interventions (NPIs) are deployed.

Interpretation
More broadly, we explore the profound and long-lasting ways in which the pandemic and response to it will shape the world's health, economy, politics and societies. We identify critical lessons learned from these futures so that the profound disruption of COVID-19 can be used as an opportunity to learn, reform and act to create better global outcomes.

Funding
The collaborators in this project did not receive specific funding.

Introduction

We can't predict the future of the COVID-19 pandemic, but the short- and long-term responses to it can be informed by considering its possible trajectory. Such a thought experiment also helps us to prepare for other epidemics and pandemics; threats that are expected to become more common and more complex in response to such factors as human-animal interactions, changing environments and land use, increasing urbanisation and travel.[1]

We describe a framework to explore four possible futures of the COVID-19 pandemic over the next five years, examining how each could combine with different social, political and geographical contexts. As well as informing the immediate response, we hope that this framework will support and provoke others to take a longer-term view that moves us towards the global actions needed to reach equitable future outcomes.

Methods

Defining futures based on biological and medical factors
We have defined four possible futures for COVID-19 looking five years ahead. To create these futures we considered a range of possible best, middle and worst cases for different aspects of virus and host biology (e.g., emerging levels of immunity), and possible medical interventions (particularly vaccines and antiviral drugs). Importantly, the four futures describe a set of possible outcomes, although the factors considered could combine in other ways, leading to better or worse outcomes than those we discuss. The key features of these alternative trajectories are summarised in below and in Table 1. The full range of variables is set out in Table S1.

(i) Future 1 - "Vaccines work, antivirals fail": Strong natural immunity after infection and moderate interaction with other diseases. Vaccines are produced relatively rapidly with long-lasting immunity, but no effective antiviral is developed. There is no change in virus virulence over time. Seasonality develops.
(ii) Future 2 - "Antivirals work, vaccines fail": Very limited natural immunity after infection and moderate interaction other diseases. Multiple effective antivirals are developed, but no effective vaccine. Widespread evolution means antivirals need regular updating, but there is no change in virus virulence over time. Seasonality develops.

(iii) Future 3 - “Medical interventions are effective and evolution works for us”: Some natural immunity after infection and limited cross-protection from other pathogens. Moderately effective vaccines and antivirals are produced but doses are limited. Virulence declines over time. Seasonality develops rapidly.
(iv) Future 4 - “Medical interventions fail and evolution works against us”: Very limited natural immunity after infection. No effective vaccines or antivirals are developed. Virulence increases over time and new transmission routes evolve. No seasonality develops.

Global context: creating archetype settings
To explore the impacts of these four futures across social, political and geographical contexts, we created five archetypical settings with different social, economic and political characteristics (Table 2).

These settings are illustrative and do not represent every possible context. There are important components that cannot be adequately captured in this simplified approach, for example differences in governance structures and the nature of local inequities. Similarly, the various characteristics defined could be combined differently. Since local variation will likely significantly enhance or limit the response, we do not expect that every country type is represented or will respond in the same way as the archetype to which it may be closest, and there will be significant outliers.

Combining the biological futures and the archetype settings
We overlaid each of the four biological and medical futures with the five archetype settings, taking into consideration how SARS-CoV-2 may spread (Tables S2(a)-(d)).

Three typical characteristics of disease spread (in the absence of interventions) informed this exercise:
- Global connections: More globally connected areas will have earlier outbreaks and are more vulnerable to repeated outbreaks.
- Community contact: The more contact between individuals in a community, the more rapidly the infection will spread. Three important factors are considered: the degree of proximity to others, the type and setting of social activities that bring an individual into contact with others, and the length of potential exposure. This will be influenced by socio-cultural and behavioural factors, as well as population density and mobility.
- Older people: Where there is a greater intergenerational mixing, older people are more likely to be infected. Where multiple generations share a household, it is also harder to reduce older people’s exposure, even during a lockdown.

These characteristics are often correlated and may reinforce each other, for example global connectivity and high community contact in global cities. This explains why densely-populated international hubs, such as London and New York city saw early and relatively large outbreaks. Rural areas that are more sparsely populated and have fewer connections are likely to experience later outbreaks. While these characteristics of epidemics commonly hold across different outbreaks, the scale of policy and behavioural responses to COVID-19 adds complexity.

We also considered socio-behavioural, economic and political factors, and the interdependencies between them, to inform this exercise:
- Socio-behavioural responses: People will respond to the outbreak of an epidemic on their own, with or without a response from government (e.g. additional handwashing, not attending restaurants or avoiding large gatherings). The extent to which people will alter their behaviours and practices (how, when and why) depends on factors including what information they have about the outbreak and their level of trust in that information, their perceptions of risk, their willingness, ability or agency to adopt measures such as physical distancing, or remote working. The relationship between individual behaviours and collective behaviours is important.
- Economic factors: How people behave affects the economy, and in turn economic factors influence people’s behaviour. Lockdowns have adversely affected the global and national economies, exerting pressure on individuals to return to work, particularly where savings buffers are lower, and potentially elevating their risk of transmission. The slowdown in the global economy makes it more difficult to enforce NPIs. However, people might also put themselves into voluntary lockdown, adversely affecting the economy, if they feel unsafe.
- Political factors: Government policy and its implementation is influenced by the political system and its stability, legitimacy of government institutions, strength of political parties and civil society, interactions between national and local governance, and issues of public authority. How a population behaves influences the need for government policy, while policy can have a direct impact on the population (e.g. financial incentives). In turn, their response determines how effectively a policy (e.g. physical distancing) is implemented. The clarity of message and level of trust in government are important in determining how people engage with government guidance.

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Table 1: Summary of key parameters relating to the biology and host interactions of SARS-CoV-2, and developments in vaccines and anti-viral drugs.
Each possible future is a combination of best (no shading), middle (light grey shading), and worst (dark grey shading) case scenarios. Details are provided in the supplementary Information.

Biological Feature	Future 1 "Vaccines work, antivirals fail"	Future 2 "Antivirals work, vaccines fail"	Future 3 "Medical interventions are effective and evolution works for us"	Future 4 "Medical interventions fail and evolution works against us"
Immunity	• Strong and long-lasting immunity after infection. • Immune individuals can be identified through robust biological indicators. • Possible immunological cross-protection.	• Very limited natural immunity after infection. • Reinfection possible after less than a year. • Antibody-dependent enhancement. • exacerbates disease.	• Some protective immunity, but this is variable and wanes after around two years. • False positives make identification of immune individuals unreliable. • Possible weak immunological cross-protection.	• Very limited natural immunity after infection. • Reinfection possible after less than a year. • Antibody-dependent enhancement. exacerbates disease.
Vaccines	• Vaccine developed in 12 months. Fully protective and long lasting (~5 years). • Relatively easy and quick to produce in large quantities. • No antibody-dependent enhancement.	• No effective vaccine developed in the next 5 years because of a lack of protective immunity. • Antibody-Dependent Enhancement and/or other negative consequences.	• Vaccines developed providing partial protection developed in 18-24 months. • Takes several months to produce so limited doses and global supply chain issues.	• No effective vaccine developed in the next 5 years because of a lack of protective immunity. • Antibody-Dependent Enhancement and/or other negative consequences.
Antivirals	• No effective antiviral identified in the next 5 years.	• Multiple effective antivirals are developed that are easy to produce. • Antiviral resistance emerges after first year.	• A limited number of partially effective antivirals developed over the next 12 months. • Some supply chain issues.	• No effective antiviral identified in the next 5 years.
Antigenic evolution	• No large-scale antigenic evolution/escape in the virus, even following widespread vaccination.	• Widespread and rapid antigenic evolution, even before the onset of widespread vaccination. • Reinfection possible on short time-horizons. • Vaccines need to be updated annually.	• No large-scale antigenic evolution/escape in the virus, even following widespread vaccination.	• Widespread and rapid antigenic evolution, even before the onset of widespread vaccination. • Reinfection possible on short time-horizons. • Vaccines need to be updated annually.
Evolution in virulence, transmission and seasonality	• Virulence stays as it is now. • Transmission increases in younger cohorts. • Develops into a winter seasonal disease after 12-24 months.	• Virulence stays as it is now. • Transmission increases in younger cohorts. • Develops into a winter seasonal disease after 12-24 months.	• Virulence declines over 12 months with no increase in transmissibility. • The use of vaccines and antivirals further reduces virulence. • Develops into a winter seasonal disease within 12 months.	• Virulence increases over the next 12 months. • Virulence increases in younger cohorts. • New transmission routes emerge. • No seasonality evolves.
Interaction with other pathogens and/or co-morbidities	• Some interactions with other pathogens in some populations increase COVID-19 morbidity / mortality.	• Some interactions with other pathogens in some populations increase COVID-19 morbidity / mortality.	• Possible weak cross-protective immune responses.	• Interactions with pathogens commonly circulating in some populations increase morbidity / mortality.

Table 2: Characteristics of five settings
Summarising hypothetical characteristics of five archetypal settings

	Globalised high-income country	Mid-income country	Stable low-income country	Chronic conflict zone	Refugee camp
Economy	• Globalised open economy	• Partly globalised open economy • Developing market	• Emerging fragmented market and informal economy	• Low income country	• Reliant on international aid
Governance	• Stable democratic government • High levels of public trust in government • High state capacity to deliver essential public services • Strong, independent media, broadly reliable information	• Relatively stable democratic government, sometimes with autocratic tendencies • High levels of public trust in government from most demographics • Mid-level state capacity to deliver essential services • Strong media, often controlled by special interests; disinformation common	• Flawed, but largely stable democracy • Low public trust in government • Low state capacity to deliver essential services • Weak media, controlled by special interests; disinformation rampant	• Flawed democracy • Unstable governance with pivotal non-state actors • Strong military presence • Widespread distrust of government • Very limited state capacity • Very little media; disinformation rampant	• No state capacity to deliver essential services and raise revenue • Reliance on media in other countries with sporadic interest in the situation
Demography	• At least one large, densely-populated, highly globally connected city • Comparatively well-connected rural areas that are sparsely populated • Small immediate family households • Ageing population • High interpersonal trust and life satisfaction	• Includes a very large, densely-populated, globally-connected mega-city which includes at least one very densely-populated informal settlement • Less connected rural areas • Mixed household structures, including large proportion of multi-generational compound households • Medium levels of inter-personal trust and life satisfaction	• At least one major city (capital) which includes at least one very densely-populated informal settlement • Large sparsely populated and poorly-connected rural areas with high proportion of subsistence farmers • Young population, with large proportion of multi-generational compound households • Low levels of interpersonal trust and life satisfaction	• Stagnant population • Large number of child-headed households • Extremely low levels of interpersonal trust and life satisfaction	• Very densely-populated settlements connected to basic camp services • Younger population • Large number of child-headed households • Extremely low levels of interpersonal trust and life satisfaction
Health	• Widespread access to high quality healthcare system • High levels of obesity and associated diseases	• Variable access to healthcare system with mixed levels of quality service provision • High levels of obesity and associated diseases, and undernutrition	• Weak healthcare system, with limited access particularly in rural areas • High levels of obesity and associated diseases, undernutrition and micronutrient deficiencies • Gavi-eligible	• Very limited access to poor quality healthcare services • High levels of chronic undernutrition	• Very limited access to poor quality and sporadic healthcare • High levels of chronic undernutrition
Water, sanitation & hygiene	• Excellent reliable access to water, sanitation and hygiene everywhere	• Mixed access to facilities for water, sanitation and hygiene	• Poor access to facilities for water, sanitation and hygiene across much of the country	• Very limited access to facilities for water, sanitation and hygiene across the whole country	• Very limited access to facilities for water, sanitation and hygiene
Climate	• Temperate climate	• Tropical climate • High risk of cyclones	• Dry climate • High risk of drought and flooding	• Tropical climate • High risk of flooding	• Tropical climate • High risk of flooding

Findings

Living with a global, endemic infection
SARS-CoV-2 is not globally eradicated within five years in any of these futures and becomes endemic, at least in some regions. Over this period, the futures show how different places – even within a country – will experience outbreaks at different times. This highlights that different regions and population groups may experience outbreaks in different ways. For example, it is already clear that COVID-19 affects individuals differently due to both biological and socio-economic determinants, with older people, men, those who are overweight or obese, Black, Asian and minority ethnic people and people living in deprived areas more likely to die from the infection.[2,3,4]

Some countries may be able to eliminate community transmission within their national borders but, in a globally-connected world, all areas will be vulnerable to the arrival of new infections while there are ongoing outbreaks elsewhere. This is a particularly unstable and dangerous situation for a virus as infectious and virulent as SARS-CoV-2. This highlights the importance of finding alternative approaches to manage COVID-19 globally because there will be limits to the effectiveness of border controls unless these are absolute, which would have serious economic implications.

Over five years, the futures also illustrate how biological factors may shape the trajectory of COVID-19. For example, resistance to antivirals could emerge as in Future 2, or natural or vaccine-induced immunity may be short lived as in Future 3. Seasonality emerges in Futures 1, 2 and 3 as the susceptible population declines. Global real time surveillance is needed to identify such changes, and alongside an ongoing R&D effort to generate new vaccines and antivirals if existing ones are no longer effective.

Deploying vaccines and antivirals
Although effective vaccines and antivirals do not eliminate SARS-CoV-2, these interventions have a transformative role in making COVID-19 easier to manage in most contexts. This is most apparent in Future 1.

The four futures highlight the importance of decisions about how vaccines or antivirals are used within and between countries. The choices about who can access vaccines and antivirals are harder when supply is limited, as emphasised in Future 3. The global nature of this virus means that no country can isolate itself from the threat of COVID-19 while there are insufficient doses of a vaccine to reach herd immunity. To reduce global vulnerability and minimise the impact of COVID-19, strategies must be designed and agreed to multilaterally and critically, must target those who need them most.

These futures also highlight practical barriers to the delivery of vaccines and antivirals, which could be more complex if, for example, cold chain storage or multiple doses are needed. Demand-side barriers to uptake must be made as low as possible, making access safe, cheap and easy. Trustworthy systems and good communication will be essential to ensure citizen trust in the product and related services. It may not be possible to overcome these issues in all contexts. For example, severe outbreaks may continue in some settings with lower state capacity and in areas of conflict. There could also be considerable resistance to immunisation in many high-income economies.

Responding without vaccines or antivirals
Without pharmaceutical interventions, the four futures demonstrate the choice countries face between robustly deploying appropriate public health interventions to interrupt transmission and manage infection to reduce direct impacts, and the economic impact of any intervention. In this context, effective strategies to test, trace and isolate suspected and confirmed cases are particularly important to minimise the need for more general lockdowns. This situation is most extreme in Future 4, where it is necessary to rely on NPIs to manage COVID-19 without effective vaccines or antivirals. Until effective vaccines or antivirals are available, all four futures across the five settings include further waves of infection where it is not possible to deliver robust NPIs.

The futures highlight the extent to which a country's capacity to deploy NPIs depends on its existing strengths and fragilities. This capacity is likely to coincide with a country's ability to deliver vaccines and antivirals, including its ability to fund these interventions; the government machinery to deliver them; connectivity and the effectiveness of state communication; citizens' priorities and trust in the state; and the level of state coercion. It may be expected that high-income countries with higher state capacity would have the best chance of delivering NPIs successfully. In the first wave of cases, however, some developing and emerging economics were seen to implement stronger responses than advanced economies (according to some measures).[5]

Implications

The actual trajectory over coming years is likely to be a mix of outcomes rather than follow any one of the futures outlined here. It is clear, however, that COVID-19 is an intertwined medical emergency and economic crisis with far-reaching political and social impacts. Many of the multifaceted consequences appear in all four futures and across the five archetype settings. The nature and extent of the impacts differ, however, with Future 4 producing the gravest and longest lasting consequences.

In economic terms, COVID-19 is the greatest shock to the global economy since the Second World War. Every country covered by the IMF's forecasts has seen its expected growth revised downward; most economies will contract this year because of the pandemic.[6,] Even the economies of countries which did not officially adopt 'lockdown' measures have been impacted because of changes in consumption behaviour.

In high-income countries, output has dropped and unemployment risen at an unprecedented speed as governments imposed lockdown measures and people withdrew from the economy.[7] The impact on the world economy has been further aggravated by the disruption of global supply chains and falls in commodity prices. In response, most governments have implemented aggressive monetary policies and large fiscal support programmes to sustain citizens and companies through the pandemic.[8]

Many developing countries have experienced the global economic downturn before the virus took hold there, due to falling commodity prices, collapsing tourism revenues, declining remittances and large capital outflows.[9] Most middle- and low-income countries implemented stricter lockdown measures than their high-income counterparts, resulting in further economic decline.[10] With high levels of informal employment these countries often lack the resources and the tools necessary to support people during lockdowns.[11] As a result, stringent policies are unlikely to be sustainable for very long, and governments are forced to reopen the economy before infection rates and the pressure on health systems have fallen.

In places with multiple deep fragilities governments lack the capacity to respond effectively to both the health emergency and the economic crisis. Many health systems are fragile and limited. Living conditions preclude physical distancing and insufficient personal savings (if any) force people back to work. Vulnerable populations rely heavily on support from the international community to mitigate both health and economic impacts, with the situation most extreme in refugee camps.[12, 13]

COVID-19 will reverse the positive trend of reduced poverty globally and falling income inequality across countries over the last 30 years. Moreover, the tendency towards increasing income inequality within countries will be reinforced as the economic crisis disproportionally impacts poorer people.

The costs of responding to the medical emergency and the economic crisis will force many countries to take on more debt. In most high-income countries this will create an issue of intergenerational equity. In many low- and middle-income countries the increased debt levels will create greater financial vulnerabilities, potentially undermining the achievement of the Sustainable Development Goals by 2030, potentially jeopardising decades of development and access to international capital markets.[14]

Widespread exposure to such dramatic disruption and deterioration in lives and livelihoods will have political consequences. People lose trust in political institutions, leaders and health systems, but in varied ways. The experience from previous epidemics suggests that COVID-19 may leave a "long-lasting political scar" in attitudes, particularly among younger people (ages 18-25).[15] People in middle- and low-income countries generally have a more negative perception of their governments' trustworthiness and response to the pandemic.[16]. There is also evidence that, contrary to some common perceptions, epidemics undermine trust in scientists, if not in science itself.[17]

SARS-CoV-2 arrived in a world where many polities, including in some high-income countries, were moving in an authoritarian direction.[18] Some governments have used the pretext of the pandemic to reinforce this trend.[19] More generally, policy measures adopted during COVID-19, such as sharing private data for public good, raise questions about balancing individual behaviour, choices and rights with those of collective action to protect public health.

A loss in trust in governments and critical institutions undermine states' capacity to respond to new waves of the current pandemic and future viruses. The pandemic may also amplify underlying inter-religious and inter-ethnic tensions within societies, potentially leading to open conflict.[20] There is also potential for local and global disputes to escalate over the supply of protective equipment and medicines, travel restrictions or the response to the virus.

A deteriorating international political climate – including the rising tension between China and the United States – impedes efforts to find multilateral solutions to critical global challenges. Global health governance is particularly at risk, demonstrated by the decision of the United States to withdraw its financial support for the World Health Organisation. Other countries have stepped in to fill the gap, but the pandemic highlights that the WHO does not have enforcement capacity and must work through member states, generating political willingness to act.[21]

A strong global response is needed to mitigate the profound and long-lasting negative impacts on the world's health, economy, politics and societies. We should see this pandemic as a sign of things to come, rather than a one-off event. Pandemics are likely to become more common and more complex to respond to through this century. Society faces other challenges where health, politics and economy are intertwined in complex ways, such as climate change and drug resistant infection. There is an imperative to use the profound disruption of COVID-19 as an opportunity to learn, reform and act to create better global outcomes.

Mobilising an effective, equitable global response

Some people and settings will be disproportionately affected due to existing and emerging vulnerabilities, but nowhere – including high income settings – will be unaffected. In a globally connected world all areas remain vulnerable to the arrival of new infections while there are ongoing outbreaks elsewhere. This truly global problem demands a global solution where the risks and benefits are shared, because no single country has the resources or capability to achieve solve it alone. For example, the large costs and high failure rate in drug development make it impracticable for each country to develop its own vaccines or antivirals. The chance of a good outcome will be maximised by pooling the risk, and global coordination of high quality R&D and manufacturing capacity.

There will be a critical choice about how effective vaccines and anti-virals are used. Delivering these products effectively and equitably will maximise global benefit, creating the best chance of controlling COVID-19 and reducing its impact. To achieve this, cooperation is needed to ensure vaccines and antivirals reach those who need them most, rather than countries and individuals who can afford to pay. The geopolitical outlook puts this outcome at risk, but like-minded actors must continue to work together to ensure this choice defines the world they want to see.

Harnessing the full weight of research

Tackling an issue where health, economy, politics and society are intertwined means that research must play a broader role than delivering medical solutions. Decisions rest with democratically elected bodies but must be informed by research from a broad range of disciplines. For example, the social sciences can help understand economic factors in policy choices, and overcome social barriers to deploying interventions. Research is also needed in terms of learning from the outbreak and response over time and must be supported by a rigorous approach to collecting and sharing data on interventions and their impacts.

Governance of the local, national and global response

A coordinated global response is necessary but not sufficient. Regional, national and local approaches are essential to implement sustainable and locally-owned solutions by considering the strengths and fragilities of the context. The futures show that the ability to deliver public health interventions is a key factor in the effectiveness of the response. Investment in public health systems is crucial, and the response may also be influenced by what a country has learnt from past epidemics, exemplified by strong responses in South Korea, Japan and Hong Kong.[22] This is more important when we consider the likelihood that other emergencies will occur in parallel with COVID-19, exacerbating both health and wider impacts.

Local, national and global responses should reinforce each other. The need for good governance and coordination at local, national and global levels is a crucial lesson from the first wave of COVID-19. Some key weaknesses in the response stem from gaps in accountability between national and local authorities, and the response has exposed the limitations of global governance as a check on national policies.

Concluding Remarks

COVID-19 will be with us for a long time. Even if we find a vaccine within the five-year period considered here, it will shape the world's health, economy, politics and societies in profound and lasting ways. Everyone will be affected, through both direct medical impact and economic, political and social effects, although the nature and extent of the impact will differ across settings and depend on the policies implemented. Globally, people will adjust their behaviour in relation to the information they have about the pandemic and the perceptions they hold about the virus and response. The extent of that adjustment will also be shaped by the constraints they are facing, and the ability of governments to introduce, enforce and financially sustain NPIs will differ considerably. Progress on vaccines and antivirals will be central to moderating the impact of COVID-19, as will our ability to design and implement solutions based on evidence from the social sciences.

The deep and inequitable impacts of COVID-19, combined with existing geopolitical fragilities, means there is a risk that countries will adopt isolationist and protectionist responses. But these very impacts mean it has never been more important to work together in enlightened self-interest to shape a global response that reaches people in a fast, effective and equitable way.

Author Contributions

J. Bedford; E. Berglof; C. Buckee; J. Farrar; B. Grenfell, C.J.E. Metcalf and D. Sridhar: Conceptualization, Methodology, Writing - Review & Editing. E.C. Holmes: Conceptualization, Methodology, Visualization, Writing - Review & Editing. B. Thompson: Project administration, Visualization, Writing - Original Draft.

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Declaration of Interests

J. Farrar is a member of the UK Scientific Advisory Group for Emergencies. B. Grenfell is a member of the Royal Society's Data Evaluation and Learning for Viral Epidemics (DELVE) group. D. Sridhar is a member of the Scottish Government COVID-19 Advisory Group and the DELVE group. All other authors declare no competing interests.

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