4 Mobilising science in times of crisis: Lessons learned from COVID-19

Science played an essential role in generating the knowledge and technologies needed to respond to the COVID-19 crisis. The pandemic offers lessons that can position science to respond more effectively to future crises. For instance, much can be learned from successful co-operation between various actors during the pandemic, but reinforcing these relationships over the longer term may require significant change to academic culture, structures, incentives and rewards. Many of the required changes – including in research performance assessment, public engagement, and transdisciplinary research – are already underway but have not yet been adopted at the necessary scale and speed because of embedded inertia in science systems. More radical change is necessary to spur science to engage with other societal stakeholders to produce the broader range of outputs and solutions that are urgently required to deal with complex global challenges and crises.

Key messages

- The COVID-19 pandemic has been a complex and cascading global crisis, with science playing an essential role in generating the knowledge and technologies to enable effective policy responses. Ensuring the necessary scientific capacity is a critical consideration for governments in preparing for and responding to other ongoing and future crises, including the climate emergency.

- The scientific response to a complex crisis depends on the mobilisation of existing knowledge and resources across a broad range of disciplines. This requires long-term commitment and sustainable support for research infrastructures (RIs) and basic research across the breadth of science.

- The pandemic has illustrated both the potential and challenges in using big data and digital tools for crisis management. It has positively accelerated access to research data and scientific information and at the same time revealed the limits of current open science approaches. It is important that this progress continues after the pandemic, and that inclusion (in terms of both data coverage and access) becomes embedded in open science policies.

- The traditional distinction between policy for science and science for policy weakens during a crisis, when science becomes easily politicised. Nevertheless, maintaining the independence and autonomy of scientific research and advice is critical to ensure public trust.

- It is a primary responsibility of the scientific community to ensure the rigour and completeness of the scientific research and communications that inform policy and decision-making during crises. This requires integrating insights and knowledge across many different disciplines, and open discussion of knowledge gaps and uncertainties.

- Ultimately, the effectiveness of the scientific response to a crisis depends on the relationships between science and other sectors of society, including politicians and policy makers, business and industry and, most importantly, the public. Establishing resilient and trusted relationships across these sectors is essential.

- Although public trust in scientific institutions has increased overall during the pandemic, it is fragile and needs to be nurtured. Scientists must play an active role in responsibly communicating scientific evidence to the public and engaging citizens in transdisciplinary initiatives. Training, support and new incentives will be required to achieve this.

- A global pandemic requires a global response. International scientific co-ordination and co-operation structures and mechanisms were severely tested by the pandemic, and showed their limitations. Many countries and populations could not access the benefits of science for a variety of reasons. Ensuring equity and inclusion is not the sole responsibility of science but it is in the mutual interest of all countries to enable a global and inclusive scientific response to crises.

Introduction

Science underpinned the fight against the COVID-19 pandemic from the outset. It was expected to provide both the tools (e.g. diagnostics, vaccines and therapeutics) and knowledge (e.g. understanding of viral infectivity, epidemiological monitoring and behavioural insights) that policy makers could use to effectively respond to and manage the crisis. The scientific response had to be rapid and encompass many different scientific domains and sources of evidence. The response also had to be rigorous, yet the evidence base for various interventions was severely limited and even basic questions (such as how the virus was spread) could not be fully answered during the first few months of the pandemic. The pandemic did not wait for science, and what had originally been framed as a largely biomedical/public health crisis soon expanded across all sectors of economies. It was quickly apparent that openness and accountability would be important to establish and maintain the necessary public trust in science and associated policies.

Science was in the spotlight more than ever before and endowed with huge expectations, and yet the pandemic dramatically disrupted normal scientific practice itself. As in other economic sectors, many scientists had to adapt rapidly to a new virtual and working environment for extended periods. International travel and meetings, which are critical mechanisms for scientific exchange, were largely replaced by video calls and virtual conferences (Buchanan et al., 2021[1]). Physical access to experimental resources and facilities was replaced by remote access. Doctoral and early-career researchers were particularly affected: as laboratory investigations and fieldwork were disrupted, they were forced to adopt digital tools to maintain essential contact with colleagues, mentors and peers. As in other areas of the economy, women scientists were harshly affected, as they often had to balance the double burden of care duties and professional responsibilities while working from home (OECD, 2021[2]) (OECD, 2021[3]).

Given the rapidly changing, high-pressure context, this chapter analyses how science performed in response to the pandemic. It draws out lessons that can position science to respond more effectively to crises – including those that are already with us (such as climate change or biodiversity loss), those that we can reasonably foresee (such as the next infectious disease pandemic) and those that we cannot predict, but which will surely arrive. Previous OECD work (OECD, 2018[4]) has investigated the different roles of science in terms of the so-called "crisis management cycle", i.e. preparedness, response, and recovery / feedback. Science is embedded across the whole of this cycle, and in each phase, it interacts with other stakeholders outside the public science system, including policy makers, the private sector, and civil society. Such interplay is critical to mounting effective responses to crises. It is important in relation to COVID-19 and crisis response more broadly to consider not only how the science ecosystem responded but also – and perhaps more saliently – to evaluate the efficacy of the interactions and relationships with other sectors and actors.

Rather than simply producing excellent research, science has had to engage rapidly with other sectors on a major scale to develop "fit-for-purpose" technological tools and evidence to enable effective policy responses to the crisis. Science policymakers have implemented a number of different initiatives in order to achieve this. At the same time, they have had to pay careful attention to ensure the continued functioning of the broader science system and balance urgent versus long-term needs and expectations. While the resources for science have increased in some countries – specifically to support the pandemic response – this increase has not reflected the scale of additional demands. Hence, the scientific response has been highly dependent on what already existed, and actions by science policy makers have been largely concentrated on re-focusing, adapting, accelerating, enabling and scaling-up existing activities and processes.

The OECD has compiled a detailed description of science, technology and innovation (STI) policy initiatives taken by different countries during the first six months of the pandemic. An updated catalogue can be found on the Science, Technology and Innovation Policy (STIP) Compass COVID-19 Watch portal[1] (see also Chapter 1). This chapter analyses the challenges faced by countries in implementing these policy

initiatives. It delves into what policies worked well (or less well) – and why – and discusses the policy implications for the future. This analysis focuses on two main areas:

1. **Policy for science**, i.e. the policies adopted to facilitate the necessary research for addressing the pandemic. The chapter focuses on three broad topics that have been particularly important in the science response to the pandemic, namely: (i) access to data and scientific information; (ii) mobilisation of RIs; and (iii) development of transdisciplinary research and multinational partnerships.

2. **Science for policy**, i.e. the policies adopted to ensure that research agendas reflected policy needs, and that research evidence effectively informed policy and decision-making (including by citizens). The chapter focuses on three critical areas for attention, namely: (i) ensuring that research addresses policy needs; (ii) the operation of science advisory systems; and (iii) public communication and engagement.

Figure 4.1. Policy for science and science for policy
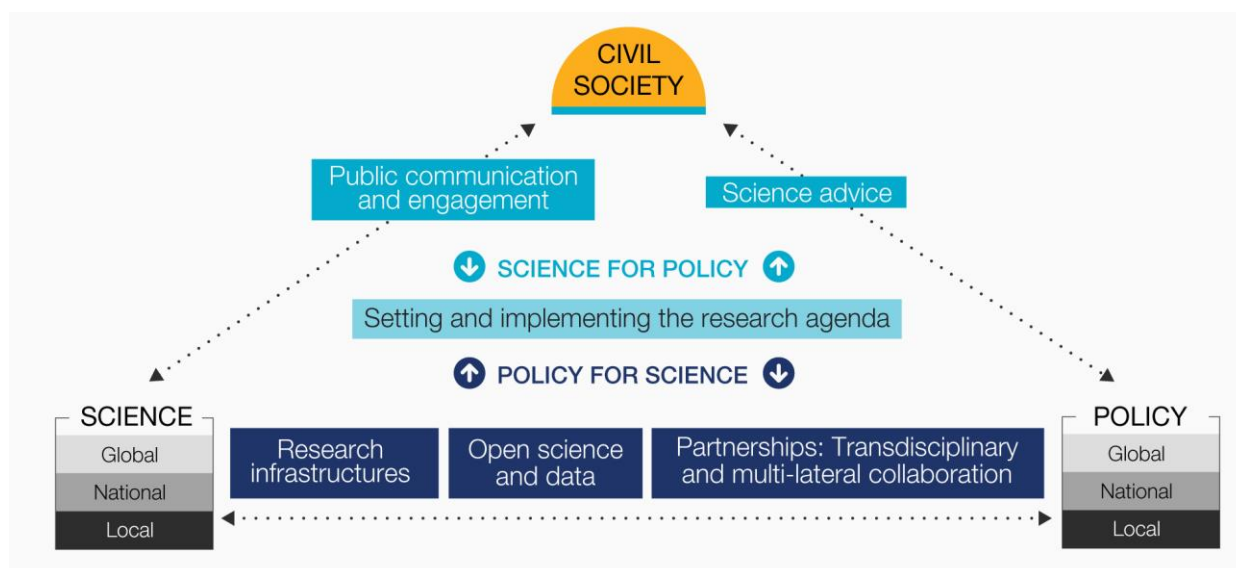
Note: Science policy influences the development of science through support for science system assets – RIs, data, and science-industry collaborations – and science has a role in facilitating broader policy development through enabling activities – research agenda setting, public communication and engagement, and provision of science advice during crises. However, there are interplays between these areas, with science assets contributing to the ability of science to inform policy development and enabling activities influencing science policy choices and the direction of science.

These two main areas map onto what might normally be considered as core business for science – i.e. research and knowledge generation – and what may be referred to as "third-mission" activities, which generally receive less attention and are less valued within academia. Although this division is commonplace, COVID-19 – where science has been put squarely at centre stage – has clearly illustrated the continuous interaction between science for policy and policy for science, and the importance of considering them together and allocating them equal attention during crises (see Figure 4.1). This has required a major shift in thinking from science policy makers and research providers. For example, individual scientific excellence as measured by publication outputs needed to be balanced against urgent policy needs, rapid sharing of data and information, and public communication and engagement. As science ministries, agencies and institutions now begin to evaluate their response to the crisis, it will be important to adopt criteria and indicators that reflect the full range of demands on science.

Over the past two years, the OECD has organised a series of international workshops on "lessons learned from COVID-19", exploring each of the six topics listed above.[2] Building on earlier OECD work in each of these areas, the workshops included case presentations and panel discussions. Their aim was to identify actions that science policy makers could take to better mobilise science in response to crises. As the COVID-19 pandemic was the primary focus of these discussions, some of the issues identified were specific to pandemics. Strikingly, however, many of these issues could readily be extrapolated to overall crisis preparedness. This chapter focuses on these more generic areas for policy action.

Policy for science

Open science and data

Prior to the pandemic, science policy makers in many countries had already begun to implement policies to promote the three main pillars of open science, i.e. open access to scientific publications, increased access to research data and public engagement (OECD, 2015[5]) (Dai, Shin and Smith, 2018[6]). At the very onset of the pandemic, it became clear that access to scientific information and data would be critical for all countries, and this was an early target for science policy initiatives. In January 2020, the open sharing of the original SARS-Cov-2 virus sequence by an international consortium led by Yong-Zhen Zhang of the Shanghai School of Public Health was the starting point for scientists across the world to begin work on diagnostic tests, vaccines and therapeutics (Wu et al., 2020[7]). Meta-analyses of literature from previous infectious disease pandemics, combined with the development and sharing of epidemiological models and scenarios, enabled evidence-based policy making. Effective public engagement was important not only to collect data and information, but also to inform researchers and policy makers about the real-life effects of the pandemic. As the pandemic progressed, it also became clear that access and sharing within the scientific community was not sufficient and that the public wanted access to the scientific data and information that were informing policies. Indeed, the pandemic significantly shifted the emphasis on openness and transparency, while at the same time raising new ethical considerations around the collection and use of personal data and information.

Several national and international organisations took initiatives early on to promote open access to COVID-19 related scientific publications and this has had a major impact on the accessibility of most of this information. Figure 4.2 shows that the proportion of open access publications on COVID-19 is significantly higher than for other medical conditions, e.g. dementia and diabetes. There has also been a significant increase in scientific publications related to COVID-19 between 2020 and 2022. In a landmark initiative facilitated by the National Institutes of Health in the United States, a group of major science journal publishers made relevant articles available in formats and under licence terms that facilitated text mining and secondary analysis.[3] Similar open-access collections of published scientific literature were developed in other countries and scientific domains. One example is the COVID-19 LOVE (Living Overview of Evidence) initiative, launched in Chile as an open repository and classification platform that uses systematic methods and automation technologies to connect users to a comprehensive collection of published COVID-19 evidence for decision-making (Verdugo-Paiva et al., 2022[8]) (see also Figure 4.5). Some of these initiatives integrated pre-prints in their collections. Indeed, the growth in openly accessible pre-prints was one of the characteristics of scientific information dissemination during the pandemic (Fraser et al., 2021[9]). This was a response to the demand for rapid and timely access to new scientific research information and in that regard, it can be considered a success. Scientific research published in pre-prints helped inform policies. However, in the absence of prior peer review, the rigour of the research was not always assured, and the media and public made little distinction between preliminary research results published in pre-prints and peer-reviewed articles in scientific journals.

Figure 4.2. Open access of COVID-19, diabetes and dementia publications, 2020 and 2022

Total and free full text Pubmed publications

A.2020

B.2022
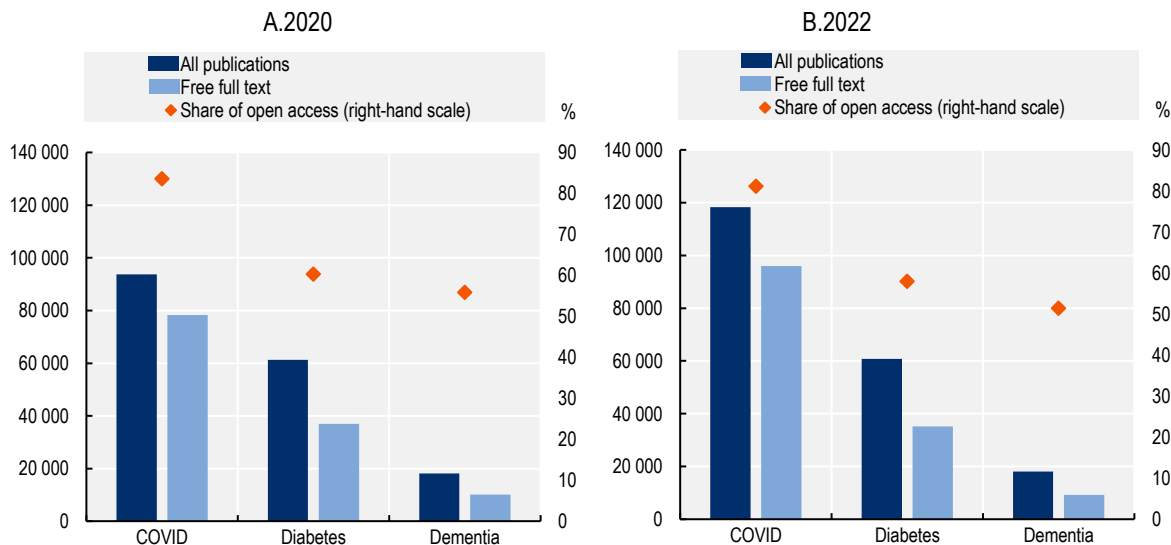
Note: Publications include the following types of peer-reviewed articles: Books and Documents, Clinical Trials, Meta-Analysis, Randomized Controlled Trials, Reviews and Systematic Reviews[4].
Source: OECD calculations based on US National Institutes of Health PubMed data, https://pubmed.ncbi.nlm.nih.gov (accessed 2 December 2022).

StatLink 🔗📊 https://stat.link/lta0je

Ensuring scientific integrity was sometimes a challenge, jeopardising public trust

A number of unsubstantiated, poorly designed or fraudulent scientific results were communicated via pre-prints, undermining science and in some cases promoting conspiracy theories and populist political positions. At the same time, it was not only pre-prints that were used as vehicles for dissemination of false and fraudulent results – one of the most notorious cases was a publication in the prestigious medical journal *The Lancet*, for which the purported international patient data set did not exist (Baker, Van Noorden and Maxmen, 2020[10]). This publication added to the confusion and controversy around the use of hydroxychloroquine as a therapy for COVID-19. Ensuring scientific integrity, and the quality and rigour of scientific publications and other information outputs in a crisis when there is increased emphasis on timeliness and openness, is a critical challenge for the scientific community. Mandating that the data underpinning a pre-print or publication are made openly available – or, in cases where these data are sensitive, ensuring that they are peer-reviewed – are important safeguards that should be widely implemented. If this issue is not adequately addressed, then public trust in science can rapidly dissipate.

*Scientific domains varied in making their research data open*

Many different types of scientific or research data are relevant to the COVID-19 pandemic, and should ideally be findable, accessible, interoperable and re-useable (FAIR) (Research Data Alliance, 2020[11]). While the specific details may differ, the requirement for FAIR data across many scientific domains is characteristic of any complex or cascading crisis. When such a crisis is international, operating across different jurisdictions or borders further complicates efforts to make data FAIR. This is even more the case when much of the data of interest are personal or otherwise sensitive, as was the case for COVID-19. The pandemic was a stress-test for all research domains to assess where they are up to in making their data FAIR. In this regard, the infrastructures, processes, standards, and trusted relationships for managing and

sharing data that had been established prior to the pandemic, proved to be critical. Those fields, such as genetics, which had made significant investments in FAIR data prior to the pandemic were able to build rapidly on this. Other fields, such as clinical research or social sciences, with a narrower data-sharing culture were generally ill-prepared for the demands of a complex crisis like COVID-19.

The revised OECD Recommendation concerning Access to Research Data from Public Funding was adopted in January 2021 and identifies the generic areas to be addressed in making research data FAIR (OECD, 2021[12]). At a more operational level, the RDA-COVID-19 WG Recommendations and Guidelines for Data Sharing, which were developed bottom-up by the inter

national research community, were published six months into the pandemic and provided detailed advice for specific research domains (Research Data Alliance, 2020[11]). Different actions (see Figure 4.3) are required at different stages of the research data life cycle to make data FAIR, and many of these can be supported and incentivised by judicious policy interventions. Different areas of research will require varying levels of support and incentives to implement these actions and make their data FAIR.

Figure 4.3. The Covid-19 research data life cycle and policy levers
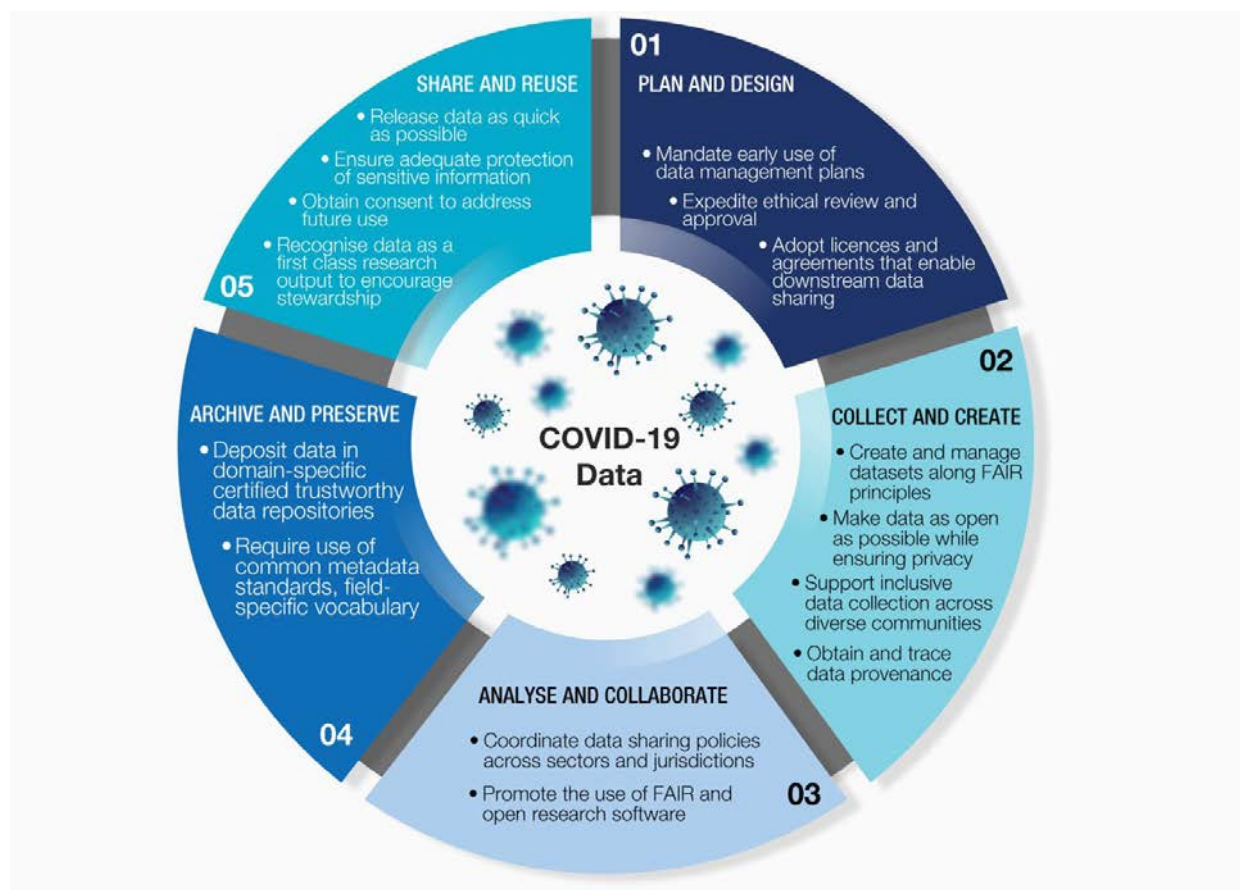
Note: Policy actions are necessary across the different steps of the research data life cycle to ensure enhanced access to COVID-19 research data.
Source: developed by the OECD and the Research Data Alliance.

Trusted data repositories are needed to deal with privacy concerns

While the research community has the primary responsibility for providing access to the data (and the associated software) it collects or generates, much of the data used for research during the pandemic

came from other sources and were not primarily designed for research. This is particularly the case in social sciences, which use data from multiple sources – including administrative data from the public sector and social media data, which are controlled by the private sector (OECD, 2016[13]). Much of these data are personal and, even when anonymised, are subject to specific regulatory and ethical considerations. Clinical and health services data, which are important for epidemiological modelling and many other areas of pandemic research, are subject to similar considerations, and need to be managed and shared accordingly (OECD, 2020[14]).

Much of the value of population data depends on their being disaggregated, e.g. by gender, social status or ethnicity. Such granular information can be critical for crisis management and – as with COVID-19 – targeting policy interventions and communication strategies (OECD, 2020[15]), (OECD, 2021[16]). However, this is precluded in many jurisdictions because of privacy concerns. It is important to support trusted data repositories, located in academic centres or other public-sector organisations such as national statistical agencies or medical institutions, in ensuring FAIR, ethically correct, legally compliant and timely access to sensitive or personal data, and to enable their "safe" usage by accredited academic researchers. The science community needs to be involved, together with other relevant stakeholders, in defining the policies and processes governing access to different types of administrative data. Dialogues and agreements should also be established with commercial-sector data holders and citizens to determine which data should be made available to scientists (and under what conditions), both routinely and in times of crisis (OECD, 2016[13]).

Recommendations:

1. Accelerate efforts towards open access to publications, provision of FAIR data and safe sharing of sensitive data, building on the momentum provided by the pandemic and supporting and consolidating ongoing initiatives in each of these areas.

2. Prioritise the collection of quantitative and qualitative data and robust evidence for use in designing public health and social measures (PHSMs). In particular, "baseline data" on the effectiveness of commonly deployed measures are required, which will often require international collaboration.

3. Ensure inclusion across countries and population groups in data collection. Many of the groups that are most vulnerable during crises are absent or under-represented in the administrative and research datasets that are commonly used to inform policy. Online collection represents a particular challenge for those who are not "digitally connected".

4. Support and incentivise efforts to share and integrate administrative, research and commercial data that are relevant to crisis management. Some of these data will be sensitive, and provisions and protocols should be put in place to enable safe and timely access in emergency situations.

5. Accelerate the adoption of new technology and processes to deal with real-time collection of big data for policy and decision-making. A combination of human expertise, workflows and technologies (apps, algorithms, high-performance computers, etc) is required to extract the maximum benefit from the massive – and increasing – amounts of data that are available to inform both crisis management and routine policy development.

Research infrastructures

RIs provide shared experimental facilities and resources for the scientific community. There exist many different types of RI which operate at different scales, from local/regional to global, and play a critical role in facilitating research in most scientific domains. The primary mission of all RIs is to enable excellent science, requiring long-term strategic investment. In this regard, they overlap with some public research institutes, as well as research and technology organisations that also provide research services – although typically focusing more on the needs of specific economic sectors and supporting applied research and

innovation. The distinction between these groups, which differs across countries, is not critical to this chapter, which uses the term "research infrastructure" generically. RIs provide the scaffolding for scientific research. Because of their service function, unique expertise and established links with multiple users – and often multiple countries – they are a critical scientific resource in responding to crises.

Bio/health RIs played a central service provision and co-ordination role

RIs from the biomedical, clinical and life sciences (bio/health) were at the centre of the science response from the very outset of the pandemic. In many countries, dedicated public health institutes played a central co-ordination role, working closely with academic researchers to develop the necessary data, information and tools to inform policy decisions. For instance, the Norwegian National Institute for Public Health, the Robert Koch Institute in Germany, and to a lesser extent the Centers for Disease Control and Prevention in the United States performed this function at the axis between policy, science and the public, placing them in a sometimes exposed and vulnerable position (see section on science advice). Other bio/health RIs played a critical role in the early development and testing of diagnostics and therapies, working closely with scientists from academia and industry. Many also played an essential role in providing the FAIR data and analytical services that have underpinned efforts by the research community to understand the pandemic and support policy makers.

Networking and co-operation among bio/health RIs proved particularly valuable. As the scientific questions raised during the crisis were often complex, researchers often required services and data from multiple RIs. Close liaison between RIs enabled the development of common cross-infrastructural workflows that could be readily integrated in regular operations (e.g. linking chemical screening, structural biology and data analytics). Trusted relations and collaborations established before the crisis were important as they enabled partners to align different administrative requirements rapidly and streamline their normal processes. Existing links sometimes consolidated into more concrete alliances that further facilitated access to connected data and services. Notable examples include the Alliance of Medical Research Infrastructures,[5] the Analytical Research Infrastructures of Europe,[6] and the Collaborating Network of Networks for Evaluating COVID-19 and Therapeutic Strategies in the United States.[7] Capacity-building and training was a particularly important charge for many RIs. In some instances, RIs or alliances of RIs provided direct support to public health systems, boosting existing diagnostic capacity to manage samples, developing high-throughput screening, and training health service staff on diagnostic testing and biosafety.[8]

Many clinical RIs, including dedicated clinical trial centres, played an important role in developing and testing new diagnostics and therapies.[9] However, clinical trials were one area in which the response from the scientific community was "mixed" (see Chapter 1). There was a particular challenge in ensuring adequate patient sample sizes to produce reliable and reproducible results.[10] This was compounded by a lack of trial registrations and, in many instances, limited access to the trial data even after results were published (Besançon et al., 2021[17]). Overall, a large number of underpowered clinical studies and trials were performed in many countries (OECD, 2020[18]). Many of these could not be reproduced and generated little useful information. At the same time there are a number of exemplary initiatives, where clinical RIs and other academic and private-sector actors worked together internationally, adopting common protocols and processes to recruit large patient numbers and generate rigorous results in record time.[11] In areas where such networks did not exist, most notably with regard to testing the efficacy of PHSMs, the evidence base for policy has been severely lacking. It is important that the clinical and public health research community learn from the experience during COVID-19 and establish the necessary infrastructures, networks and protocols to support rigorous evaluation studies.

RIs from other research domains also played important roles

The mobilisation of RIs during the crisis was not restricted to bio/health RIs. At the beginning of 2020, physics RIs, which provide access to specialist equipment and services, developed fast-tracked access

for COVID-19-related projects. This was largely the case for synchrotron facilities, which can be used to explore the structure and interactions of molecules, including viral proteins and potential drugs. High-performance computing (HPC) was another area of major mobilisation. HPC has played a critical role in data analysis and modelling for multiple aspects of COVID-19 research, from exploring viral replication mechanisms to drug design, and from understanding transmission to developing large-scale epidemiological models (Nature Computational Science, 2021[19]). Large RIs (such as CERN) with HPC systems and know-how made their resources available for COVID-19 research, and federated HPC networks were established to provide easy access to both public and private facilities.[12] As the pandemic progressed, RIs in the social sciences and humanities were also mobilised in a number of countries to conduct social surveys, analysing attitudes towards and the potential impacts of the PHSMs that were being implemented in response to the pandemic.[13]

With the exception of Europe, there was a lack of international co-ordination

Although RIs are often used by international communities of researchers, the COVID-19 crisis highlighted a lack of international co-ordination. Despite increased networking between RIs, those links were mostly restricted to the national or regional level (Europe was an exception in this regard, with RI strategies and co-operation mechanisms having been developed at the European level for some years). The lack of international co-ordination hindered the sharing of data (particularly in clinical and social domains where countries have different ethical and regulatory standards) and the full mobilisation of other complementary assets. Furthermore, the uneven distribution of RI capacities at the global level prevented access to resources and data in many parts of the world, contributing to the disconnect between needs and solutions. Thus, effective global action on crises will require science stakeholders to address a lack of engagement with, and funding for, low- and middle-income countries (LMICs). This applies not only to future pandemics, but also to ongoing and future crises related to environmental change and natural disasters.

The notable exception with regard to cross-border co-ordination was Europe, where the European Commission (EC) framework programmes have promoted European research co-operation for many years. This investment paid off in mobilising science across national borders (Veron and Di Ciommo, 2020[20]). European RIs, such as ELIXIR and BBMRI-ERIC, provided access to data, materials, facilities and services across countries. In addition, many European research projects were re-oriented to address COVID-19, and new projects were rapidly initiated using well-tested cross-national funding mechanisms. The pandemic gave extra impetus to the European Open Science Cloud, moving it from an attractive but ambitious concept for the science community to an essential requirement for the evidence-based management of complex long-term crises. Many EC-funded activities provided an anchor point for scientists from outside the European Union to co-operate with multiple European countries. In some cases (e.g. for genomic data), European co-operative activities have provided a basis for intercontinental collaboration.[14]

Recommendations

1. Consider RIs as strategic assets with a major role to play in crisis preparedness and response. This means integrating RIs into crisis preparedness and response strategies, and ensuring that this role is included in the missions of individual RIs (and incentivised accordingly).

2. Recognise RIs as unique resources for training and capacity-building and support them in building and maintaining the capacities required to respond to ongoing and future crises. This entails ensuring sustainable career paths for the professional staff required to keep an RI operating effectively and supporting their role in upskilling other personnel in preparation for emergencies.

3. Provide long-term strategic investment to RIs, focusing on resilience as well as efficiency. While maximising efficiency and operating to maximum capacity may be understandable targets during

times of calm, having some spare capacity and immediate access to deployable resources is critical to ensure a timely response to crises.

4. Facilitate networking across RI ecosystems and partnership-building between different stakeholders. RIs demonstrated during the pandemic that they can play a critical intermediary or brokering role across disciplines and sectors. This function should be emphasised and supported during their normal operations.

5. Recognise the unique role that RIs play in international co-operation, including through the provision of data and analysis, and make the necessary long-term investment in building trusted cross-border relationships.

Partnerships: Transdisciplinary and multi-lateral collaboration

Given the scale and complexity of the pandemic and the urgent need for information and tools to effectively respond, it has been critical that scientists from different disciplines, sectors and countries are able to combine their resources and expertise. In practice, this has translated into a variety of co-creation (Kreiling and Paunov, 2021[21]) and transdisciplinary (OECD, 2020[22]) initiatives, some of which are focused around RIs (see previous section) or collaborative platforms, and all of which are characterised by the involvement of multiple different actors.

Vaccine development drew heavily on public-private partnerships

Promoting knowledge transfer and public-private partnerships (PPPs) between academic research and industry has long been a focus of STI policy. The main challenges to this objective are well-known: different aims and incentives, different approaches to openness and different approaches to intellectual property rights. In fields such as biotechnology and biomedicine, these challenges have been a focus of policy attention for several decades and – providing commercial interest and a potentially viable market can be identified – PPPs are relatively easy to establish and often flourish. Many such "classical" PPPs played a role in the response to COVID-19, most notably vaccine development. In addition, more recent experimentation with novel open science-industry-academia partnerships, in which multiple companies and academic institutions share expertise in pre-competitive research, provided a basis for the establishment of similar arrangements in response to COVID-19 (Gold, 2021[23]).

The early days of the pandemic were characterised by a considerable lack of clarity on the potential commercial returns from diagnostics, vaccine and antiviral therapeutics, and there was strong demand from many LMICs and international organisations to ensure equitable access at reasonable prices. Ensuring affordable access was an important motivation for some academic institutions, as witness the role of Oxford University in developing a 'low cost' vaccine with AstraZeneca, or Baylor College of Medicine, Texas with its patent-free CORBEVAX vaccine (OECD, 2021[12]). This was less the case for several other vaccines, including the mRNA[15] vaccines that were developed by biotech companies in partnership with the pharmaceutical industry, albeit on the back of long-term public investment in academic research (Dolgin, 2021[24]). The commercial return for several of these vaccines was assured by prior procurement commitments from individual countries in return for preferential provision, with equitable worldwide access a secondary consideration (OECD, 2021[2]). Despite efforts by the World Health Organization (WHO), COVID-19 Vaccines Global Access (COVAX) and other organisations, many countries are still deprived of equitable access to vaccines (see also Chapter 1 for an overview of the current status of COVID-19 vaccine development).

There has been less success in developing new therapeutics

With several effective vaccines developed using different technologies, and tested and rolled out in record time, the vaccine story is nevertheless an excellent demonstration of what can be done when academia

and industry combine resources. The process of developing antiviral therapies has been less positive: moving promising compounds from the laboratory to the bedside continues to be a challenge owing in part to issues around ownership and appropriation of commercial returns.[16] These challenges mirror those that prevail in the development of antibiotics and there are lessons that can be learned from this field, such as the use of novel market guarantee and procurement mechanisms, and new not-for-profit business models that might be more broadly applicable for the provision of essential medicines during crises and beyond (Lobanovska and Pilla, 2017[25]), (OECD, 2021[3]).

Many new partnerships were transdisciplinary

The response to COVID-19 was characterised by the creation of new partnerships and networks that engaged actors beyond academia and industry in developing solutions for a diverse range of practical challenges.[17] Many of these joint activities were truly transdisciplinary – integrating knowledge and perspectives from different science disciplines and different sectors (business, the public sector and civil society). Establishing trust between different actors has proved to be the critical factor in getting such arrangements to function effectively. Not surprisingly, many of them relied on existing relationships, and involved institutions and organisations that were well respected in their respective sectors.[18] Funding such transdisciplinary activities was a challenge in many countries as they do not fit neatly with traditional research-funding schemes, which tend to focus on specific research domains and recognised public research providers such as universities or public research institutes. In some cases, existing in-house institutional funds were used, or (as in Ireland) "one-stop-shop" emergency research-funding mechanisms were established to enable multiple actors to apply for joint projects.[19]

Citizen science was also an important part of the pandemic response

Citizen science – defined in this context as the engagement of citizens in research activities – contributed in important ways to many aspects of the pandemic response. Much of the data used to understand the pandemic "belonged" to individuals. Some of the data were not just donated but also collected by citizens, for example by using apps that were themselves sometimes developed by citizen scientists.[23] Digital tools were also used to organise a number of "hackathons" – crowdsourcing events open to multiple actors (including citizens) that focused on applied research or solutions to specific challenges (Paunov and Planes-Satorra, 2021[26]). Nevertheless, recognising citizens as true partners in research raises sensitive issues about scientific expertise and power relations between experts and lay persons. The identification and professional recognition of "long COVID" is illustrative in this regard (see section on public communication and engagement). There is still some way to go before academia recognises the full value of citizen science and embraces citizens not just as data collectors, but also as purveyors of expertise and knowledge in co-designing and co-producing research.

Disciplinary silos hindered co-operation between science, technology, engineering and mathematics (STEM), and social sciences and humanities (SSH)

Just as the pandemic shed light on the power relations between experts/scientists and citizens, it also highlighted the differences between science disciplines, most notably STEM and SSH. There has been criticism of the focus on numbers, numerical models and indicators in assessing and communicating the pandemic's progression, to the detriment of more qualitative research insights that could help explain infection patterns (Bardosh et al., 2020[27]) (see section on science advice). Pandemic modelling largely ignores important insights from behavioural research that do not easily fit into conventional statistical models.[20] Part of the challenge is that quantitative and qualitative data from SSH are often not openly available. Where they are available, they are frequently not well described or structured and, in the absence of common standards, are difficult to integrate with data from other sources. Where SSH and STEM have worked effectively together, such as in transdisciplinary research projects and some science advisory systems, this has generated valuable new insights for fighting the pandemic in a more holistic manner.

Disciplinary silos within research institutions and funding agencies have hampered the inter- and transdisciplinary research that has been required during the pandemic and will be necessary to address complex societal challenges in the future (OECD, 2020[18]).

A globally inclusive response to the pandemic has remained elusive

The pandemic has been truly global in nature. It has been clear from the outset that no single country will be safe until all countries are safe. Intergovernmental bodies, most notably WHO, and related international scientific networks, such as GLOPID-R, have tried hard to co-ordinate the global research effort. International RIs, networks and collaborations that existed prior to COVID-19 have been mobilised to support pandemic monitoring, identify research needs, and establish global research priorities and agendas. While researchers from all over the world have collaborated with each other regardless of their countries' geopolitical and ideological differences (see Chapter 2), the strategic global co-ordination of research has not been immune to such differences. The WHO research agenda for COVID-19 was established early in the pandemic, following consultation with leading experts from many countries (WHO, 2020[28]). It undoubtedly influenced many national research agendas, although this influence has not always been fully acknowledged. However, co-ordinated action to implement the global agenda was lacking, with governments competing rather than co-operating. It became a matter of national pride for the largest economies to have the best data sets and epidemiological models, produce their own vaccines, or lead their own clinical trials.[21] In the meantime, LMICs – which wanted to co-operate but struggled to compete – were largely left behind (or sometimes invited to host clinical studies led by other countries). The lack of political will to adopt a more global and inclusive approach to managing the pandemic was accentuated by a dearth of mechanisms allowing national research funders to truly co-operate and collaborate. While scientists do collaborate internationally, public research funding rarely crosses borders. There exist very few global RIs and, although international co-operation around data management and access is common in some scientific domains, it is not the norm in many fields.

Recommendations

1. Promote collaboration across disciplines and countries. Major global challenges cannot be fully addressed by a single scientific domain or country; shared RIs and digital technologies provide powerful tools to make effective links.

2. Adopt and promote a sociotechnical framing for solutions-focused research that addresses grand societal challenges and complex crises, recognising these cannot be adequately addressed by technology alone.

3. Recognise that citizen engagement and trust in science is critical to effective crisis response; promote citizen science and transdisciplinary research that addresses citizens' "lived experiences".

4. Establish international funding mechanisms, trusted relationships and scientific networks *now* that can respond to existing and future crises. It is important to build on what already exists, avoiding excessive duplication while recognising that a degree of redundancy can increase the overall resilience of a global system.

5. Address barriers to co-operation across disciplines and sectors, i.e. academia, government, the private sector and civil society. Much can be learned from successful co-operation efforts during the pandemic, but sustaining these over the longer term may require significant changes to academic culture, structures, incentives and rewards.

Science for policy (and decision-making)

Setting and implementing the research agenda

As discussed in the previous section, the international science community was engaged from the very early stages with WHO in setting a global research agenda to track the course of the pandemic and develop universally applicable interventions, such as diagnostics and vaccines (Figure 4.4). However, implementing this agenda proved challenging. Even within Europe, most COVID-19-related research was supported and performed at the national level, either to further basic understanding of COVID-19 or address national priorities and policy needs.

Figure 4.4. Setting global research priorities during the COVID-19 pandemic
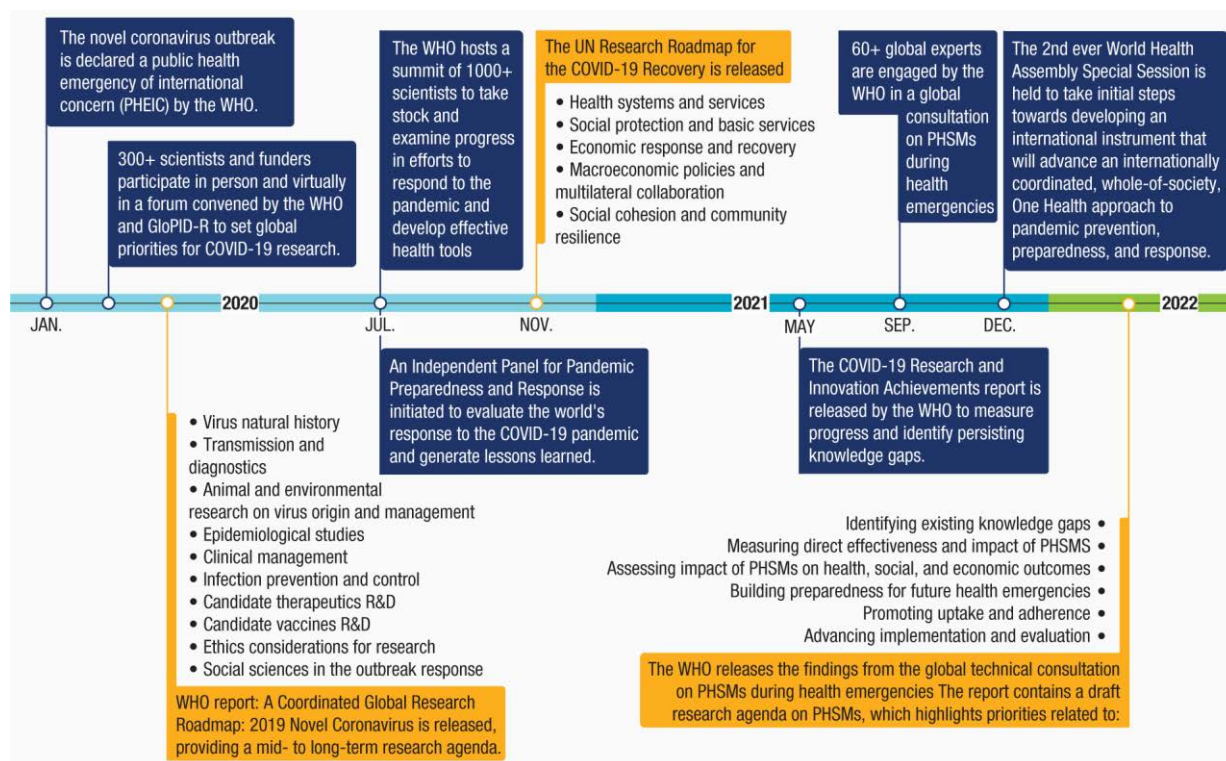
Note: The initiatives are illustrative and are not a fully comprehensive representation of all established international initiatives mobilised to set global research priorities during the COVID-19 pandemic response. Events outlined in orange represent times when formal priorities were released in reports. Summarised priorities are listed.
Source: Adapted by the authors from the timeline of the WHO's COVID-19 response (WHO, 2022[29]).

The biomedical community set the agenda early on

At the beginning, the pandemic was widely perceived as a mainly biomedical challenge, so that in most countries, the biomedical community and its relevant research-funding institutions took the lead in establishing a national research agenda. At this incipient stage, the challenge was to understand the disease and the likely progression of the pandemic, and to support the rapid development of diagnostic and therapeutic tools. Crisis managers and policy makers across government needed scientific information to understand what was happening, and what the options for mitigation were. To a large extent, the research community was left to develop its own research agenda and in so doing, to estimate future policy requirements based on past experience.

In early 2020, most OECD member countries rapidly implemented a variety of emergency funding measures to expand existing biomedical research and support new research to address COVID-19 (Paunov and Planes-Satorra, 2021[26]), (OECD, 2021[16]). As the pandemic developed and more scientific information

became available, knowledge gaps were identified and specific policy questions formulated, albeit still mainly focusing on biomedical issues. A number of basic questions, such as how the infectious agent was spread, were only adequately answered several months into the pandemic, and some of the initial assumptions, based on past pandemics, were probably given too much weight. Although the academic community held active discussions on some of these issues, rigorous studies were surprisingly slow to be implemented. In contrast, basic knowledge and understanding of the Sars-CoV-2 virus expanded enormously, leading to the rapid development of diagnostic tools, followed in record time by vaccines.

Public health and social measures came into the picture later

Once the extent of the pandemic became clear and the necessary data collection systems and epidemiological models were in place to generate reasonably reliable scenarios for its future course, the main policy questions and evidence gaps related to PHSMs. The expertise required to address these measures transcended biomedical research. In most countries, research on PHSMs barely featured in the initial emergency research-funding priorities that had been largely established by the biomedical research community; the response to COVID-19 from the social science research community was less of a priority and less co-ordinated, with a plethora of small-scale projects being funded and critical knowledge gaps remaining largely unaddressed. Thus, it was only in September 2021 that a rigorous study on the effectiveness of face masks in preventing the spread of COVID-19 was published (Abaluck et al., 2022[30]). While the effectiveness of measures such as lockdowns, school closures and "social bubbles" are context-specific and very much predicated on behaviour and compliance, the lack of a rigorous evidence base to inform the use of such policies has been a major challenge for managing the crisis (Glasziou, Michie and Fretheim, 2021[31]) (Figure 4.5). Where efforts have been made to implement the necessary research, they have sometimes been stifled by inflexible regulatory and ethical requirements that are not adapted to emergency public health situations.[22] There exists a need to establish baseline data on the effectiveness and acceptability of PHSMs, which will often require large sample numbers and internationally co-ordinated studies. As illustrated with clinical trials, establishing the conditions for conducting social intervention studies in untroubled times can be an important step in preparing for future crises.

Figure 4.5. COVID-19 evidence for health decision and policy making
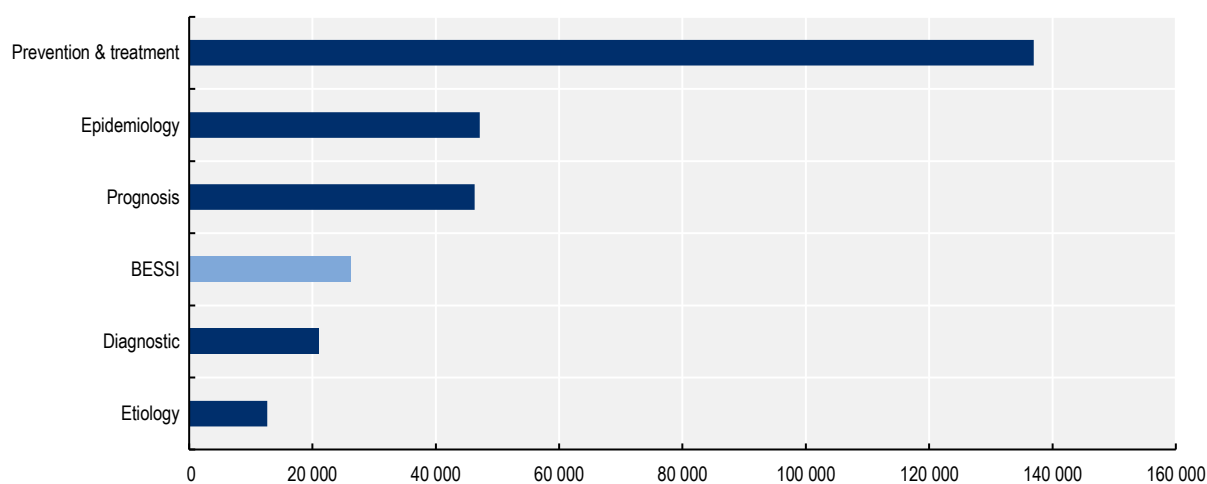
Note: The Living Overview of Evidence (L.OVE) data platform aggregates evidence for systematic reviews from multiple different sources, including the major scientific publication databases and clinical trial registries. It includes a dedicated collection for COVID-19 evidence, which classifies published materials according to treatment categories and is continually up-dated. The importance of behavioural, environmental, social and systems interventions (BESSI) in managing the epidemic is in contrast to the relatively limited amount of published scientific evidence in this field.
Source: Search results from the L.OVE database on COVID-19 Evidence (https://iloveevidence.com/) accessed on1 Dec.2022. Publications on behavioural, environmental, social and systems interventions (BESSI) articles are a sub-group of the Prevention & treatment articles category.

StatLink 🔗 https://stat.link/dqnvik

The contrast between the rapid development and testing of new vaccines and the lack of evidence for the use of PHSMs is reflected in how the pandemic was perceived from the outset, and which scientific disciplines were (or were not) involved in setting the initial research agendas and priorities. The biomedical research community did its job well, but the need to integrate existing knowledge and insights from a breadth of other disciplines (including SSH) was not fully recognised, and the processes for achieving this were lacking in most countries (see section on partnerships). In most OECD countries, interdisciplinary or cross-agency bodies were only established after several months to provide advice on research needs and broaden the evidence base for policy making (see section on science advice).[23] Moreover, the historical legacy of relatively weak co-operation across the social sciences, in areas such as standards for data management and access, impeded the integration and synthesis of this knowledge with other disciplines (Research Data Alliance, 2020[11]).

Future preparedness measures should ensure societal engagement

Several countries conducted pandemic preparedness exercises prior to COVID-19, although most were led by public administrations and did not heavily involve the science community. For a variety of reasons, these exercises – some of which were very insightful – seem to have been largely ignored or forgotten.[24] Only a small number of economies established formal public consultation or foresight exercises to inform research priorities during the pandemic.[25] Citizens have valuable expertise and experience that can improve the scientific response to crises (as discussed above in relation to long COVID). Their input will be critical in preparing for future crises and establishing research agendas that address the needs of different communities. In this context, non-governmental organisations, representing patient groups and different (often marginalised) communities, have an important role to play in ensuring that the research community pays the necessary attention to critical issues such as health inequalities or access to indigenous knowledge. Trusted civil society partners have a role play both in co-designing research agendas and co-producing the research that will allow a more inclusive response to ongoing and future crises.[26]

Recommendations:

1. Ensure better planning and co-ordination between research actors and authorities with responsibility for policy making and crisis response. This starts with joint risk assessment and preparedness exercises, feeding into improved mechanisms and processes for working together during crises.

2. Establish more effective two-way communication mechanisms and processes to alert policy makers to the implications of scientific research and analysis (e.g. early in a crisis) and ensure that research is conducted to address urgent policy questions (often later in a crisis).

3. Ensure that emergency research agendas are not too narrowly focused and address all aspects of a crisis from a scientific perspective; adopt more inclusive co-design approaches in identifying research priorities so that citizen concerns are considered and addressed as necessary.

4. Adopt a research-portfolio approach not only to support different aspects of research that directly address an immediate crisis, but also to ensure that the fundamental scientific knowledge base across all scientific domains continues to expand as a motor for socio-economic development and basis for responding to future crises.

5. Ensure that national and international research agendas focus strongly on health inequalities/social determinants of health, recognising that public health (and other) crises tend to affect disproportionately individuals with pre-existing health conditions; likewise, prioritise the collection of baseline data and rigorous evaluation of PHSMs for specific contexts.

Science advice

The interface between science and policy making is complex. It operates at different scales and involves multiple actors, including scientists, policy makers, risk analysts and crisis managers. As mentioned in the introduction to this chapter, scientific expertise and evidence were required to respond to multiple different policy demands during the COVID-19 pandemic. Scientists involved in providing policy advice were also often expected to play a role in communicating directly with the public. COVID-19 highlighted the critical importance of trust between the various actors within science advisory ecosystems and the public at large. In ideal situations, a virtuous triangle of trust between science, politics and the public was established; in practice, most countries struggled to maintain this trust over the duration of the crisis (Jasanoff et al., 2021[32]). In the absence of such trust, sound scientific evidence was either poorly taken up into policies and/or evidence-based policies were poorly taken up by significant sections of the public.

There exist as many different ways of organising science advice as there are OECD countries, although two broad categories of centralised or distributed systems have previously been described (OECD, 2018[4]). Both include a mix of permanent and ad-hoc structures and may, or may not, report to the centre of government through a chief science advisor (CSA). Often, government-employed risk managers play a critical intermediary role in interpreting scientific evidence for their political masters. Many ministries have considerable in-house scientific expertise and their own science advisory structures and, in some economies, the health ministry played the lead role in managing the COVID-19 crisis and advising government more broadly.

Distinctions between science advice and public policy were often blurred

Scientific evidence is only one input into policy making. There exists an important distinction between the roles of scientific advisors, who provide evidence to inform policy, and policy makers, who use this evidence as one of multiple considerations in deciding policy action. In a rapidly evolving crisis such as the COVID-19 pandemic, this distinction can be difficult to maintain and, where policies are unpopular, "following the science" can quickly revert to "blaming the science" (Greer et al., 2022[33]). This is exacerbated when the science itself is uncertain and there are divergent views within the science community, as was the case for many issues relating to COVID-19. Science advisors were often at the frontline, having to defend or explain policy actions for which they were not responsible. At the same time, scientists did not hesitate to publicly criticise some of these policies when they conflicted with their own scientific views. For example, the initial decision to close schools in some economies was based on best available, but incomplete, scientific evidence concerning COVID-19 transmission and also had to take into account many other socio-economic factors that were weighted differently in different contexts. This was not a purely scientific decision, although it was frequently portrayed as such in the public discourse, and many scientists voiced their opposition publicly.

In some jurisdictions, individual science advisors, e.g. CSAs or chief medical officers (CMOs), had more or less direct influence or control over certain policy decisions, whereas in others, a distance was maintained between advisory and decision-making functions. In this regard, there exists an important distinction between scientists employed directly by government (e.g. CSAs, CMOs or directors of national public health institutions), who may be mandated to directly advise on (or make) policy decisions, and independent academic scientists (e.g. chairs and members of ad-hoc scientific advisory committees), who are invited to provide advice to inform policies (MacAulay et al., 2021[34]). Being clear on the roles and responsibilities of individual scientific advisors and advisory committees, including any direct role in policy formulation and decision-making, is critical during a crisis (OECD, 2015[35]). While it is important that government scientists are able to express disagreement and dissent with their political masters in relation to scientific evidence, they are also limited by their mandate and responsibilities towards their employer (National Science and Technology Council, 2022[36]). Independent advisors from academia have more freedom in this respect, and have a major responsibility to ensure the rigour and completeness of the

evidence that informs policy. In a well-functioning advisory system, maintaining the balance between the roles of government scientists and independent academic scientists is critical; this is particularly true in a complex emergency such as the COVID-19 pandemic, where multiple scientific advisory structures may operate at different scales and with different remits (OECD, 2018[4]). Policy makers, scientists and the public at large need to develop a clearer understanding of the role of science in policy making, and how this operates in different jurisdictions.

A hierarchy of evidence emerged that favoured numerical data

As indicated previously, the early stages of the pandemic were characterised by the rapid mobilisation of the biomedical research community, which established the early research agendas and dominated the policy advisory processes. National and international scientific advisory committees mainly comprised researchers, epidemiologists, virologists, statisticians and mathematical modellers, with little room for behavioural and social sciences or humanities at the main table. Over time, as policy questions became clearer and the knowledge gaps were recognised, additional expertise was either brought to the main table, invited to set out its own table or simply self-organised to provide the necessary inputs.[27] However, the hierarchy of evidence that had been established from the outset, with a particular emphasis on "objective" numerical indicators, such as the "R factor", was difficult to resist, and social sciences have continued to struggle to make their voice heard in many contexts (Bardosh et al., 2020[27]). As discussed earlier, members of the SSH community were perhaps also less well-organised than their biomedical counterparts to respond collectively at the international level and influence the main policy messages coming from WHO and similar bodies that either directly or indirectly impacted national agendas.

Scientific consensus was often elusive under conditions of uncertainty and evidence gaps

The novelty of the infectious agent, the scale of the crisis and the absence of a prior knowledge base meant there was huge scientific uncertainty in the early stages of the pandemic. This decreased over time as fresh evidence was generated, data collection became more comprehensive, and models were refined to integrate a greater range of relevant variables. However, the SARS-Cov-2 virus has turned out to be highly unpredictable. Data gaps persist, particularly for certain countries and population groups, and pandemic models struggle to integrate behavioural insights, even when these are available.[17] The result is that there continues to be considerable uncertainty associated with much of the 'best available' scientific evidence that informs policy making. There are also different views within the scientific community as to the value of some of this evidence and, in particular, how it is translated into policy and decision-making. Hence, in the first few months of the pandemic, scientists could be heard advocating both for and against the use of face masks, and there have been several highly publicised disagreements by "experts" about the value of different COVID-19 treatments. While such differences in opinion are a normal part of the scientific process, the challenge in a crisis like COVID-19 is to manage them in such a way as to ensure that the 'best available' evidence is clear and can inform policy while additional evidence is collected, and at the same time, maintain public confidence and trust in science.

COVID-19 has taught us that reaching a scientific consensus on some of the critical issues in a complex crisis is not always possible, and that scientific uncertainties and ambiguities need to be openly discussed and debated (see Section 3.3.3 on science communication). Where advisory processes have not been completely transparent, or the scientific evidence informing policy has not been made openly available, this has led to considerable unease within both the scientific community and the public.[28] A lack of transparency, openness and accountability provides the ideal conditions for the development of conspiracy theories by those with an active interest in undermining science. In some economies, dissatisfaction with the transparency of the formal advisory processes led to the spontaneous creation of alternative science advisory mechanisms.[29]

The scientific response to the pandemic was "data-driven"; similarly, the policy response was dependent on having timely – ideally "real-time" – access to the necessary scientific data. The availability of data, and the ability to analyse and interpret them, were crucial for providing sound scientific advice. Two critical issues previously discussed in this chapter are worth emphasising again with respect to science advice:

1. *Data gaps and biases*. A lack of data from many countries, and from marginalised or vulnerable groups within countries, has translated into significant gaps in understanding the global epidemic and in the neglect of certain high-risk populations, such as migrants and homeless groups. In some countries, existing social surveys have been adapted or new data collection studies have been implemented to address specific data gaps.[11] However, even when inclusive data exist, there can be significant regulatory challenges to disaggregating them to identify particular population groups, severely limiting their usefulness.

2. *Integration and synthesis of information and data from different sources*. While many different disciplines and sectors have worked to make data FAIR, regulatory frameworks and privacy concerns often limit the integration of data from these different sources (OECD, 2020[14]). In addition to addressing technical and regulatory issues, there exists a need to develop the mindset, skills and science-based methodologies required to mediate and synthesise data and knowledge from different sources under emergency response timelines. Close engagement between disciplines using different and sometimes conflicting theories, terminologies and research approaches can generate tension. Emphasising and improving mediation and consensus-building abilities for both scientific experts and policy makers can help mitigate these tensions (Mulgan, 2021[37]).

International co-ordination around science advice has been patchy

Previous OECD work on scientific advice in crises identified systemic challenges for transnational co-operation and exchange of information (OECD, 2018[4]). Principal among these were:

1. a lack of domestic capacity in many countries

2. a lack of shared understanding of different advisory structures and mechanisms

3. a need for mutual respect and trust across countries.

It was also noted that crisis preparedness exercises have tended to focus on operational aspects and the role of crisis managers, and have rarely included scientists from outside government. All these issues were clearly apparent in relation to COVID-19 (OECD, 2020[38]). Science advice was required at different scales, from local to national, regional and global, but a lack of co-ordination was evident both within[30] and between countries, resulting in a lack of mutual learning.

No international agreement has been reached on some of the fundamental indices that have guided COVID-19 policies in all countries, such as the criteria for attributing a death to COVID-19, or how to measure the incidence and prevalence of infection (OECD, 2020[15]). Thus, drawing rigorous comparisons and monitoring the effectiveness of policy interventions has been difficult, even across countries with abundant data. Moreover, many countries have been unable or unwilling to share data. WHO health regulations provide a broad framework for the sharing of data during public health crises. WHO has worked with scientists to define international priorities for policy attention (see previously) but recognition has been poor in many countries, either owing to a lack of capacity or political will. This gap has been filled in some areas (e.g. genomics) by bottom-up science projects, but these have been largely dependent on existing infrastructure and relationships established on a voluntary basis prior to COVID-19. Hence, despite the best efforts of international infrastructure networks (e.g. ELIXIR and partners) and scientific co-ordination structures (e.g. GLOPID-R), substantial data gaps persist. Moreover, the use of international data to inform national policies has not always been sensitive to the perspectives of the countries from which the data originated. This was notably the case when South African scientists openly shared data on emerging

COVID-19 variants, leading some countries to take unilateral action to prevent travel to and from South Africa (The Lancet Infectious Diseases, 2022[39]).

Co-operation between countries in relation to science advice during the pandemic has tended to reflect prior political and economic alliances. Both the Group of Seven (G7) and the Group of Twenty (G20) made science-based declarations in the early stages of the pandemic, as did several public health monitoring and co-ordination structures in Europe and other regions.[31] As described earlier, WHO has its own science advisory mechanisms and released data and advice for all countries. In this respect, it has tried to provide a global scientific perspective and fulfil a global co-ordination role. Many of the scientific experts involved with WHO have played a leading role in providing scientific advice at the national or sub-national level and informally, this has helped to provide some coherence. However, for a global crisis, whose effects cannot be isolated to individual countries, the relative lack of effective international co-ordination around science advice has been striking (Piper, Gomis and Lee, 2022[40]).

Recommendations

1. Ensure that the full breadth of relevant scientific knowledge from different disciplines is readily available and taken into account to inform policy decisions. This begins with having the right people in the room, but also requires mechanisms for consensus-building and knowledge synthesis.

2. Ensure transparency and openness in science advisory procedures, acknowledging uncertainty and differences in scientific opinion. Holding open meetings, publishing full records of proceedings in a timely fashion and clearly presenting uncertainties and unknowns in public communications can all play a role in achieving this.

3. Establish procedures to improve real-time data collection and analysis in different scientific domains and enable information synthesis across domains with the aim of effectively informing policy makers.

4. Protect the autonomy and independence of science from political interference while at the same time ensuring that advisory processes are responsive to policy needs and societal concerns. The roles and responsibilities of science advisors, and the status and remit of different advisory bodies, should be clearly defined and understood.

5. Improve co-ordination of science advice across different scales, both between and within countries, and provide the necessary support to LMICs to build sustainable science advisory systems that leverage international expertise.

Public communication and engagement

The COVID-19 crisis has monopolised the public discourse worldwide for almost three years and continues to be a dominant subject of public debate in many countries. Science and science-based policy interventions have been the main focus for much of this communication activity. Scientists have become public celebrities in some countries, attracting both praise and criticism depending on the messages they communicate and how they are perceived by different sectors of society. In extreme cases, this has led to threats of violence, with measures needing to be taken to ensure the security of individual researchers and their institutions (Halverson et al., 2021[41]).

Building and maintaining public trust has been a critical challenge

The pandemic represented a new situation in terms of science communication, in that it is not just exciting breakthroughs and well-established facts that are being communicated to the public at the end of the scientific process, but rather the process itself that is in the public spotlight. The differing assumptions, hypotheses, uncertainties and corrections that are a normal part of how science advances are publicly

exposed and widely discussed. Debates on technical issues that would normally be expected to take place within the scientific community have become legitimate topics for open, sometimes heated, discussion on social networks. At the same time, many citizens who would not normally consider themselves scientists have rallied to the cause and contributed to the scientific evidence base that has informed policy interventions. As previously highlighted, citizen engagement – or citizen science in the broadest sense – has made many important contributions, from the development of apps and collection of data to the identification of long COVID (Provenzi and Barello, 2020[42]). Responsible and effective science communication and citizen engagement help establish public trust in both science and evidence-based policies. Building and maintaining this trust has been a critical challenge for science policy makers during the pandemic and will continue to be in the face of other complex societal challenges.

Traditional and more novel communication intermediation approaches were important

A variety of intermediaries are engaged in the public communication of science, from journalists and mainstream media to social media platforms. They play a critical gatekeeping role at the interface between science and different publics. Where good working relationships between science and these intermediaries have been established, particularly where a variety of intermediaries target different audiences, the dissemination of rigorous scientific information has generally been effective.[32] While for some audiences in some countries, access to well communicated scientific information from trusted and authoritative bodies satisfies their main demand, it has become clear during COVID-19 that many sections of society have greater expectations and needs.[33] Many citizens have specific questions relating to their particular contexts and have "lived experiences" of the pandemic they would like to be considered. For these groups, top-down delivery of scientific "facts" is not enough: they need avenues through which they can question the facts, as well as engage with and contribute to the data and information on which these are based (Best et al., 2021[43]).

The legitimacy of scientific communications rests not only on their scientific rigour, but also on the processes by which they are derived and the way in which they are delivered. Accountability, transparency and openness are equally important. An effective messenger or intermediary whom the target audience trusts is an essential element of effective science communication (Seale et al., 2022[44]), and various digital tools can provide a mechanism for effective two-way communication and engagement. It is not surprising, then, that these digital communication tools and platforms have been the main focus of the science policy initiatives implemented in many countries to improve science communication and address misinformation during the pandemic.[34] Novel partnerships between multinational social media platforms (such as Facebook), scientists and public health agencies have successfully and rapidly drawn upon resources and expertise to test different communication strategies for different population groups.[35] Such approaches have been used effectively to promote vaccination and address misinformation (Lesher, Pawelec and Desai, 2022[45]). At the same time, there are many citizens who do not have access to, or do not routinely use, digital tools. In most countries, traditional mainstream media (television, radio and newspapers) have been the main communication tool and the only source of scientific information for large population groups. The role of journalists has been critical and establishing trusted relationships between scientists and journalists has also been an important focus for improving science communication in some countries (Capurro et al., 2021[46]).[36]

Citizen engagement in science has been limited

Moving beyond communication towards deeper citizen engagement has been necessary to identify priorities, accelerate research and address certain aspects of the pandemic. Citizen-led science was important in identifying and describing long COVID. Some observers have noted a shift during the early phases of the pandemic from the traditional model of citizen engagement – which mainly views citizens as data suppliers – towards a more dynamic transdisciplinary model – which acknowledges the experience and expertise of citizens, and their contributions across the whole research. However – at least in relation

to long COVID – it has been suggested that the openness and inclusivity that characterised the first year of the pandemic response gave way to increasing polarisation as different parts of the scientific and medical establishment appropriated and "professionalised" citizens' knowledge.[37] The term "long COVID", which was initially coined in a scientific publication produced by citizens, has become a point of tension rather than a rallying point for the transdisciplinary research that will be needed to fully address a condition that is affecting millions of people worldwide.

In other areas, partnerships between scientists and non-governmental or civic organisations have been critical for accessing data and information from marginalised or neglected groups. Civic groups are often better positioned than governments or scientists to identify the needs of the public and marginalised population groups that might require specific services. Fact-checking and contact tracing can also be perceived as politicised activities that may create tension between governments and citizens. The general public does not like governments policing information (Kostka and Habich-Sobiegalla, 2022[47]). With contact tracing, citizens may perceive that their privacy is being invaded, but they may better tolerate such a policy if it is developed by a civic group they consider as trustworthy. Many citizen science or crowdsourcing initiatives during COVID-19 owe their success to the provision of open and transparent access to scientific and administrative data and resources.[23]

Knowledge deficits among citizens, scientists and communicators should be addressed

Effective science communication and citizen engagement hinge on scientific and digital literacy. As discussed earlier in relation to science advice, there exists a lack of common understanding among policy makers, scientists and the public at large concerning the role of science in policy making. The public also lacks an understanding of how science operates (e.g. the distinction between peer-reviewed and pre-print publications) and the digital literacy required to interpret data (e.g. grasping statistical significance and uncertainty). Most importantly, the scientific community itself does not always tap into the wealth of knowledge and expertise from behavioural and communications sciences when developing its public communication and engagement strategies. Educating and training scientists and the public is important to address these deficits. The pandemic has highlighted that facts alone are not sufficient to ensure effective science communication, and that relevant expertise and perspectives are not unique to scientists, particularly in relation to complex crises that affect the whole of society.

Recommendations

1. Support research integrity and efforts to ensure the rigour of the scientific information that informs public debate. The research community must establish the necessary quality control processes to ensure that publicly released research data and information can be trusted, and the caveats around their usage are clear and transparent.

2. Recognise that scientific communication cannot be restricted to hard data or "facts" – it must be contextualised for different publics. Behavioural and social scientists can play an important role in providing the necessary background for communicating relevant information to different communities.

3. Support the science community in building trusted and sustainable relationships with a variety of communication intermediaries, including journalists, non-governmental organisations and social media platforms.

4. Address scientific misinformation by improving the digital and scientific literacy of citizens and policy makers. This requires a cross-governmental approach, although science agencies have an important contribution to make in supporting and valuing public engagement and communication activities.

5. Recognise that the conditions for effective citizen engagement need to be established in "peacetime". This requires long-term support for citizen engagement as well as for open data and information infrastructures that can be mobilised and used by citizens in times of crisis.

Looking forward: Maintaining the best, improving the rest

At the time of writing, the COVID-19 pandemic is not over. Much scientific research is still focused on this area, although the attention of the public health and biomedical research community is also turning towards new epidemics, such as monkeypox or Marburg virus disease. At the same time, the immediacy of the climate crisis has become clearer, and biodiversity loss (on land and in the oceans) has accelerated, with enormous implications for societies. Natural disasters linked with geopolitical crises and wars are massively disrupting the global socio-economic system. Science has provided much of the evidence that informs our understanding of how these crises have arisen and are evolving. Scientists have developed realistic future scenarios to inform the policy response to environmental challenges, and related concerns such as energy and food security. The challenge today is for science to engage with other public- and private-sector actors and citizens to accelerate the development and implementation of the new knowledge and technological solutions required to address these issues. The scientific response to the COVID-19 pandemic can teach us a lot in this regard.

Science has a critical role to play in the transition to sustainable development trajectories. As with the response to COVID-19, this will depend on refocusing, adapting, accelerating, enabling and scaling up existing activities and processes. Four essential steps need to be taken to achieve this:

1. The importance of the full breadth of scientific knowledge needs to be clearly recognised. It will be essential for policy makers to continue supporting a broad range of discovery science and investigator-driven research, like that which underpinned the development of COVID-19 vaccines.

2. At the same time, there will need to be a significant shift from business-as-usual to rapidly scale-up research approaches that focus on urgently required solutions for complex socio-technical challenges. This means addressing some of the long-term structural challenges embedded in academia. It means implementing new incentive and evaluation systems that promote inter- and transdisciplinary research, and strengthening the three pillars of open science (access to scientific information, access to data and public engagement).

3. Sustained, long-term investment is required to ensure that underlying infrastructures, resources and methodologies are in place, and that inclusion and equity are embedded in science planning and throughout the research process.

4. It will be important to address entrenched geographical, disciplinary and sectoral silos. Actors from across countries, scientific disciplines and sectors must come together to better understand, navigate and develop solutions that advance the collective position, while engaging with conflicting priorities and interests. Shepherding such complex interactions will require new approaches to governance that are capable of facilitating, enabling, and uniting bottom-up and decentralised initiatives with broader top-down and future-focused strategies (see Chapter 5 on mission-oriented innovation policies for net zero).

Many of the required changes are already underway but are not yet being adopted at the necessary scale and speed. There is considerable inertia embedded in science systems. Over the past decades, science policy has mainly focused on incremental developments, which have enabled them to improve their performance as judged by traditional output measures (such as bibliometrics or patents). More radical change is now necessary to spur science to engage with other societal stakeholders to produce the broader range of outputs and solutions that are urgently required to deal with complex global challenges and crises.

Many countries and organisations have initiated their own evaluations of their response to COVID-19. The performance of science should be an important focus of such exercises. The four steps above, and the more detailed thematic recommendations in this chapter, provide a starting point for considering how national science systems can – and must – evolve to function as part of a balanced, well-connected and inclusive global science ecosystem. Sustainable investment will be critical, but this must be accompanied by institutional change and policy actions that support and incentivise science for the global good.

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Notes

[1] Several earlier OECD reports have reviewed the scientific initiatives and policies introduced in the initial phases of the COVID-19 pandemic response. See, for example, (OECD, 2021[16]), (Paunov and Planes-Satorra, 2021[26]) and (Paunov and Planes-Satorra, 2021[48]). Additionally, a catalogue of country-submitted COVID-19-specific science policies is available through the COVID-19 Watch portal of the EC-OECD STIP Compass (https://stip.oecd.org/covid/).

[2] Six international virtual workshops were organised in the context of the OECD "Mobilising science in response to crises: Lessons learned from COVID-19" project. These workshops addressed the following topics: 1) research data; 2) research infrastructures; 3) the interface between academia and the private sector; 4) research agenda-setting; 5) scientific advice; and 6) public communication and engagement. All background materials and resulting reports can be accessed online (https://www.oecd.org/sti/inno/global-science-forum.htm).

[3] The COVID-19 Open Research Dataset (CORD-19) provided the basis for the CORD-19 Challenge (https://www.kaggle.com/allen-institute-for-ai/CORD-19-research-challenge), a collaboration between NIH and the Allen Institute that uses the Kaggle platform. The challenge launches competitions in which the community uses AI and machine learning to analyse the literature and come up with new insights in response to specific questions. While the CORD-19 corpus is extensive, it does not include all articles relevant to the pandemic; there are gaps, for example, in relation to social sciences and humanities (SSH). There are also longer-term questions about its continuing availability and what will happen post-pandemic (see also the workshop report on research data (https://www.oecd.org/fr/sti/inno/improving-academia-private-sector-interactions.htm).

[4] Publications are identified as COVID-19 related based on the following PubMed search: ("COVID-19" OR "COVID-19"[MeSH Terms] OR "COVID-19 Vaccines" OR "COVID-19 Vaccines"[MeSH Terms] OR "COVID-19 serotherapy" OR "COVID-19 serotherapy"[Supplementary Concept] OR "COVID-19 Nucleic Acid Testing" OR "covid-19 nucleic acid testing"[MeSH Terms] OR "COVID-19 Serological Testing" OR "covid-19 serological testing"[MeSH Terms] OR "COVID-19 Testing" OR "covid-19 testing"[MeSH Terms] OR "SARS-CoV-2" OR "sars-cov-2"[MeSH Terms] OR "Severe Acute Respiratory Syndrome Coronavirus 2" OR "NCOV" OR "2019 NCOV" OR (("coronavirus"[MeSH Terms] OR "coronavirus" OR "COV"). Publications are identified as diabetes related based on the following PubMed search: "diabete"[All Fields] OR "diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields] OR "diabetic"[All Fields] OR "diabetics"[All Fields] OR "diabets"[All Fields]) Publications are identified as dementia related based on the following PubMed search: "dementia"[MeSH Terms] OR "dementia"[All Fields] OR "dementias"[All Fields] OR "dementia s"[All Fields]

[5] The European Alliance of Medical Research Infrastructures (AMRI) is a novel collaboration between three European research infrastructure consortiums (ERICs): the Biobanking and Biomolecular Resources Research Infrastructure (BBMRI)-ERIC; the European Advanced Translational Research Infrastructure in Medicine (EATRIS)-ERIC; and the European Clinical Research Infrastructure Network (ECRIN)-ERIC. The Alliance aims to streamline access to services, tools and expertise. During the COVID-19 response, AMRI established a fast-response service to accelerate access to facilities and services.

6 The Analytical Research Infrastructures of Europe (https://arie-eu.org/) is a consortium of 7 European research networks that collaborate to address missions that have been identified in the European Commission (EC) research programme "Horizon Europe". The consortium has helped co-ordinate European efforts across many aspects of the COVID-19 response, from identifying the virus to developing countermeasures.

7 NHLBI CONNECTS (https://www.nhlbi.nih.gov/science/collaborating-network-networks-evaluating-covid-19-and-therapeutic-strategies-connects) is the US-NIH National Heart, Lung, and Blood Institute's (NHLBI) Collaborating Network of Networks for Evaluating COVID-19 and Therapeutic Strategies. The network was formed in response to the COVID-19 pandemic. It provides a centralised and adaptive platform and has established master protocols to integrate all major NHLBI clinical trial networks.

8 During the COVID-19 pandemic, the UK-based Pirbright Institute supported the National Health Services in building diagnostic testing capacity. It supplied critical infrastructure, staff and scientists while also providing training to new staff on sample management, biosafety and scientific diagnostic procedures (see the workshop report on Research Infrastructures (https://www.oecd.org/sti/inno/research-infrastructures-mobilisation.htm).

9 Several clinical research infrastructures have provided support for developing and testing new diagnostics and therapies during the COVID-19 response. The European Clinical Research Infrastructure Network established a COVID-19 Taskforce (https://ecrin.org/covid-19-taskforce) with national partners to perform a variety of tasks. These included developing a metadata repository for COVID-19 trials and a database of fast-track approvals (regulatory, ethical, data protection) across European countries. The European Research Infrastructure on Highly Pathogenic Agents (https://www.erinha.eu/access-our-services/covid19-services/) also provides targeted support for SARS-CoV-2 studies, including access to various high-containment in-vitro and in-vivo capacities, pre-clinical research co-ordination, and information on research protocols and design.

10 Participants in the OECD "priority setting and funding workshop" (https://www.oecd.org/sti/inno/priority-setting-and-coordination-of-research.htm) attested that by November 2020, hundreds of clinical trials had been registered, with many lacking the size or standardisation required to produce robust results. By May 2021, more than 2 900 COVID-19-related clinical trials had been registered; however, many were underpowered and lacked the necessary conditions for developing robust, statistically significant scientific results (Pearson, 2021[49]), (Seidler et al., 2021[50]). The urgency of the situation in which the majority of trials were launched resulted in significant duplication of efforts.

11 Aside from NHLBI CONNECTS (see Note 6), a variety of efforts have been undertaken to develop COVID-19 vaccination and therapeutic platforms capable of co-ordinating and streamlining countermeasure development and testing efforts. Randomised Evaluation of COVID-19 Therapy (RECOVERY) is an international clinical trial run by the University of Oxford aiming to identify and assess potential treatments for hospitalised COVID-19 patients (https://www.recoverytrial.net/). VACCELERATE is a pan-European clinical research network (including 29 national partners in 18 EU Member States) that co-ordinates the second and third phases of COVID-19 vaccine trials (https://vaccelerate.eu/). Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV) is a US-based public-private partnership created to expedite the development of COVID-19-specific vaccines and treatments (https://fnih.org/our-programs/ACTIV). In France, COVIREIVAC was established by the Innovative Clinical Research Network in Vaccinology (I-REIVAC), with support from several other national organisations, to enable academic and industrial COVID-19 vaccine trials (Bonneton et al., 2022[51]).

[12] The US COVID-19 High Performance Computing (HPC) Consortium (https://covid19-hpc-consortium.org/) is a network with members from industry, academia, and federal laboratories and agencies that share computing capabilities ranging from small clusters to large supercomputers. The consortium was established in March 2020, originally as a US-based public-private partnership between the Office of Science and Technology Policy, the Department of Energy, the National Science Foundation and IBM. Its goal is to provide a single point of access to HPC and cloud computing resources, technical expertise and other forms of support to underpin research on COVID-19.

[13] In Some countries, long-term investments in social-science data infrastructures and community-based surveys proved important in ensuring that scientists and policy makers had timely access to the necessary data. Examples from the United Kingdom and South Africa were discussed at the project workshop on scientific advice (https://www.oecd.org/sti/inno/scientificadviceincriseslessonslearnedfromcovid-19.htm). South Africa was able to draw on an extensive network of social science infrastructures to conduct timely surveys on public perceptions of interventions. The United Kingdom was able to accelerate its regulatory and ethical approval processes and rapidly adapt existing longitudinal household surveys to understand the local characteristics of viral transmission and individual experiences.

[14] The European life sciences infrastructure for biological information, ELIXIR, has supported the co-ordination and advancement of COVID-19 research efforts through services related to storing, sharing and accessing relevant data, publications and computing resources (https://elixir-europe.org/services/covid-19). The European and Developing Countries Clinical Trials Partnership is a research partnership between 14 European and 16 African countries founded in 2003 (https://www.edctp.org/). In 2020, the Partnership launched an emergency funding call to support 24 international COVID-19-related research collaborations. Since 2018, it has also supported ALERRT (African coaLition for Epidemic Research Response and Training) and PANDORA-ID-NET (Pan-African Network for Rapid Research, Response, Relief, and Preparedness for Infectious Disease Epidemics) in improving the pandemic preparedness and response capacities of sub-Saharan African countries.

[15] mRNA: Messenger RNA.

[16] The COVID Moonshot project (https://postera.ai/moonshot/), an international open science consortium of scientists, pharmaceutical research teams and students, is one of the few (at least partial) success stories regarding novel COVID-19 therapeutics. The collaboration was developed bottom-up: it was initiated through Twitter and supported at the institutional level by recognised stakeholders, including the University of Oxford, the UK Synchotron Diamond Light Source and the Wellcome Trust. The project has pioneered a novel approach to drug discovery, using informal and open collaboration in the absence of formal contracts or ex ante intellectual property rights agreements. It has managed to leverage the resources, knowledge and expertise of hundreds of scientists and other actors to develop and undertake early-phase testing of several promising drug candidates. However, the project has struggled to find a business model to move these products from the laboratory to the bedside, and in such a way as to provide equitable and affordable access.

[17] A number of these initiatives were presented as case studies in the September 2021 OECD workshop on academia-private-sector interactions (https://www.oecd.org/sti/inno/improving-academia-private-sector-interactions.htm), as well as in (Kreiling and Paunov, 2021[21]). These cases illustrate some of the novel collaboration models introduced to improve science-industry partnerships, many of which were also characterized by the participation of community groups or citizens.

[18] In Finland, the Fast Expert Teams initiative (https://oecd-opsi.org/covid-response/fast-expert-teams-vs-covid-19-how-to-help-finland-avoid-paralyzing-when-experts-cannot-meet-f2f/) leveraged digital tools and platforms to accelerate the development of trust across sectoral barriers, and align different expectations. The project used an informal "snowball" approach to accelerate the engagement of new participants.

[19] To streamline and accelerate applications for research grants during the COVID-19 pandemic response, several national agencies in Ireland shared the same application portal. Project selection and funding was determined at the "back end" in accordance with funders' specific mandates, but applicants submitted single proposals (see workshop on academia-private sector interface (https://www.oecd.org/fr/sti/inno/improving-academia-private-sector-interactions.htm).

[20] The engagement of super-forecasting experts may help integrate a broader array of variables into conventional statistical modelling efforts. Alternatively, the University of Hong Kong School of Public Health has used epidemic nowcasting during the COVID-19 response to inform policy decisions. This multidisciplinary approach has enabled scientists to assess and forecast transmissibility and epidemic size with greater accuracy, and to identify emerging variants (see workshop on research agenda setting, (https://www.oecd.org/sti/inno/priority-setting-and-coordination-of-research.htm).

[21] Nationalism has been a major barrier to international pandemic preparedness and response activities. Countries tend to prioritise only those activities that will advance domestic scientific standing and interests (see workshop on research agenda setting (https://www.oecd.org/sti/inno/priority-setting-and-coordination-of-research.htm). In addition, despite early consensus regarding the need for equitable allocation of countermeasures, many developed countries used advanced purchasing agreements to secure domestic supplies, delaying access for LMICs (Thornton, Wilson and Gandhi, 2022[52]).

[22] For example, attempts by the Norwegian Institute of Public Health to use randomized control trials to assess the effectiveness of PHSMs during the pandemic were thwarted by regulations that require individual consent from all participants (see workshop on research agenda setting, (https://www.oecd.org/sti/inno/priority-setting-and-coordination-of-research.htm).

[23] Most OECD countries initially focused on engaging experts from the biomedical and life sciences fields before it was recognised that broader disciplinary expertise was required to address some aspects of the evolving pandemic. In some countries, including the Netherlands, dedicated behavioural and social science research units were created, but they were not fully integrated into the formal apparatus informing policy makers (see workshop on scientific advice (https://www.oecd.org/sti/inno/scientificadviceincriseslessonslearnedfromcovid-19.htm).

[24] For example, the 2017-21 US administration was criticised (Diamond and Toosi, 2020[53]) for its failure to effectively apply guidelines outlined in the Playbook for Early Response to High-Consequence Emerging Infectious Disease Threats and Biological Incidents. The playbook was developed in 2016 by the National Security Council in response to the country's reaction to of the 2014 Ebola crisis. Similar pandemic preparedness exercises – often focused on the influenza virus – were conducted in other countries, including the United Kingdom, and at the European level, but the weaknesses identified, including shortages of protective equipment, were not addressed prior to COVID-19 (Cohen and Rodgers, 2020[54]).

[25] Based on an analysis of countries' COVID-19-specific science policies using the COVID-19 Watch portal of the EC-OECD STIP Compass (https://stip.oecd.org/covid/), only a small number of policies from the European Union, Germany and Belgium referenced foresight, preparedness or risk assessments. Regarding public communication and engagement, the reported policies focused mainly on making science advice accessible to the public, and only a handful explicitly engaged citizens.

[26] In Chinese Taipei, the participation of civilians and civil society organisations in COVID-19 mitigation activities has contributed in important ways to the initial success of the pandemic response. Civilians voluntarily engaged in efforts to monitor and trace transmission of the virus. In addition, private individuals and community groups led the development of inventory maps for personal protective equipment (Perng, 2022[55]) (see workshop on public communication and engagement (https://www.oecd.org/sti/inno/public-communication-engagement-in-science.htm

[27] For instance, like many OECD countries, behavioural science was not part of the initial response in the Netherlands. The country's Corona Behavioural Unit only came together in late March 2020, in response to rapidly increasing case numbers and recognition of the important role of human behaviour in the pandemic response. However, the new group moved quickly, securing funding and research grants, and assembling a scientific board over the course of several weeks (see workshop on scientific advice (https://www.oecd.org/sti/inno/scientificadviceincriseslessonslearnedfromcovid-19.htm) and behavioural science webinar, https://ianphi.org/news/2020/covid-19-behavioral-science-webinar.html).

[28] Norwegian public health officials adopted several tactics to communicate transparently regarding the COVID-19 response, including active participation in televised debates and direct engagement with the public through social media platforms (Ihlen et al., 2022[56]) (see workshop on scientific advice (https://www.oecd.org/sti/inno/scientificadviceincriseslessonslearnedfromcovid-19.htm).

[29] In the United Kingdom, concerns about the methods and procedures of the government Science Advisory Group on Emergencies (SAGE) led to the creation of an "alternative SAGE", which had no official mandate but was chaired by a former CSA. In the Netherlands, dissatisfaction with the formally mandated Outbreak Management Team led to creation of a shadow science advisory process by the so-called Red Team (see workshop on scientific advice (https://www.oecd.org/sti/inno/scientificadviceincriseslessonslearnedfromcovid-19.htm).

[30] Access to comparable data, disaggregated by location, was important to develop science advice and policies targeted to the local situation. However, some countries found this challenging for a variety of reasons, including poor compatibility between federal and local processes. For example, participants in the workshop on scientific advicenoted that in Australia, data gaps contributed to a lack of policy co-ordination and integration across different levels of governance (https://www.oecd.org/sti/inno/scientificadviceincriseslessonslearnedfromcovid-19.htm).

[31] The "G7 Science and Technology Ministers' Declaration on COVID-19", released on 28 May 2020, provides a shared vision for the use of science and technology to develop effective countermeasures, global co-ordination of R&D and improved access to data (G7, 2020[57]). Under the UK G7 Presidency, leaders also committed to a "100 Days Mission" targeting the development of diagnostics, therapeutics and vaccines (UK G7, 2021[58]). In November 2020, the G20 released the "Extraordinary G20 Leaders' Summit Statement on COVID-19 recognising the global need for a transparent and science-based response to COVID-19" (G20, 2020[59]).

[32] In some countries, scientists were able to rely on connections with the news media that had been established prior to the pandemic. For example, FactCheck Initiative Japan (https://en.fij.info/), established in 2017, brings together scientists and journalists to verify online information. A number of new science communication initiatives were also launched in response to the COVID-19 pandemic, including the Royal Society of Canada's Task Force on COVID-19 (https://rsc-src.ca/en/themes/rsc-task-force-covid-19), which has published over 150 opinion pieces in news publications (see workshop on public communication and engagement (https://www.oecd.org/sti/inno/public-communication-engagement-in-science.htm).

[33] The COVID-19 pandemic has highlighted the importance of health equity and social determinants of health, which help explain why certain population groups were more severely affected. It is important to take fuller account of these groups in the development of scientific advice, linking this to targeted communication campaigns that address specific needs. The US Centres for Disease Control has taken steps to integrate health equity into science activities across its portfolio, including the investigation of underlying drivers such as racism (Centers for Disease Control and Prevention, 2022[60]) (see workshop on scientific advice (https://www.oecd.org/sti/inno/scientificadviceincriseslessonslearnedfromcovid-19.htm).

[34] According to the snapshot of COVID-19-specific policies captured through the STIP Compass COVID-19 Watch, digital tools and platforms made up the bulk of the communication initiatives policy makers deployed to communicate or engage with the public. Approaches ranged from passive communication via websites to more active engagement through social media and mobile applications, including WhatsApp or chatbots (EC-OECD, 2021[61]).

[35] Social media companies have been involved in a variety of initiatives to amplify validated scientific narratives and address harmful or questionable claims across countries. For example, Facebook has: used COVID-19 vaccine profile frames to improve visibility and trust of vaccines; supported users in exploiting marketing tools for public health campaigns campaigns tailored to specific demographics; and subsidised the advertisement budgets of trusted public health authorities (see workshop on Public communication and engagement https://www.oecd.org/sti/inno/public-communication-engagement-in-science.htm).

[36] FactCheck Initiative Japan (https://en.fij.info/about/) is a coalition of academics, journalists and non-profit organisations created in 2017 to address the risks posed by misinformation. During the COVID-19 pandemic, the network focused on validating COVID-19 information originating in Japan and checking questionable claims that had spread to Japan from abroad. Several national and international media partners are engaged in the initiative, including SmartNews, Yahoo! Japan and BuzzFeed Japan.

[37] The term "long COVID" was coined on Twitter in May 2020 by Elisa Perego, a social scientist experiencing a chronic reaction to the virus (Callard and Perego, 2021[62]). Use of the term gained traction in a matter of weeks. However, the condition or syndrome and its symptoms have been contested within the scientific community and there have attempts to give it a variety of medical labels, with patients often excluded from pertinent discussions (see workshop on Public communication and engagement (https://www.oecd.org/sti/inno/public-communication-engagement-in-science.htm).
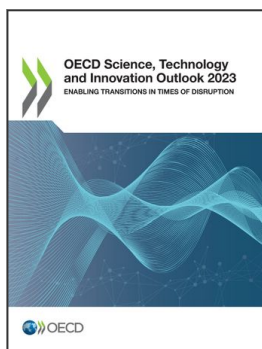
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