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SCIENTIFIC ADVISORY SYSTEMS: EXPERIENCES FROM ACROSS THE WORLD

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1. INTRODUCTION

Policy decisions are often influenced by changing social, ethical, political, environmental, and technological issues that challenge policy-makers' ability to respond to these challenges. To navigate changing scenarios, science advice and evidence are key inputs for policy-making. However, experts' authority and legitimacy are under increasing scrutiny, particularly in pressing health or climate change issues. Simultaneously, questions and challenges that require answers and solutions that depend on the knowledge and experience of scientists, engineers and other experts continue to multiply (Wilsdon, Allen, & Paulavets, 2014). This difficult balance makes scientific advice more relevant than ever. However, barriers such as misinformation and limited scientific expertise among decision-makers can prevent scientific evidence from informing government decisions. One way to mitigate this gap is through scientific advisory systems, which comprise departments, commissions, research centres or other entities that provide knowledge and expert advice to decision-makers (OECD, 2017). Advisory systems and the entities that comprise them can exist at the international, national or national level.

Scientific advisory systems have evolved over the years to adapt to countries' social and political contexts or to respond to emergencies or unusual situations. Some advisory systems have long trajectories and have been in place for decades, like those in Germany and the UK. Others have been modelled on successful systems and continue to adapt – for example, Canada's system. Despite their differences, the experiences of existing advisory systems are a valuable source of information for similar systems in other countries. Lessons and good practices are particularly relevant currently as countries devise strategies to recover from the global pandemic and to respond to future challenges, and rely on science to do so. This document gathers experiences from different advisory systems worldwide and identifies key features that can inform advisory processes elsewhere.

An advisory system and its actors (e.g. government entities, universities and think tanks) are a part of the broader knowledge ecosystem in which different types of actors interact at various times and at different levels, generating and using knowledge (OECD, 2017). Thus actors from different arenas (e.g. government or private sector) can provide scientific advice to each other. The process can also be informal (e.g. think tanks advising the government on an ad hoc basis) or formal (created and regulated by law). This paper focuses on scientific advisory systems and entities whose primary function is to formally provide scientific advice to the government (central government, ministries, parliament). At whatever level the scientific advice is received, the government is considered the recipient. This

distinction is made because there are entities financed with public funds or a mixture of public and private funds, and their primary function is to advise the private sector or other actors, not governments. This review also does not focus on actors such as independent think tanks or research centres. However, we recognise that they can and do fulfil advisory functions in specific contexts.

We understand *scientific advisory systems* as the institutions and practices through which governments and decision-makers receive and use science and technology as inputs for developing public policies in various fields (Quirion, Carty, & Jabr, 2016). Scientific advisory entities are usually aligned with departments of government but are independent. Their primary role is to provide access to a wide range of knowledge, skills and experience that help to ensure that public policies and government decisions are based on scientific evidence (OECD, 2017; Glynn, Cunningham, & Flanagan, 2003).

We have chosen to review the structures and practices of advisory systems that focus on governments, given the important role they played (and still play) during the COVID-19 pandemic. The global pandemic shocked the world and showed governments' strengths and weaknesses in their responses to the crisis. Arguably, one of the most important lessons governments learnt (or should have learnt) from the pandemic is that science advice is necessary to inform crucial decisions. It is not optional. While there are various sources of scientific advice, governments play a key role in creating the spaces for scientific evidence to be created and used promptly to inform crucial decisions affecting the public. As global challenges become increasingly complex, scientific evidence should be an integral element of decision-making and policy design. With this review, we seek to identify practices and lessons that can strengthen the production and use of scientific evidence and can inform the development of scientific advisory systems across the world.

Since advisory systems are strongly connected to their contexts (their characteristics and functions respond to local conditions and challenges), we have selected systems from nine countries so as to provide regional and institutional diversity. In this paper, we look at two countries from the Commonwealth (Canada and the United Kingdom), two from the European Union (Germany and Spain), and two from Latin America (Chile and Brazil).

This review of current scientific advisory systems is based on secondary sources of information in academic journals, official reports, policy analysis, news outlets and institutional websites. Section 2 briefly outlines advisory systems' key characteristics, offering a frame for understanding the different systems across

the selected countries. Section 3 describes the scientific advisory systems in the selected countries. Finally, section 4 summarises the main findings of the analysed cases and identifies lessons and good practices that could inform the creation or reform of advisory systems.

Throughout this report we use several terms that have different definitions and interpretations in the research and policy fields: *science*, *scientific evidence*, *knowledge ecosystem*, *scientific advisory system*, and their entities. The definitions used in this document are set out in Box 1 below.

Box 1. Key terminology

Science

We are aware that the concept of science is contested, and we recognise diverse understandings of what science entails. However, in many instances of scientific advice, the term *science* refers to the natural sciences, including the life sciences and physical sciences. It is important to note that many governments use *science* to refer to the natural sciences. In the context of scientific advice, a broader definition of science (including the social sciences) is not common, though is not entirely absent.

Scientific evidence

We understand scientific evidence as information gathered from scientific research that has been conducted in a methodologically robust way and that has been peer reviewed.

Knowledge ecosystem

A knowledge ecosystem is the space in which actors, such as universities, government entities, public research institutions, think tanks, interact and collaborate to create new knowledge. Knowledge ecosystems can form around specific technological or societal challenges or among geographically co-located organisations in complementary fields.

Scientific advisory system

Scientific advisory systems are the institutions and practices through which governments and decision-makers receive and use science and technology as inputs for the development of public policies.

2. KEY CHARACTERISTICS OF SCIENTIFIC ADVISORY SYSTEMS

Scientific advisory systems can have different characteristics depending on the context they operate in and their purpose. Before discussing the characteristics of advisory systems, it is important to understand that scientific advice can fulfil two functions: 1) *science for policy:* scientific evidence is provided to inform policy in different areas; and 2) *policy for science:* policies related to science and technology (i.e. promotion of science, innovation, higher education policies, etc.). In this review, we focus on the first type: science for policy. Advisory systems can sometimes fulfil both functions. In the countries we reviewed, when an entity fulfilled both functions, we only focused on the policy for science function.

Other important features that characterise advisory systems include their formality (permanent or ad hoc), functions relative to the public policy formulation stage, and organisational structures.

Formality

Advisory entities can be permanent or ad hoc. *Permanent advisory entities* are often part of the organisational structure of the state. In some cases, they are a formal part of ministries or other official entities. They are usually appointed by the highest decision-making levels (e.g. president or prime minister). *Ad hoc entities* are instances that are created for a particular purpose and are usually temporary. They have explicit functions, and can be dissolved when the purpose for which they were created has been fulfilled. They can also cease to exist if the issue or problem they address is no longer relevant or has changed.

Structures

Advisory entities have different organisational structures. According to a classification by the OECD (2017), scientific advisory systems can be structured in three ways:

- *As part of the government.* They encompass individuals or entities of the public service, such as political advisers or strategic and advisory units that are part of the government's formal structures, for example, a chief scientist office.
- *Close to the government but not part of the public service (at arm's length).* These actors and entities function within the government but are not an institutional part of the public service. These include, for example, advisory bodies, commissions, councils, institutes, and research funds. Entities of

this type function within the government, but usually as autonomous or semi-autonomous entities.

- *External to the government*. These entities function outside of the executive branch of government and are entirely autonomous. Examples of this type of entity include universities, think tanks, research institutes, unions and citizen committees.

Within these three main structures, entities can also be structured as committees, commissions, working groups, panels or boards of experts, offices (of the chief scientific adviser, for example) (OECD, 2017). Organisational structures vary significantly depending on the context and the functions of the advisory entity. For example, permanent advisory entities tend to have structures similar to research institutes or organisations with fixed positions and hierarchical structures (Glynn, Cunningham, & Flanagan, 2003; Grobbelaar, 2008). Ad hoc entities are often created by presidential or ministerial decree and can receive administrative or logistical support from existing entities. In general, the most common forms of organisation of advisory entities are: [1]

- *Principal scientific adviser*

  The principal scientific adviser is usually appointed by the head of government to provide scientific advice at the highest level. One of the functions of the main scientific adviser is to be a link between science and policy. In addition, and depending on the country, the principal scientific adviser may have an office or secretariat that carries out support functions.

- *Expert committees or commissions*

  Expert committees and commissions are groups of people selected or appointed by the competent authority to fulfil a specific function for a specified period. Although it is common for committees and commissions to be ad hoc in nature and to dissolve once the purposes for which they were created have been fulfilled, they can also be created permanently.

- *Experts panel*

  A group of independent experts called to evaluate or give their opinion and/or specialised advice on a particular subject. Panels of experts are not always permanent, but they can be part of an institution's organisational structure and called upon to confer in specific situations.

[1] These definitions are based on those used in the literature and on observations of the functions and forms of structures in different national contexts.

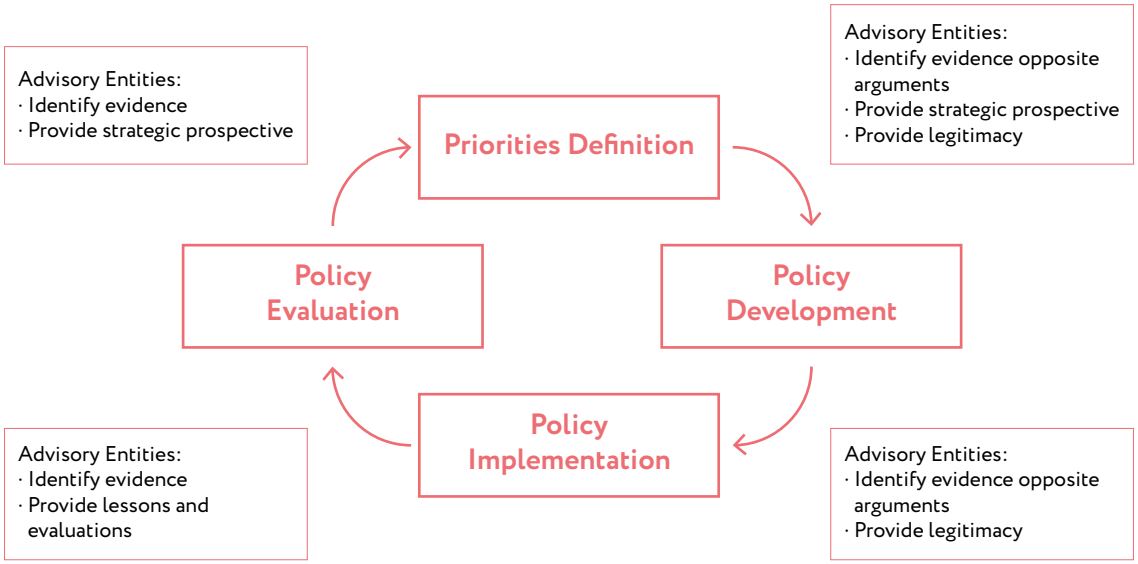
- *National academies*

  National academies are entities that, in some cases, operate with state funding and are considered part of the state science and technology structure. However, in some countries, national academies are non-profit entities with more independence from government. They coordinate research activities, develop standards for different branches of science, and create and manage memberships and expert groups in various science fields.

Functions

Scientific advisory entities play an essential role in the public policy cycle. Being close to the government but 'far away' at the same time, they have the potential to act as knowledge 'intermediaries' and provide governments with scientific advice at different stages of the public policy cycle (OECD, 2017).

Figure 1. Public policy cycle and the roles of scientific advisory entities.



Source: Based on OECD (2017)

Depending on the public policy formulation stage, advisory entities can participate in and contribute to the process in different ways (OECD, 2017). Advisory entities combine several of the following functions:

- *Definition of priorities and agendas*

  Scientific advisory entities play a crucial role in the first stage of the public policy cycle. They can generate interest or attract public attention to a specific

issue and provide the necessary evidence so that the issue gains importance and visibility on the political agenda. This is the phase where advisory entities can have the most influence.

- *Development of public policies*

  Advisory entities can provide advice and support during the policy development stage by identifying new options and strategies to solve a problem or generate a desired result. Its independent position gives legitimacy to the process. At this stage, advisory entities can help identify new public policy options, provide evidence to help adopt changes and create legitimacy for selecting a particular option.

- *Implementation and monitoring of public policies*

  In the implementation and monitoring phase of public policies, advisory entities can offer perspectives and scientific evidence on the evolution and results of a policy, contribute to correcting its course or provide information on its implementation at different stages.

- *Evaluation of public policy*

  In the evaluation phase, advisory bodies can help identify evidence and data for evaluation. Additionally, their independent position provides legitimacy to the process and the evaluation results. It separates them from the political interests of presenting positive or negative outcomes.

3. COUNTRY EXPERIENCES

This section presents the main characteristics of advisory systems in eight countries from different regions and institutional backgrounds, and we show the diversity of structures and features of advisory systems. Two countries from the Commonwealth (Canada and the United Kingdom), two from the European Union (Germany and Spain) and two from Latin America (Chile and Brazil) were selected for examination. A brief section about the government's response to the global pandemic is included for each country.

The presentation of these country experiences is not intended to suggest that they are the 'best' advisory systems. Instead, we are aiming for a diversity of contexts and institutional structures. For each country experience, we have drawn key aspects of their models: their degree of formality, their structures (and the key bodies that are part of them) and their functions. We have also described the main features of the key elements of the advisory system in each country.

We have included the most important elements of the advisory systems in each country; however, our list might not cover all the instances and bodies that are part of the country's wider advisory system, including universities, privately funded research institutions, and think tanks. In addition, it is important to note that the availability of information (mostly secondary sources) varies from country to country, which explains why we were able to gather more information from some countries than from others.

Brazil

The science and technology system in Brazil has undergone significant changes since the election of President Jair Bolsonaro in 2018. Since then, various entities and links with the science and technology sector have been dismantled. In 2019, the government announced the freezing of 42% of the national budget of the Ministry of Science and Technology. Since then, decisions at the highest level have contributed to weakening the science and technology system (Angelo, 2019). Scientific advisory processes have also been deeply affected by a general environment of scepticism towards science.

Key features of the scientific advisory system

The Brazilian science and technology system is complex since it is divided between federal and state governments and non-governmental organisations. Like other countries in the region, Brazil has a Ministry of Science, Technology, and Innovation at the centre of science and technology policy. In addition to regulating the sector's

policy, the ministry has broad functions that include coordinating and articulating activities of independent research centres, related entities and collegiate bodies. The functions of the ministry are mainly those of policy for science.

Elements of the scientific advisory system

Ministry of Science, Technology, Innovations and Communications

In Brazil, the governing body of the sector is the Ministry of Science, Technology, Innovations and Communications (MCTIC), which is the entity in charge of the formulation and implementation of the National Policy on Science, Technology and Innovation. In addition to dictating sector policy, the Ministry of Science has, as part of its organisational structure, bodies that provide direct assistance to the Minister of State. These include an undersecretary for coordination of research units, planning, budget, administration, and an advisory body for international affairs.

The ministry is in charge of the national telecommunications policy; national broadcasting policy; national policies for scientific and technological research and the promotion of innovation; planning, coordination, supervision and control of science, technology and innovation activities; IT development and automation policy; national biosafety policy; space policy; nuclear policy; control of exports of sensitive goods and services (Ministerio de Ciencia Tecnología e Innovación, n/d). The ministry also coordinates the activities of nine research institutes in various areas of knowledge. They are under the jurisdiction of the MCTIC, and include the National Research Institute of the Amazon, the National Institute of Technology, the Brazilian Centre for Physical Research and the National Astrophysics Laboratory.

National Council of Science and Technology

The National Council of Science and Technology (CCT) is the advisory body for the President of the Republic that formulates and implements the national policy for scientific and technological development. The Ministry of Science and Technology is the secretary of the CTT. The CCT is also the agency in charge of channelling research funds to other actors in the science and technology ecosystem.

The CCT has 13 permanent members, who are representatives of various ministries, including the Ministry of Science and Technology, the Chief of Staff of the Presidency of the Republic and the Ministry of Defence. In addition, it has eight regular representatives (and eight alternates) of producers and users of science and technology and six representatives of national entities representing the teaching and research sectors.

National Council for Scientific and Technological Development

The National Council for Scientific and Technological Development (CNPq) aims to promote scientific research and development in the country and is accountable to the Ministry of Science, Technology, Innovations and Communications. The CNPq is responsible for facilitating and integrating the advancement of academic research in Brazil. It hosts important academic network platforms and offers scholarships for undergraduate research in the Institutional Programme of Scholarships for Scientific Initiation.

Brazilian Academy of Sciences

The Brazilian Academy of Sciences (ABC), founded in 1916, is an independent, non-governmental and non-profit organisation, which acts as an honorary scientific society and contributes to the study of subjects of primary importance for society and provides scientific subsidies for the formulation of public policies. The ABC receives contributions from its individual and corporate members and financial support from government agencies. With a current staff of more than 900 members in total, the ABC is one of the oldest scientific associations in the country.

Response to COVID-19

Brazil is the country with the third highest number of confirmed cases of COVID-19 worldwide. This critical situation is even more complicated due to the anti-science stance of the government of President Bolsonaro (Fraser, 2020). The Brazilian government was slow and uncoordinated with policies adopted by the Ministry of Health and its response the scientific evidence available on the coronavirus. In March 2020, the Ministry of Science, Technology and Innovation (MCIT) created RedeVírus, a platform with resources for developing projects for diagnosis, treatment, vaccines, and the production of knowledge about the virus. This network allocated USD 3.5 million on 23 March 2020 to projects related to the pandemic. In May 2020, MCIT announced the allocation of an additional 352 million reais, just under USD 30 million, to strengthen the pandemic-related work conducted by reinforcement of the federal state (Sosa & Scargiali, 2020).

The lack of leadership at the political level has led to actions and initiatives led by academia and other sectors to counter the effects of misinformation from the national government (Fraser, 2020). Although the national government has been entirely closed to the advice of the country' s scientific sectors, governments at the subnational level have generated alliances and spaces for collaboration in the face of the crisis. An example of this is the creation of a scientific committee of experts from the southeast of Brazil, which provides advice to the northeast of the country, one of the country's most vulnerable regions (Fraser, 2020). The committee works closely with the

northern provinces' governors and generates recommendations and guidelines for the new reality.

The ABC has played a fundamental role in the crisis as it has established itself as the body that has demanded the government provide more security for researchers and medical personnel in the face of the pandemic, more funds for research, and more openness and transparency on the use of scientific evidence.

Canada

The scientific advisory system in Canada has been through important changes over the years. Scientific advisory bodies have been created and phased out, reflecting national priorities and political agendas (Quirion, Carty, & Jabr, 2016; Canadian Government Executive, 2016). In 1964, the Secretariat of Science was created as part of the Privy Council to provide scientific advice to the prime minister and the parliament. In 1966, it was replaced by the Science Council of Canada, a corporation, part of the Crown but independent from the government. In the same year, the position of Principal Scientific Advisor was created but then eliminated in 1971. Further attempts to institutionalise scientific advice followed. The Council of Science and Technology Advisors was created in 2000 and abolished in 2007. In 2017, the position of Principal Scientific Advisor was reinstated.

Currently, the Office of the Chief Science Advisor (OCSA) leads scientific advice, and it is supported by other entities that provide advice to the government. The advisory system fulfils policy for science and science for policy functions. Often, the same entities engage in both functions. Due to the scope of the paper, we are focusing on the science for policy function.

Key features of the scientific advisory system

Although many institutions have been created over time to provide advice to the government, Canada did not have a formal path for providing science advice to assist government decision-making until the creation of the OCSA. Therefore the system is relatively new and is in the process of establishing its building blocks. In many ways, the Canadian advisory system follows a similar model to the UK advisory system. It is led by a chief science adviser who leads the OCSA and a network of departmental science advisers.

Key bodies of the scientific advisory system

The scientific advisory system in Canada has gone through several changes. Its most recent change was the creation of the OCSA in 2017. It has established guidelines for the development and use of scientific evidence in Canada. OCSA is a permanent office, considered part of the government, but has the independence to fulfil its mission. In addition to OCSA and, other entities, such as the National Research Council, the Council of Canadian Academies, and the Royal Society of Canada, provide scientific advice to the government.

Office of the Chief Science Advisor

The Government of Canada created the OCSA in late 2017. The key functions of the Chief Science Advisor are: a) to provide advice on the development and implementation of guidelines to ensure that science funded or produced by the government is available to the public; b) to provide advice on creating and implementing processes to ensure that scientific evidence is considered when policy-makers make decisions; c) to assess and recommend ways to improve the existing advisory function; and d) to assess and recommend ways for the government to better support quality scientific research at the federal level.

Departmental Science Advisors Network

The Departmental Science Advisors Network was created in 2019. Within their respective departments, the science advisors perform a range of functions that include the development of high research standards, the promotion of departmental science portfolios, the recruitment of scientists, the development of external scientific partnerships, and the promotion of a culture of scientific excellence. The network has currently eight members, who are experts from different backgrounds and who have been active contributors to the OCSA.

National Research Council

The National Research Council (NRC) is the largest federal research and development agency in Canada. It reports to Parliament through the Ministry of Innovation, Science and Industry. The NRC works in partnership with Canadian industry to bring research benefits to the market for people to experience first-hand. The NRC is managed by a Board of Directors, which oversees the organisation's performance and provides strategic directions. The NRC Council comprises the chairman of the council, the executive chairman, and 10 members (Government of Canada, n/d). The NRC has 14 integrated research centres focused on critical sectors of the Canadian industry, such as transport, manufacturing, engineering, life sciences, and technology. These research centres represent strategic importance and economic value for Canada (Government of Canada, n/d).

Council of Canadian Academies

The Council of Canadian Academies (CCA), established in 2002, is a private non-profit corporation that brings together experts in different fields to evaluate scientific topics of public interest to inform decision-making (Council of Canadian Academies, 2020). The CCA' s work spans the natural, social and health sciences and engineering and the humanities. The government of Canada funds the CCA (through a grant). At the start of operations in 2005, the CCA received CAD 30 million in financing to support the Council's core operations. This financing was renewed in 2015 for CAD 15 million for five years. The founding academies of the CCA are independent organisations representing Canada's best scientists. Its members serve on the CCA' s Board of Directors and represent the broader CCA membership base. The academies provide key input and guidance to the CCA during research and study design, evaluation, planning, and nomination of experts. The academies of the CCA are the Royal Society of Canada (RSC), the Canadian Academy of Engineering and the Canadian Academy for Health Sciences.

The Royal Society of Canada

The main objective of the Royal Society of Canada (RSC), which was created in 1882 as the National Academy of Canada, is to promote learning and research in the arts, humanities, social and natural sciences. The RSC generates independent reports based on the experience of experts to inform decision-making on various topics (Quirion, Carty, & Jabr, 2016). Additionally, the RSC provides scientific advice to the government in specific situations. In the 1960s and 1970s, for example, the RSC played a fundamental role in alerting the government to imminent issues such as the need to develop a national strategy for the treatment and prevention of AIDS, and for gaps in educational and health policy issues (Quirion, Carty, & Jabr, 2016). In 2015, the RSC published a report recommending that the government strengthen scientific advisory systems and provide advice to the Minister of Science to create the position of Chief Science Advisor (Quirion, Carty, & Jabr, 2016).

Response to COVID-19

Canada's response to the pandemic in terms of scientific advice is led by the Public Health Agency of Canada and is coordinated through the Federal/Provincial/Territorial Public Health Response Plan for Biological Events. This plan aims to coordinate the response at the national level and consists of a general governance plan to guide health responses in emergencies (Government of Canada, 2017). The plan outlines the roles and responsibilities of different entities:

- *Special Advisory Committee (SAC)*

  Its mandate is to advise the Council of Ministers of Health on issues related to a significant public health event. The products and activities developed by

SAC may include recommendations, guides, protocols and communication products, depending on the type of emergency (Government of Canada, 2017). The SAC is co-chaired by representatives of the Public Health Network of Canada Council.

- *Technical Advisory Committee (TAC)*

  Through the SAC, the TAC provides inputs of a technical nature to respond to a particular crisis. The proposals generated in the TAC go through a validation process before being presented in the SAC. The TAC is co-chaired by the National Advisory Committee on Infection Protection and Control, and provides advice through epidemiological reports, public health measures, recommendations on drugs and vaccines.

- *Public Health Network Communications Group*

  This group aims to support consistent and coordinated communication to the public across different jurisdictions during a crisis. During an emergency response, it provides support and advice to the SAC.

- *Health Portfolio Operations Centre*

  This is the coordinating body for activities during public health emergencies. It is a point of contact to facilitate the dissemination of information and evidence to key actors in the management of an emergency.

The Canadian government's response has provided important lessons, especially in its handling of the crisis at the federal level. While the management of the crisis in Canada has not been an example for other countries globally, the main challenges have been experienced at the provincial level (Marchildon & Bleyer, 2020). The provinces have experienced challenges related to adopting national standards and filling gaps in health infrastructure (Marchildon & Bleyer, 2020).

Chile

In Chile, the Ministry of Science, Technology, Knowledge and Innovation, created in 2018, is the governing body for science and technology policy at the national level. This ministry's functions have constantly evolved over the years. This ministry replaced the National Commission for Scientific and Technological Research under the Ministry of Education. Despite having one of the most robust scientific and knowledge ecosystems in Latin America, Chile has not institutionalised channels to provide advice to the government. Therefore, the main role of Ministry of Science and its associated entities is

to support the development of the knowledge ecosystem across the country and provide evidence to inform the national science, technology, knowledge and innovation policy.

Key features of the scientific advisory system

The ministry's main function is to strengthen institutional capacity to efficiently manage national opportunities and challenges in science, technology and innovation (policy for science). While not explicitly mentioned in its mission, the ministry's agencies provide advice to the government. However, the channels for this function are not fully institutionalised.

Key bodies of the scientific advisory system

The scientific advisory entities with a clear government advisory mandate are linked to the Ministry of Science, Technology, Knowledge, and Innovation. Until 31 December 2019, the National Scientific and Technological Commission (CONICYT) was the entity in charge of advising the president of the Republic about planning the scientific and technological development of Chile (policy for science). However, the use of evidence in public policy is relatively new in Chile and is in the process of change and institutionalisation (Jaque, 2020). Therefore, in early 2020, the CONICYT was replaced by a new entity, the National Research and Development Agency (ANID).

Additionally, there are advisory bodies in Chile created to respond to specific situations or needs. These bodies are ad hoc and are from academia and the public and private sectors. For example, the Ministry of Science created an advisory committee to inform the government on the National Policy on Artificial Intelligence (Gobierno de Chile, 2019). The members of the committee were selected for their professional expertise in different science fields. A presidential advisory committee for Conference of the Parties 25 (COP25) was created, which was convened to provide advice to the presidency of COP25 to develop public policies associated with climate change (Ministerio del Medio Ambiente, 2019). Other public entities and programmes have internal advisory bodies made up of experts in various areas. The main role of these advisory councils is to provide advice and scientific evidence to strengthen a particular entity' s decision-making and lines of work.

Below we describe the functions of the Ministry of Science, Technology, Knowledge, and Innovation, the ANID and the National Council of Innovation for Development. It is worth noting that many of the functions carried out by these entities relate to the policy for science function. While this function is outside the scope of this paper, we will briefly mention the key areas where these bodies contribute to the use of scientific evidence.

Ministry of Science, Technology, Knowledge, and Innovation

The Ministry of Science, Technology, Knowledge, and Innovation is responsible for advising and collaborating with the president in designing, formulating, coordinating, implementing and evaluating policies, plans and programmes to promote science, technology and innovation in Chile.

National Research and Development Agency

The ANID is the service in charge of managing and executing the programmes and instruments destined to promote, foster and develop research in all areas of knowledge, technological development and scientific-technological innovation, following the policies defined by the Ministry of Science, Technology, Knowledge, and Innovation. With the restructuring of the CONICYT, there is still no clarity on the advisory functions that the ANID will carry out. The Minister of Science and Technology has recently expressed interest about creating a specialised office (Science and Government) to promote evidence in decision-making (Jaque, 2020). However, this initiative has not yet materialised.

The ANID has a sub-directorate that uses through knowledge transfer mechanisms to link existing research and innovation centres and programmes to society, the state and industry (Agencia Nacional de Investigación, 2020). The ANID's Network, Strategy, and Knowledge sub-directorate seeks to design and implement mechanisms and strategies that allow dynamising the articulation of knowledge and information between science, industry, academia and the public sector.

National Council of Innovation for Development

This is an advisory body of the Presidency of the Republic that generates strategic guidelines to strengthen the contribution of science, technology and innovation to the development of Chile. The council comprises a president, four independent members and two ministers of state. Also, the ministries of Economy, Development and Tourism and of Science, Technology, Knowledge, and Innovation are represented on this c council.

Response to COVID-19

As in other countries in the region, the Ministry of Health has led efforts to manage the effects of the pandemic. However, the unusual nature of the emergency led to the creation of an advisory council on 15 March 2020 (Román, 2020a). The advisory council was created specifically to advise the Ministry of Health on issues related to COVID-19. The advisory council has 10 members. Among the members are medical researchers (specialists in public health, microbiology, family medicine, surgery) and representatives of different sectors of the Ministry of Health (Minsal, 2020). The council

was formed with direct suggestions from the Medical College and the Ministry of Health (Román, 2020a).

Since its formation, the advisory council has been involved in debates and controversies related to its role and the level of coordination between the decisions made by the government vs the opinions provided by the experts (Román, 2020a). Discussions and questions posed by the media and official reports reveal the lack of clarity about the council's functions. On the other hand, the government has been emphatic in indicating that decisions concerning COVID-19 are made based on the advice of experts.

The COVID-19 Social Board is a consultation body that aims to give a voice to the sectors that have objected to the mitigation actions adopted by the central government. The College of Physicians and representatives of local governments participate in this space (Román, 2020a). As in the case of the advisory council, the Social Board has been involved in public debates because of the lack of clarity of its functions and attributions (Catena & Latorre, 2020; Román, 2020b).

Germany

The scientific advisory system in Germany is decentralised, and is considered highly complex as various entities work together at different government levels to produce and use scientific evidence (Glynn, Cunningham, & Flanagan, 2003; Gluckman, 2014). The structure of German advisory system reflects Germany's consensus-based democracy. As in other consensus-based democracies, institutions and procedures encourage consensus across all government levels, so it accommodates many social organisations that take an institutional role in policy implementation and decision- making (Pattyn et al., 2019).

Germany has a long history of producing research and relying on internal scientific advice by specialised agencies and departmental research institutes (Pattyn et al., 2019). Germany has some of the oldest departmental research institutes, such as the Robert Koch Institute, founded in 1891, and the Institute for Employment Research, founded in 1967. Also, academic think tanks have a long tradition in Germany and have been historically tied to the policy-making system. For example, institutes such as the Fraunhofer Institutes and Max Plank Institutes have received sustained public funding and carried out commissioned academic research for the German government for decades. However, Germany has also gone through important changes that have resulted in the pluralisation of the advisory landscape reflected by the emergence of

the consulting industry and the expansion of parliamentary expert resources (Pattyn et al., 2019).

Key features of the scientific advisory system

Deliberative processes are a central feature of the German decision-making system and are key when formulating cross-sectoral policies. The high levels of interaction between the entities of the political system mean less power is concentrated in the state, which results in a decentralised system (Glynn, Cunningham, & Flanagan, 2003). There are no general guidelines for advisory structures and processes. Permanent and ad hoc structures co-exist and provide advice to different government entities simultaneously. For example, each ministry has its research institute that delivers ad hoc analysis on demand and independent research to support decision-making processes (Pattyn et al., 2019).

Unlike systems in the UK and Canada, the German system is not centralised under the figure of a chief scientific adviser. Instead, the advisory function is embedded at all government levels, and various actors from the knowledge ecosystem perform it. Thus, the German scientific advisory bodies include experts, governmental commissions, and scientific advisory boards from different ministries.

Key bodies of the scientific advisory system

The German advisory system is formed by many entities (institutes, commissions) that provide scientific advice to the government. We will not name or describe all of them, but to portray the complexity of the German system we will focus on different types of advisory entities, their functions and connections with other actors.

Ministry-level departmental research institutes

All ministries have departmental research institutes that provide analysis and advice on different topics (Grobbelaar, 2008). For example, the Federal Institute for Risk Management (Bundesinstitut für Risikobewertung [BfR]) was created under the jurisdiction of the Federal Ministry of Food and Agriculture and is mandated to advise the ministry on all scientific aspects of food safety and consumer protection. Additionally, the BfR has a scientific advisory board that provides it with advice on research priorities, promotes cooperation between the BfR and other research institutes in Germany and abroad, and provides advice on the appointment of experts to the committees that are part of the institute (Bundesinstitut für Risikobewertung, n/d). The federal Ministry of Health has a departmental research institute that independently investigates, and advises the federal ministry on, emerging health, care, and social needs (Bundesministerium für Gesundheit, 2020). The Ministry of Health also has five subordinate entities, four of which have research and advisory functions: the Federal

Institute of Medicines and Medical Equipment, the Federal Cent re for Health Education, the Federal Institute of Vaccination and Biomedicine and the Robert Koch Institute.

Committees and councils

Committees and councils are supplementary and independent advisory entities with high visibility and access to the highest decision-making spheres. Commissions' and councils' work often spans across ministries and they report directly to the Cabinet or inter-ministerial committees. Some examples include:

- The Science Council (Wissenschaftsrat), established in 1957, advises the federal government and the federal states (Bundesländer) on the development of science, the generation of research and the university system.
- The Sustainable Development Council (Rat für Nachhaltige Entwicklung [RNE]), established by the federal government in 2001, provides advice for the National Sustainability Strategy, identifies areas for action and contributes to raising public interest in sustainability (Rat für Nachhaltige Entwicklung, n/d). The RNE also has a crucial role in engaging different social actors in participatory forums and spaces, such as the Sustainable Cities Dialogue or the Fund for the Culture of Sustainability.
- The Advisory Council on Global Climate Change (WBGU) was established in 1992 as an independent advisory body for decision-makers. The WBGU has nine members[2] appointed for four years by the federal cabinet of the German government. The federal Ministry for the Environment, Conservation, and Nuclear Safety, and the federal Ministry for Education and Research finance and administer the WBGU. Additionally, the WBGU is monitored by an inter-ministerial committee on which the federal Chancellery and all ministries are represented.
- The Expert Commission on Science and Innovation was established in 2006 to advise the federal government on structures, trends and prospects for the German research and innovation system. Members are appointed for four years by the federal Ministry of Education and Research with the approval of the federal government and are academics familiar with the decision-making process and the design of public policies (Schwaag Serger, Wise, & Arnold, 2015).

[2] A list of current WBGU Council members is available here.

Parliament

At the parliamentary level (Bundestag), Germany has an internal advisory body called the Scientific Service (Wissenschaftliche Dienste [WD]). The WD is a scientific information and advisory centre for members of parliament, and has 11 departments. Its functions include researching and analysing scientific evidence on behalf of members of parliament and their committees and reducing and synthesising available information on specific topics (Deutscher Bundestag, n/d). In addition, the WD conducts investigative processes at the request of members of parliament and identifies and analyses issues of future relevance to Germany's political agenda (Deutscher Bundestag, n/d). The WD is also dedicated to generating research reports to inform the public about various topics of general interest. The work produced by the WD does not represent the views of parliament (Deutscher Bundestag, n/ d).

Within the parliament, the Office for Technological Analysis (Technikfolgen-Abschätzung beim Deutschen Bundestag [TAB]) aims to monitor and analyse science and technology trends and provide advice to parliament and its committees[3] on these issues. The TAB is governed by the Committee for Education, Research and Technology Assessment and is operated by the Karlsruhe University Institute of Technology (KIT) under a direct contract with parliament. This KIT appoints the TAB director in agreement with the Committee for Education, Research and Technological Analysis of the Parliament. The TAB also provides advice to the Food and Agriculture Committee, the Economy and Energy Committee and the Conservation, Construction and Nuclear Safety Committee.

Response to COVID-19

The highly decentralised but coordinated nature of the German scientific advisory system allowed for one of the most efficient responses to the pandemic (Wieler, Rexroth, & Gottschalk, 2020). It is important to indicate that the advisory system is considered highly efficient because it exists in a favourable environment that has a solid and well-articulated national and federal health system, well-funded research and technology institutions, and clear political leadership (Wieler, Rexroth, & Gottschalk, 2020; Spahn, 2020).

During the first weeks of the crisis, the government established an inter-ministerial group for crisis management. At the same time, protocols and guidelines for action and containment, available since January 2020, came into use. The German government entered the pandemic with a detailed National Pandemic Plan, which allowed the government to act quickly and without political delays. The Ministry of Health led and

[3] The German parliament (Bundestag) currently has 23 standing committees. The full list is available here.

coordinated the health response. As Germany is a country with a federal system, the responsibility for health provision rests with the 16 federal states, which have the power to adapt national guidelines to local realities and needs (Wieler, Rexroth, & Gottschalk, 2020). The public research institute for disease prevention, Robert Koch, also played a vital role in the crisis.

Actions to prevent infections were taken quickly and since February 2020 scientific evidence has been available to inform the measures adopted by the government. For example, the first case was reported on 27 January 2020 in Bavaria. On 1 February, the government announced the national obligation for doctors and hospitals to report suspected coronavirus cases to local authorities within 24 hours (Wieler, Rexroth, & Gottschalk, 2020).

A crucial element of the response to the crisis was transparency in handling information, which strengthened public confidence in the decisions made by the government. An essential aspect of the process was informing the public throughout the process about what was known about the coronavirus and what was unclear or unknown (Spahn, 2020). In addition, transparent information management strengthened public trust and generated a sense of collective responsibility (Spahn, 2020; Singh, 2020).

Spain

Spain does not currently have formal mechanisms for the provision of scientific advice. The competencies related to science and technology have been divided between the ministries of education and science with limited success. For example, in 2000, the government created the Ministry of Science and Technology; four years later, this ministry was merged with the Ministry of Education. Two years after that, the government divided the competencies of the Ministry of Education and reinstated the Ministry of Science and Innovation. This level of institutional instability has led to an absence of clear policies for producing and using scientific evidence. The need to develop scientific advisory entities and strengthen the use of evidence was newly formalised with creation of the current Ministry of Science and Innovation in 2020. Furthermore, in March 2021, Congress approved the creation of the Office for Science and Technology, whose main function will be to provide scientific advice to members of Congress.

Key features of the scientific advisory system

The scientific advisory system in Spain is still being developed. The science and innovation policy is the responsibility of the Ministry of Science and Innovation, which is

responsible for executing the government's policy on scientific research, technological development, and innovation in all sectors. While the government has recognised the importance of scientific evidence and advice, there are no formal mechanisms to organise or regulate scientific advice for policy-making. However, the Ministry of Science and other ministries exercise functions related to research and scientific advice (Diez Bueso, 2013).

Key bodies of the scientific advisory system

Most scientific structures and bodies in Spain are closely related to the policy for science function, led by the Ministry of Science and Innovation and associated institutes and bodies. These entities' key role is to promote the production and use of scientific evidence in Spain. While this function is out of the scope of this paper, we will briefly mention where these bodies contribute to the use of scientific evidence in different government departments.

Ministry of Science and Innovation

The Ministry of Science and Innovation provides guidelines and designs policies to strengthen Spain's knowledge and innovation ecosystem. There are two entities under the jurisdiction of the Ministry of Science that complement this function: the General Secretariat for Research and the General Secretariat for Innovation. The General Secretariat for Research promotes and coordinates relations with the autonomous communities and local corporations in research matters. The General Secretary for Innovation oversees matters of innovation and knowledge transfer. Although they do not have an explicit advisory mandate, both secretariats strengthen the research, innovation and knowledge transfer system.

State Research Agency

This is a body associated with the Ministry of Science and Innovation. Its mission is to promote scientific and technical research by allocating public resources and advice on the General State Administration's research and development policies. Among its functions, the agency undertakes the scientific-technical evaluation of proposals or initiatives to facilitate decision-making related to financing research projects and the subsequent analysis of their results.

Higher Council for Scientific Research

The Higher Council for Scientific Research (CSIC) was founded in 1939, and its mission is to promote, coordinate, develop and disseminate scientific and technological research, and provide scientific advice to public and private entities. In 2007, the CSIC was deemed an 'agency ', which allows it to operate with more autonomy. The CSIC exercises its functions through research institutes organised into departments and

research groups. Currently, the CSIC has 120 affiliated research institutes in Spain (CSIC, n/d). It also has two committees: the Scientific Advisory Committee, which provides ongoing advice to the Presidency on scientific and technological issues (as opposed to advice only where there is an emergency or when it receives a specific request), and the Ethics Committee, which issues reports and makes recommendations on the ethical principles of scientific research.

Spanish Foundation for Science and Technology

The Spanish Foundation for Science and Technology (FECYT) is a public foundation that aims to strengthen the link between science and society, promote scientific education and respond to the needs of the Spanish system of science and technology. The FECYT generates resources and research on the innovation and research system in Spain (science for policy).

Office for Science and Technology

In March 2021, Congress approved the creation of the Office for Science and Technology to provide scientific advice to parliament. This new office will operate with autonomy and will be co-led by a representative of Congress and another representative from the FECYT. It was established in collaboration with the FECYT. The FECYT's role in the collaboration will include a) gathering evidence on specific issues, and b) organisation of evidence dissemination activities, including public debates, to keep citizens informed about the latest scientific evidence.

Response to COVID-19

In Spain, the management of the pandemic is led by the Ministry of Health. The force of the pandemic had a devastating effect on the Spanish health system, which highlighted, as in many countries, the structural weaknesses, both of the hospital system and the innovation research system (García-Basteiro et al., 2020). The government's response to the crisis has focused on creating ad hoc entities to provide scientific advice to the government to deal with the pandemic. New funds and research funding structures have also been created within the Ministry of Science and Technology to generate responses to the crisis.

In March 2020, a scientific committee on the coronavirus, comprising six experts appointed by the government, was created to provide advice to the government (Ministry of Health, 2020). The committee has representatives from the Preventive Medicine and Epidemiology Service of the Hospital Clínic de Barcelona; the Centre for Epidemiology, Health Surveillance and Environmental Sanitation of the Generalitat Valenciana; the Research Unit in Health Care and Services of the Carlos III Health Institute; the Official Laboratory of Control of Medicines of Biological Products

(vaccines and blood products) the Spanish Agency of Medicines and Health Products; the National Centre for Microbiology of the Carlos III Health Institute; and the Harvard University School of Public Health.

Additionally, the Ministry of Science and Innovation has developed a science and innovation programme to fight COVID-19, financed with public funds and implemented through research centres and companies. The projects seek to generate evidence to advise the national government on issues that include prevention, studies of the biology and behaviour of the virus, development of vaccines, drugs and treatments, infection during pregnancy, clinical manifestations of the virus, immunity studies, epidemiology (Ministerio de Ciencia e Innovación, 2020).

The CSIC has launched an interdisciplinary thematic platform called Global Health in which more than 200 research groups from different specialities collaborate to address the challenges posed by the pandemic from the point of view of science. The intention is to propose solutions in the short, medium and, especially, long term (CSIC, 2020).

One of the central criticisms of the government's handling of the pandemic has been focused on the lack of preparation for an emergency of this type and the government's late response to the crisis (García-Basteiro et al., 2020). Although the government has taken significant steps to deal with the aftermath of the virus, these actions must form part of the institutional capacity to respond to other similar emergencies. In addition to financing for initiatives related to COVID-19, this implies the strengthening of systems for generating evidence and scientific advice (García-Basteiro et al., 2020). Unfortunately, deficiencies in data generation and monitoring systems have limited the ability of subnational governments to react to the pandemic (García-Basteiro et al., 2020).

United Kingdom

The UK has a long-standing scientific advisory system that has served as a model for other countries like Canada, Australia and New Zealand. The UK science system has been shaped by the experience of past crises and shifting government support for the sciences. In the late 1980s, the Thatcher government laid out the basis for the 'science for policy and policy for science' approach. In the 1990s, the Labour government, led by Tony Blair, popularised the idea of evidence-based policy-making. In 1993, the Office of Science and Technology (the predecessor of the current Government Office for Science) was created. The response in the 2000s to the foot and mouth pandemic changed how science was used in government, and led to the call for stronger leadership, knowledge

transfer and investment in science. In 2019, the Government Office for Science's review challenged the assumption that science capability could be entirely outsourced from the government, and emphasis ed the need for retaining internal scientific capability. Today, the UK advisory system has several interconnected bodies that provide scientific advice through various mechanisms.

The advisory system in the UK fulfils two key functions: policy for science and science for policy. We will only focus on the science for policy function where the government is the central 'recipient' of the scientific advice and where the entities involved in science advice have been formally set up as part of the government or 'close' to it (ad hoc).

Key features of the scientific advisory system

The level of formality of the entities that are part of the UK advisory system is one of its key features. Several sources of scientific advice are permanent and were created by the government to fulfil a set of functions often regulated by law. The UK system also has ad hoc bodies such as scientific advisory committees and councils that are activated in specific circumstances (e.g. in emergencies). Overall, scientific advice is catalysed through the Chief Scientific Advisor, who provides direct advice to the prime minister and coordinates advice across various entities.

Key bodies of the scientific advisory system

The mechanisms for informing policy with science are:

- *Formal science advice mechanisms in government*

  This is led by the Chief Scientific Adviser and the UK Government Office for Science. Scientific capabilities and advice are coordinated across 22 government departments and administrations by a network of departmental chief scientific advisers (CSAs). There is also the Government Science and Engineering Profession, a network of science and engineering staff across the civil service, supported by the UK Office for Science. In addition, other advisory bodies provide advice to Parliament, such as the Parliamentary Office for Science and Technology (POST)

- *Independent advice from academic councils and committees*

  In addition to the government bodies, academics contribute to policy-making through science advisory councils (SACs) and committees (SAComms) established to inform departments and ministers. The Council for Science and Technology (CST) and the Scientific Advisory Group for Emergencies (SAGE) are among these bodies.

- *Advice from government units specialising in research and evidence*
  These units include evidence centres that provide policy support through the What Works Network and the national academies.

FORMAL ADVICE MECHANISMS IN GOVERNMENT

The Chief Scientific Adviser and the Government Office for Science

The CSA role was created in 1964, although many earlier governments sought advice from individual scientists since at least the Second World War. The CSA leads the UK Office of Science, is responsible for coordinating science and technology strategy across all government entities and acts as an ambassador for science (Glynn, Cunningham, & Flanagan, 2003). The CSA is a permanent secretary, the most senior civil servant role in a government department. They are appointed by the prime minister, but it is not a political appointment.

The CSA's main role is to advise the prime minister and the Cabinet directly on scientific issues. The CSA also acts and provides advice through other channels: a) they are the head of the Government Science and Engineering Profession (which supports senior decision-makers and ministers to access science and science-based evidence); b) chair SAGE and co-chair the CST; and c) speak directly to the public about scientific evidence informing policy decisions.

The Government Office for Science is an independent office that works across all government departments and hosts important research and planning teams, such as the foresight and futures teams, who conduct reviews into topics of current and future importance to the UK. The Government Office for Science's disciplinary scope focuses on the natural sciences and engineering. Other separate government entities focus on other disciplines, such as economics and social research.

Departmental scientific advisors and government departments

The UK system extends responsibility for scientific advice to each government department that provides and uses scientific evidence. Each department has a departmental scientific advisor whose role is to ensure that the department has the necessary evidence to inform its decisions (Gluckman, 2014). The first departmental scientific advisors were appointed after the foot and mouth crisis of 2001, highlighting the need to develop a structure to align advice and knowledge across government departments.

The departmental scientific advisors are part of the network of CSAs at all levels of government and are coordinated by the Chief Scientific Advisor. The network comprises 70 experts (Government Office for Science, 2018). Departmental scientific advisors

come from academia and industry, although some are recruited from within the civil service. These experts meet weekly and provide advice and intelligence on different topics to ministers and support science within their departments.

The Science and Engineering profession in government

The Government Science and Engineering (GSE) profession comprises approximately 20,000 people with professional backgrounds and qualifications in science and engineering. This group of professionals provide a link between government policy-making, scientific communities, industry and academia. Their work also focuses on developing recommendations and strategies to strengthen career pathways and share good practices and ideas. The GSE profession works alongside others, including the Government Economic Service, the Government Statistical Service, the Government Operational Research Service and the Policy Profession.

Parliamentary Office for Science and Technology

The Parliamentary Office for Science and Technology (POST) is an independent office within Parliament that responds to requests from the House of Commons and the House of Lords (Grobbelaar, 2008). POST provides members of Parliament with the scientific evidence necessary for decision-making. In addition, POST produces peer-reviewed reports designed to make scientific knowledge accessible to m embers of parliament. POST regularly submits reports on relevant research requested by Parliament, evaluates scientific evidence received from other sources and makes reports at the request of different Parliament committees. POST covers a wide range of public health, physical science, engineering, ICT, environment and social science issues.

BODIES THAT PROVIDE INDEPENDENT ADVICE FROM ACADEMIC COUNCILS AND COMMITTEES

Council for Science and Technology

The CST is a non-governmental advisory body that advises the prime minister and other decision-makers on cross-cutting scientific issues. It provides independent advice to the prime minister on science and technology policy issues, such as a) opportunities and risks presented by science, technology and innovation concerning research and scientific capabilities; innovation and the economy; health and quality of life in the UK; sustainable development and resilience; b) strategies to develop science, technology, engineering and mathematics in the UK through education, capacity-building and international cooperation; and c) identification and definition of high-level priorities in science and technology in the UK (Government Office for Science, 2018).

The CSA and an independent scientific advisor co-chair the CST. The CST is supported by a secretariat that is part of the Government Office of Science. CST members

are recognised for their length of experience in science, engineering and technology. The prime minister appoints them under the guidelines set by the UK Public Appointments Office. CST meets four times a year (March, June, September, and December) (Government Office for Science, 2018).[4]

Scientific Advisory Group for Emergencies

Since the 1960s, the Chief Scientific Adviser has been responsible for coordinating scientific advice in emergencies. This role was formalised in 2009 with the creation of SAGE. SAGE is a visible part of national science advice, and it is the entity responsible for ensuring a coordinated scientific response during emergencies.

SAGE's scientific advice goes to decision-makers and supports the intergovernmental work of the Cabinet Office, but is not considered government policy (SAGE, 2020). The composition of SAGE depends on the nature of the emergency, but usually includes government experts and outside experts from different fields of science and industry (SAGE, 2020).

ADVICE FROM GOVERNMENT UNITS SPECIALISING IN RESEARCH AND EVIDENCE

The What Works Network

The What Works Network's purpose is to increase the supply of policy-relevant evidence, provide advice and generate outputs to aid decision-makers. Its key activities include: a) producing synthesis reports and systematic reviews; b) filling gaps in evidence through commissioned trials and evaluations; c) disseminating findings in accessible ways; and, d) supporting practitioners and policy-makers to use these findings. The What Works Network has nine independent centres, three affiliate members and one associate member, all led by the What Works Network National Adviser.

National academies

National academies' mission involves the promotion of excellence in academic and scientific disciplines. They also support the use of evidence in government and other policy-making organisations. National academies include the Royal Society, the Royal Academy of Engineering, the Academy of Medical Sciences and the British Academy. Some of these academies have policy units and respond to specific consultations, for example the National Engineering Policy Centre.

[4] Details on the members of the CST can be found here.

Response to COVID-19

SAGE coordinated the British government's response to the pandemic. SAGE played a key role in providing ongoing advice to support policy and decision-making during the pandemic. SAGE and its subcommittees produced 360 working papers between January and December 2020, and its staff numbers went from seven in January 2020 to over 100 in February 2020. SAGE also received external advice from scientific advisory committees and commissions, including: a) New and Emerging Respiratory Virus Threats Advisory Group, b) Group of Scientific Models for Pandemic Influenza, c) Independent Scientific Group on Behaviours related to Pandemic Influenza, and d) English Consortium for COVID-19 Genome Sequencing.

Despite having one of the most robust advisory systems globally, the UK's response to the emergency has been one of the most criticised by public opinion because of the slowness to take action and the persistent contradictions throughout the process (Landler & Castle, 2020). One key lesson that emerged during the pandemic response is that SAGE was not enough to coordinate the efforts to deal with the global pandemic. Different sources of expertise needed to be brought together.

In addition, the political response to the pandemic was strongly influenced by political rhetoric about public investment in health in the context of Brexit and a distancing of the Prime Minister's Office from the scientific elite and SAGE (Yamey & Wenham, 2020). This same context led the UK government to ignore the World Health Organization advice, which considerably delayed the adoption of measures to control and mitigate the effects of the pandemic (Yamey & Wenham, 2020). Further, the advice provided by SAGE about COVID-19 was not public from the beginning, which made it difficult to monitor and evaluate the decisions made by the government. Although the government announced that all the measures concerning the pandemic were taken based on scientific advice, there are contradictory allegations (Landler & Castle, 2020; Alwan and others, 2020; Mueller, 2020). This has led to a feeling of growing distrust on the part of the public about the government's actions in the context of the crisis (Fletcher, Kalogeropoulus, & Nielsen, 2020).

4. TAKEAWAYS AND LESSONS

The cases presented in the previous section show the diversity of advisory systems that exist worldwide. No system by itself can be considered a model that can be transferred to another context and obtain the same results. A crucial characteristic of advisory systems and the entities that comprise them is that they are highly dependent on their environment and result from historical and political processes. While some structures can be similar (e.g. chief scientific adviser or similar positions), their outcomes are still dependent on the context.

In general, we have observed fundamentally different systems. The systems of the UK and Canada are characterised by having the position of chief scientific adviser, which has an articulating role between science and politics. In the UK, the CSA position is accompanied by CSAs at the ministerial or departmental level, facilitating the coordination of actions at various levels of government. In Canada, this role has been adopted at various times. It has recently been re-established as a mechanism to coordinate an advisory system that is considered uncoordinated and has failed to align the efforts and activities of different advisory entities. In Canada, the functions of the CSA have been extended to strengthen the integrity of scientific practice in the public sector, develop codes of practice and guidelines and develop scientific skills in young people.

An essential element of the scientific advisory system in Canada worth noting is the role of the National Research Council. This entity is a government agency that reports to parliament through the Ministry of Innovation, Science and Industry. The NRC is an interesting case because it fulfils dual functions. On the one hand, it provides scientific advice to the government. On the other hand, it carries out expanded activities that include interaction and transfer of knowledge to the private sector by managing patents, licences and channelling research funds. In addition, semi-dependent research centres aligned with the federal government's strategic priorities are part of the NRC.

The German system is highly effective, and it is made up of various entities and advisory networks. The German experience can be complex and difficult to replicate, especially considering the budgetary limitations of such a system. However, one lesson that the German scientific advisory system leaves is the importance of establishing advisory systems, which, regardless of their complexity, are transversal to all levels of government and decision-making. A balance between formal structures and sufficient flexibility is necessary for entities to request and use the evidence according to their specific needs. In the case of Germany, this balance is achieved through specialised advisory commissions that

cover crucial issues, such as the environment and climate change, and advise government entities at various levels of government.

The Spanish system bears similarities to the Latin American advisory systems to the extent that the Ministry of Science usually regulates advisory activities, technology and innovation. However, advisory entities in Spain have broader functions and include activities such as promoting the innovation and research system, the professionalisation of careers in science and the allocation of public funds for research. The Spanish system also has a strong component of disseminating research to the public.

The priority of Latin American systems is to strengthen the science, technology and research ecosystem and promote the state's capacity to generate research and robust evidence for decision-making. In both cases, a good part of the function of the advisory entities is focused on developing links between different actors of the knowledge ecosystem, especially actors from the private sector and academia. Advisory entities in Latin America have close ties to the government. Usually, the members of these entities are appointed by the president or the minister of the relevant department. One of the most significant challenges in having advisory entities close to the government is the limited independence that gives them. In the selected cases, advisory entities in Latin America are highly centralised and still face challenges in including local visions in the production and use of science. Some countries, such as Colombia, have begun to respond to these challenges by creating government bodies to promote the production and use of science at the subnational level.

One of the key differences between the advisory systems in Europe and Latin America is that the scientific advisory systems in the European countries analysed focus mainly on the function of science for policy. The entities in charge of issuing guidelines and strategies related to the policy for science function have independent structures from the advisory entities that were not reviewed in this document. In Spain and countries of Latin America, scientific advice to the government plays a secondary role within the entities that govern the science and technology sector (ministries/secretariats/offices of science, technology and/or innovation). The scientific advisory entities in these countries are usually part of ministries or other public offices, and their primary function is to provide scientific advice to inform the activities of these government entities.

The coronavirus pandemic put global advisory systems to the test and highlighted the structural weaknesses of health systems and the generation and use of scientific evidence. The main lesson from the pandemic is that the existence of scientific

advisory systems and associated entities is necessary, but not sufficient, to face a crisis or an emergency and to ensure that governments will use scientific evidence to make the best decisions. A clear example of this is the United Kingdom, one of the countries with the best-structured advisory system globally and which, nevertheless, showed deep flaws in handling the crisis. The same is true in the case of Canada and Brazil. The COVID-19 crisis shows that advisory systems depend greatly on the context and political leadership, and on a well-structured research and innovation system ready to respond to an emergency.

Lessons

Balance is the keyword when it comes to advisory systems or entities, their roles and responsibilities. The success of a scientific advisory body depends on the balance between ad hoc entities and permanent bodies, between scientific evidence and public policy considerations, between 'science for public policy' and 'public policy for science' (Gaelle, Hoffman, & Ottersen, 2018; Gluckman, 2014; Glynn, Cunningham, & Flanagan, 2003; OECD, 2017). Based on the reviewed literature, we have identified several key characteristics of a scientific advisory system.

Flexible systems can respond and adapt to challenges and opportunities

Governments should establish advisory bodies that provide them with adequate experience and information on different topics. It is crucial to find a balance between permanent and ad hoc institutions, between specialised bodies and those with a transversal approach.

Permanent scientific advisory bodies usually have long-standing experience on specific issues. However, the complexity of the challenges requires that permanent bodies cover more areas or approaches or work collaboratively with other entities and actors in other areas of knowledge. Ad hoc entities are often helpful in responding quickly to emerging questions or issues. However, countries cannot have only ad hoc entities, as they risk being poorly prepared to respond to a crisis or 'overpopulating' the system with entities that are neither permanent nor connected to the government. Permanent entities have to be flexible enough to adapt to the times and emerging advisory needs.

The Principal Scientific Advisor can play a crucial role

The CSA fulfils a public role as the most visible expert and provides direct advice to the president or prime minister of a country (Wilsdon, Allen, & Paulavets, 2014). The CSA is selected based on their experience and track record and is an independent official who does not represent a political party and provides direct advice to the head of government on political, scientific and technological issues.

In addition, as a neutral public official, the CSA can develop and strengthen interdepartmental or inter-ministerial relationships and collaborations and facilitate strategic coordination on scientific and emerging issues (Marleau & Girling, 2017). Although the CSA is not in charge of making decisions, their primary function is to advise and question the evidence to ensure that decisions are made with all the necessary information. The CSA supervises an office, provides guidelines on science research, dissemination and communication processes, and other activities to achieve this objective (Marleau & Girling, 2017).

Public trust in science and transparency in scientific advisory processes are crucial

Stakeholders' trust in any type of scientific and research advice largely depends on the integrity of the process through which such information is produced, managed and communicated (OECD, 2017). The parties' trust in the process is decisive in the decision-making process (Office of the Chief Science Advisor, 2018). This requires two mutually reinforcing actions: a) encourage responsible conduct in research, science and related activities; and b) establish transparency and accountability mechanisms in advisory processes (Office of the Chief Science Advisor, 2018). In Canada, for example, the position of scientific integrity officer has been established, and they are in charge of handling complaints or reports about possible infractions. In addition, when public employees have information that may indicate a violation of public sector values and codes of ethics, they can initiate the procedures established in the Public Servants Disclosure Protection Act, which ensures the federal public sector employees a secure and confidential process to disclose workplace wrongdoing and protect them against acts of retaliation (Office of the Chief Science Advisor, 2018). This initiative is part of a national effort to promote ethical practices in the public sector.

Advisory entities must be autonomous

The autonomy of the advisory entities is key to their proper functioning and ensures that the advice provided is free from political and private interests. Knowledge production must be transparent and independent. Too much government involvement in the process can weaken the quality and reliability of the advice provided. When the results of scientific advice are handled internally and are left to the discretion of public officials such as ministers, the process tends to be perceived as less trustworthy and not well received by citizens (OECD, 2017). For this reason, the autonomy of advisory entities should be supported by governance arrangements such as clear guidelines for selecting qualified and independent members and the availability of funding to do so. It is equally important to create the necessary conditions for freedom in using research methods and disseminating results (OECD, 2017).

Balance between representativeness and experience

To ensure that the results of scientific advice are relevant and legitimate, there must be inclusiveness in the perspectives taken into account in the decision-making process. Applied to advisory entities, inclusivity has two dimensions: a) inclusiveness in terms of socioeconomic status, ethnicity, gender and regional origin, and b) inclusiveness in terms of the need to include voices across the political spectrum and from different sectors (public, private, civil society) (OECD, 2017). Scientific advisory entities cannot ignore representativeness biases in terms of their composition; they must be representative. For example, some countries have formal processes to ensure gender equality in the composition of advisory bodies (OECD, 2017).

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