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Five years after Fukushima: scientific advice in Japan

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ABSTRACT In the last 5 years, scientific advice has emerged as a new policy theme in Japan. In 2010, virtually no one in Japan's science policy circle spoke of scientific advice. By 2015, Japan was proactively involved in international discussions on scientific advice, and both the government and the scientific community recognized it as a key area of concern. This article describes how the issue of scientific advice came to attain recognition in Japan's science policy community in the first half of the 2010s. It can be regarded as a study of a case in which attention to scientific advice greatly increased in a relatively short period of time and progress towards the goal of constructing an effective national scientific advisory system was witnessed. In Japan's case, two coinciding developments powerfully drove the phenomenon observed: the unfolding of debate on the roles and responsibilities of scientists and the government, prompted by the Great East Japan Earthquake and the ensuing tsunami and nuclear disaster in March 2011; and a parallel surge in attention to scientific advice in the international community. Having considered the path that Japan has taken, the last part of this article will call for the nation's sustained effort to be engaged in ongoing international endeavours to strengthen scientific advice. This article is published as part of a collection on scientific advice to governments.

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Introduction

In the last 5 years, scientific advice emerged as a new policy theme in Japan. In 2010, virtually no one in Japan's science policy circle spoke of scientific advice, even though there already was a lot of discussion on science–society relationships, as well as on the use of scientific expertise for such policy purposes as environmental regulation, drug approval and food safety. By 2015, however, Japan was proactively involved in international discussion on scientific advice, in such settings as the Organization for Economic Cooperation and Development's (OECD) Global Science Forum (GSF), and both the government and the scientific community recognized it as a key area of their concern in official documents. In 5 years, Japan thus made a sea change with regard to scientific advice.

In this period, growing interest in the issue of scientific advice was observed not only in Japan but internationally. Global networks of scientific advisors have begun to take shape, and fully-fledged international studies on scientific advice were conducted (Lentsch and Weingart, 2011; OECD, 2015). Scholars as well as policymakers from all over the world are now seriously looking into this issue and engaged in exchanges and debate, most notably through the International Network for Government Science Advice, launched in 2014 (http://www.ingsa.org/). Today, scientific advice is clearly becoming ever more important for a broad range of policy fields, both at national and international levels (Ambrus *et al.*, 2014; Wilsdon *et al.*, 2014). In areas such as climate change, biodiversity, epidemics, food and water security, terrorism, population control, aging, disaster prevention and cybersecurity, all nations as well as international organizations are pressed to find ever more effective solutions to problems fraught with various types of uncertainties, in a cost-effective, accountable manner.

In the last 5 years, a great transformation of the general nature of science and technology has also been taking place. Social expectations for science, technology and innovation have never been higher, while public expenditure on science and technology has begun showing signs of stagnation, particularly in advanced countries (OECD, 2016). Meanwhile, radically new modalities of science, technology and innovation, including "open science", "industry 4.0" and "inclusive innovation", have emerged. At the same time, new key technologies with potentially tremendous impacts on society, including artificial intelligence and genome editing, have appeared. In view of such fast, radical and multifaceted changes, it is expected that scientific advisory systems of nations and international bodies will need constant revisions and reforms.

This article describes how the issue of scientific advice came to attain much recognition in Japan's science policy community in the first half of the 2010s. It can be regarded as a study of a case in which attention to scientific advice greatly increased in a relatively short period of time and some progress towards the goal of constructing an effective national scientific advisory system was seen in a nation. In Japan's case, two coinciding developments powerfully drove the phenomenon: the unfolding of debate on the roles and responsibilities of scientists and the government, prompted by the Great East Japan Earthquake and the ensuing tsunami and nuclear disaster in March 2011; and a parallel surge in attention to scientific advice in the international community. On the basis of such reflection on the path that Japan has taken, the last part of this article will call for Japan's sustained effort to be engaged in ongoing international endeavours to strengthen scientific advice.

The multiple disasters

On 11 March 2011, at 14:46 Japan Standard Time, an earthquake of magnitude 9.0 occurred off the coast of Japan. The largest earthquake ever recorded in Japan, the Great East Japan Earthquake caused massive tsunami, which climbed land as high as 40 m and travelled inland up to 10 km. A total of 18,500 people died or went missing, and 400,000 houses and buildings were totally or partially destroyed. An extremely broad range of social and economic infrastructure was damaged to the extent that Japan's GDP growth rate was visibly pushed down (MEXT, 2012).

In addition, the earthquake and tsunami triggered the serious accident of Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Station. After three out of six reactors of the power station totally lost electricity, their cooling systems stopped and nuclear meltdown started. Subsequently, explosions caused by hydrogen gas released nuclear materials into the environment. People within 20 km from the site were evacuated, and tentative standards were established to regulate the shipment and supply of water and food. At one time there was a very real possibility of the worst case scenario, that is, the evacuation of a half of Japan (Funabashi, 2012).

The multiple disasters left immense damage to Japanese society. Even after the Japanese government announced on 16 December 2011 that the reactors were now stable, contaminated water was constantly generated and sometimes released. Decades of struggle will be required until Fukushima nuclear reactors will be safely contained and decommissioned. Also, decades will be needed before the contaminated area will be adequately cleaned up so that people can return to live there. Meanwhile, other nuclear reactors across the nation have been halted, drastically changing Japan's overall energy supply structure. Tens of trillions of yen will still have to be spent to achieve true recovery from this tragic disaster.

Scientists in introspection

During the months following the Great East Japan Earthquake and the nuclear accident, intense debate took place within the Japanese scientific community on how to cope with the critical situation, how scientists and engineers could and should contribute to the national effort for recovery, and how the roles and responsibilities of scientists and engineers should be reconsidered and redefined. The main arena for such debates was the Science Council of Japan (SCJ), which is the Japanese Academy of Sciences.[1]

SCJ is a representative body of the Japanese scientific community. While being a part of the government, it is chartered to operate independently. With 210 council members and 2,000 members, SCJ has four mission areas: policy recommendations to the government and the public, international activities, promotion of scientific literacy and establishment of networks among scientists. Recently, SCJ has made great effort to improve its scientific advisory function, in parallel with conducting a drastic reform of its organization and the selection mechanism of its members. However, SCJ's scientific advisory capacity is not yet as strong as had been hoped (Yoshikawa, 2016).

After the Great East Japan Earthquake struck, SCJ expressed its stance to play as much role as possible to handle the crisis. One week after the earthquake, it issued a statement on what must be done. While urging nuclear experts to collectively make the best effort to inform necessary decision-making and asking for better communication of risks to the public, SCJ declared that it "has strong intention and capability to provide necessary advice" regarding emergency operations (SCJ, 2011a). It thus eagerly sought to mobilize the academic sector to make crucial contributions.

However, SCJ was not able to play a central role in coping with the emergency, due to dearth of information. The conditions and circumstances of the nuclear reactors changed day by day, and hour by hour. Actually, SCJ requested the government to share such

information, but the government refused to do so (Yoshikawa, 2016). This might mean that there was not faith on the part of the Japanese government that SCJ would be substantially helpful in guiding policy actions. As a result, SCJ could not do much more than issuing a series of recommendations during the weeks following the disasters on such issues as public communication, environmental monitoring and waste disposal, apart from engaging itself in public and international communication.[2]

As the initial critical phase of the nuclear emergency passed by, the scientific community took to self-reflection and self-examination. However, the first to do so was not SCJ or academic societies but the Council for Science and Technology Policy (CSTP, renamed Council for Science, Technology and Innovation in 2014), the highest policy organ in this field put in the Cabinet Office of Japan. Comprising scholars and industrialists as well as relevant ministers, CSTP published a document on 2 May 2011 stating its basic stance for science and technology policy after the Earthquake. It said: "Having experienced the great disaster, we renew our recognition on the limitations of science and technology, whose estimation and control capacities were overwhelmed by the threats of nature, and gravely reflect on nuclear and other technological systems and their management". It also urged researchers, engineers and policymakers to sincerely face the situation and unite to help the recovery and reconstruction efforts (CSTP, 2011). Academic societies, such as the Seismological Society of Japan and the Atomic Energy Society of Japan, then followed suit. They published statements reflecting on the roles and responsibilities of their disciplines, and held symposia on this topic.

On 22 September 2011, SCJ also issued a statement; it was not about the need for reconsideration of science and technology *per se* but that of scientific advice needed in emergencies. The statement pointed out that in emergencies, disparate expert advices by individual scientists would not make desirable contribution to the government or the public; what is really needed is an integrated advice by the scientific community, or the "unique voice" of scientists. SCJ asked itself in the statement to what extent SCJ was able to pursue such a responsibility after the disaster, and expressed its determination to strengthen SCJ's scientific advisory function (SCJ, 2011b). Scientific advice thus came to be recognized as a critical issue for debate in the Japanese scientific community.

International discussion

Debate on scientific advice in Japan was not closed within the nation but often conducted internationally. One of the prominent figures involved in such discussion was Sir John Beddington, the UK Government Chief Scientific Adviser (GCSA) at that time. In a symposium jointly held by the British Embassy in Tokyo and the National Graduate Institute for Policy Studies (GRIPS) on 31 May 2011, Beddington explained about his actions and judgments following the Fukushima nuclear disaster. On the basis of the available information he received from the Embassy, he supported the Japanese government's decision on the setting of evacuation areas and advised the British government that there was no need to evacuate British citizens from the Tokyo area. This critical advice not only helped British people but Japanese people and other foreign nationals as well; in addition, it created positive impacts on the Anglo-Japanese diplomatic relations (Grimes *et al.*, 2014).

The British system for emergency response very strongly appealed to Japanese scientists and policymakers. In the United Kingdom, the Scientific Advisory Group for Emergencies (SAGE), chaired by GCSA, plays a central role in scientific input to the government in emergencies. It serves as a place to collect necessary scientific expertise and integrate them into advice that is helpful for decision-making. It was first activated at the time of H1N1 influenza pandemic in 2009, and then Icelandic volcanic eruption in 2010. This GCSA–SAGE system was also deemed effective after the Fukushima nuclear disaster.

The United States was also closely involved in the discussion. Bruce Alberts, then Editor-in-Chief of the *Science* magazine, spoke in a symposium jointly held by the Japan Science and Technology Agency (JST) and GRIPS on 5 October 2011 on the role and responsibility of scientists in society, drawing on his experience as the president of the US National Academy of Sciences. Jane Lubchenco, then US Undersecretary of Commerce, and Kevin D Crowley, Senior Board Director of the Nuclear and Radiation Studies Board of the US National Academies, also spoke in similar symposia held by SCJ and JST in November.

It should be noted here that the US science advisory system played no less a critical role than its UK counterpart at the time of the Fukushima disaster. Several days after the earthquake, the US government was split on the evacuation of US citizens. While the US Navy, which had strong orientation for "zero-risk", was advocating for evacuation from the Tokyo area, the Department of State recommended against it from a diplomatic standpoint. Then, John P Holdren, Assistant to the President for Science and Technology, negated the Navy's proposal based on his own simulation that was backed up by US scientific community, and this judgment became the final decision of the US government. Had he decided otherwise, that would have had a tremendous impact on US–Japan relations (Funabashi, 2012).

Meanwhile, fundamental criticisms of Japan's scientific advisory system were also heard from overseas. A *Nature* editorial pointed out in December 2011 "the absence of a strong and independent scientific voice to advice the government". Such a situation, the editorial went on, hindered the Japanese government to take effective actions in the aftermath of the disaster, instead letting the government hide the problem, "politicians fumble for answers, while ill-informed government spokespeople tell confused stories that can make them look foolish, irresponsible or deceitful". The editorial deplored that Japan had still not learned lessons from past tragedies such as the Minamata disease caused by industrial mercury poisoning in the 1960s and the HIV-tainted blood products problem in the 1980s. Establishing a structure for "fast and decisive action on critical situations", such as a Chief Scientific Advisor, as in the United Kingdom and the United States, was proposed (*Nature*, 2011).

Call for CSA position

In response to such criticisms from overseas, and through a series of symposia mentioned above and other opportunities for discussion set up by SCJ and disciplinary societies, the Japanese government recognized the need to strengthen Japan's scientific advisory system. One way to do so would be to drastically augment SCJ's scientific advisory capacity—but those in Japan's science policy circle were rather impressed by the GCSA-type scientific advisory mechanism. Thus, discussion on the possibility of creating a GCSA-like position within the Japanese government began.

On 28 October 2011, the Minister of State for Science and Technology Policy created an expert study group, chaired by Hiroyuki Yoshikawa, then Director-General of the JST's Center for Research and Development Strategy (CRDS), to deliberate on new organizational arrangements for scientific advice as well as the promotion of innovation based on science and technology in general. This study group met five times in the next 2 months and published a report on 19 December. The report recommended creating the positions of "Science, Technology and Innovation Advisors" to the Prime Minister and other ministers, and putting up secretariat functions to support them. Such advisors would be expected to provide ministers with neutral, independent advices,

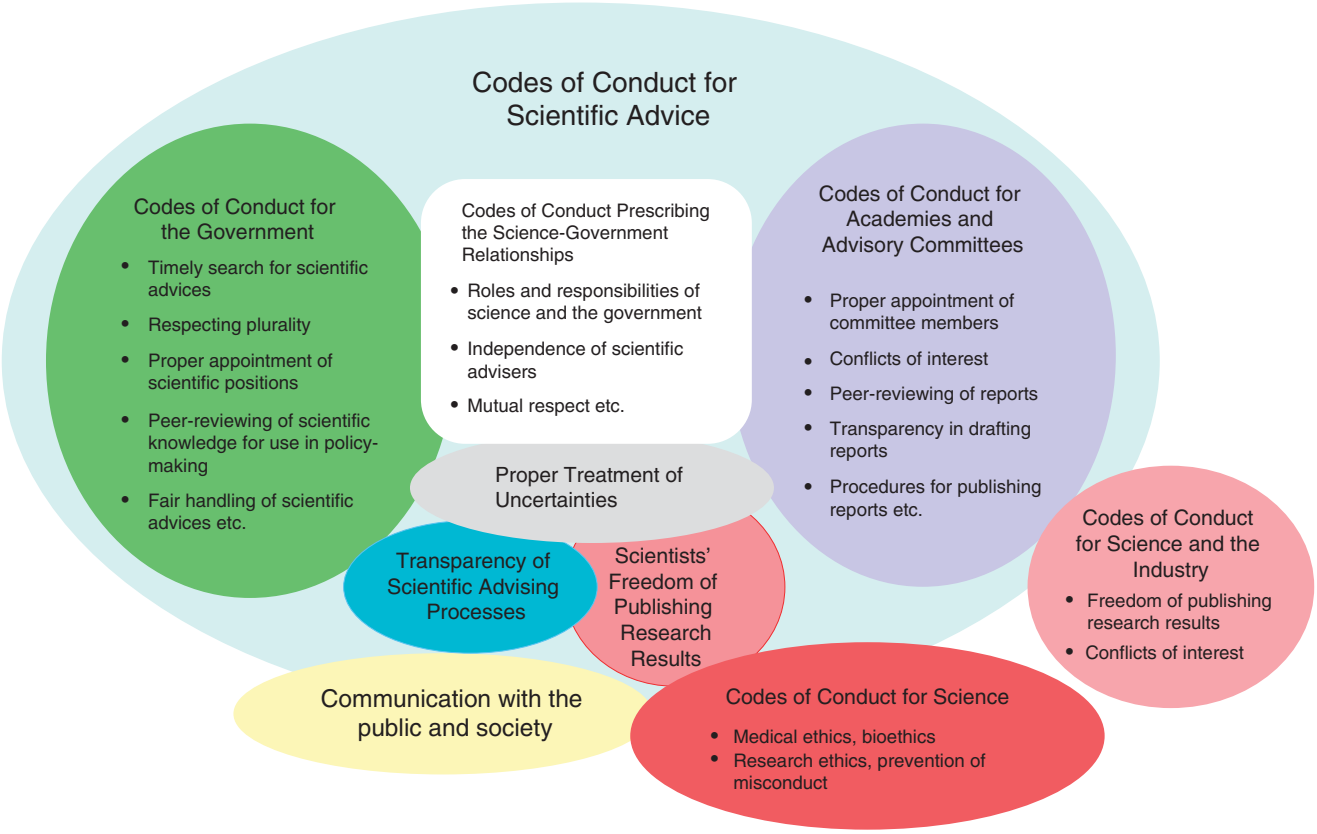

Figure 1 | A taxonomy of codes of conduct.
***Source*: CRDS (2012). It should be noted here that codes of conduct for scientific advice are different in nature and purpose from other types of scientists' codes of conduct, such as those regarding general research ethics, bioethics and medical ethics, and scientists' relationships with the industry. Needless to say, however, ensuring the integrity of science in policy-making and ensuring the integrity of science itself are interrelated.**

and integrate information in emergencies (Cabinet Office Study Group on the Promotion of Science, Technology and Innovation Policy, 2011).

However, one should note here that a GCSA-type position would not be always effective for any nation. The United States and the United Kingdom as well as some other countries such as Ireland, Australia, India, Malaysia and New Zealand have CSAs to the government or the prime minister, while many other countries, including China, France, Germany, Italy, do not have CSAs. Also, within the former category, the role of CSAs differs from country to country. For example, while GCSA in the United Kingdom has responsibility for the use of science in a broad range of policy fields, President's Science Advisor in the United States is more focused on his responsibility to coordinate and decide science and technology policy. There can be no simple explanation as to why certain countries have CSAs and not others, and the scope and focus of CSA's responsibility are varied; complex cultural and historical factors apparently play roles. For instance, Germany is generally seen as a nation with a highly decentralized structure. Therefore, concentrating scientific advisory capacity on one person may not be acceptable for the nation's political culture (Sato *et al.*, 2014; Enoki, 2015).

There was even a case where a CSA position was abolished after operating for some years. That happened not in a nation but in the European Union. In January 2012, President of the European Commission José Manuel Barroso appointed Anne Glover, former CSA for Scotland, as the first CSA to him. However, when Jean-Claude Juncker replaced Barroso in November 2014, he decided not to continue Glover's position and put up an alternative mechanism for scientific advice. After 6 months, in May 2015, the European Commission announced that it would appoint a seven-member, high-level panel of scientists to advise its policymakers. Those seven scientists were named in November 2015, and met for the first time in January 2016. The panel is planned to meet several times a year (https://ec.europa.eu/research/sam/index.cfm).

In Japan, the idea of Science, Technology and Innovation Advisors did not turn into reality, at least for some time. Since there were already a variety of positions and units that were in effect performing scientific advisory functions in each ministry, it was not easy to find convincing reasons why new positions were necessary. When the Democratic Party of Japan lost the general election in December 2012 and the Liberal Democratic Party returned to power, the idea almost died. However, as explained later, scientific advice would soon assume importance in the context of science diplomacy, and Science and Technology Advisor to the Minister of Foreign Affairs would be first appointed in September 2015.

CRDS proposal

While organizational questions of scientific advice were discussed at the policy level in the months after the Great East Japan Earthquake, its normative and procedural aspects also began to draw attention of relevant stakeholders. JST's CRDS, a think-tank dedicated to policy analysis and design, conducted a survey on the state of scientific advice in the world. In particular, CRDS analysed principles, guidelines or codes of conduct that were intended to guide and regulate the process of scientific advice in various countries and international bodies (Arimoto and Sato, 2012; CRDS, 2012).

Through the survey, it became clear that codes of conduct (including guidelines, principles and so on) for scientific advice are varied in nature and purpose. Some of them are intended for scientific advisers such as national academies and government advisory committees. Others are for ensuring legitimate handling of scientific knowledge in the government. Still others prescribe more general science–government relationships. Figure 1 roughly represents the overall structure of what those codes of conduct say.[3]

On the basis of such survey results, CRDS began working towards the goal of making a policy proposal to strengthen Japan's scientific advisory system, including draft codes of conduct for scientific advice in Japan. By analysing and reinterpreting foreign codes of conduct and taking into consideration Japan's particular institutional contexts, CRDS formulated ten principles that should undergird scientific advisory processes in Japan. This draft code of conduct was intended as a starting point for discussion involving a broad range of stakeholders in Japan. It enumerates general principles prescribing the relations between science and the government, so that each stakeholders can formulate their own codes of conduct. With such a purpose in mind, CRDS organized a couple of workshops and consulted with SCJ and CSTP in the course of writing up the policy proposal. After the Great East Japan Earthquake and the Fukushima nuclear disaster, stakeholders participated in the discussion with great interest.

CRDS published the policy proposal featuring the draft codes of conduct in March 2012, as shown below.

Codes of conduct for scientific advice proposed by CRDS (March 2012)

1. The role of scientific advice in policy-making
   The government and scientists shall share a common understanding of the importance of scientific advice and its role in policy-making. Scientific knowledge is an essential element in the policy-making process, and the government must duly respect it. Meanwhile, scientific advisers must recognize that scientific knowledge is not the sole basis of government decision-making.
2. Seeking scientific advice in a timely and pertinent manner
   The government shall endeavour to identify policy issues that require scientific knowledge in a timely, pertinent manner, and act to acquire the best scientific knowledge available on the issues.
3. Ensuring the independence of scientific advisers
   The government must not make political intervention in the activities of scientific advisers.Scientific advisers shall give their advice from an objective and fair standpoint, without being swayed by government or other organizations or individuals that can arbitrarily influence their scientific advice. As a means to ensure such objectivity and fairness, scientific advisers shall declare their own conflicts of interest.
4. Awareness of responsibility as scientific advisers
   Scientists shall provide scientific advice always for the public welfare. When scientists accept the role as scientific advisers, they shall be aware of the great influence scientific advice has on the process of public policy-making, and shall act in awareness of their responsibility.
5. Achieving broad perspectives and balance
   When the government seeks scientific advice, it should strive to secure the participation of scientists with appropriate insight and experience matched to the nature of the issues, and to obtain balanced advice based on broad perspectives.
6. Ensuring the quality of advice and integrating viewpoints
   Scientific advisers must ensure the quality of their advice to the maximum extent possible. To that end, scientific advisers shall strive for a balanced treatment of observational and experimental results and of cited papers, and seek to improve the quality of scientific advice through peer reviews. The SCJ and academic societies shall, where appropriate, endeavour to present high-quality scientific advice by integrating views of the nation's scientific community.The government shall ensure, as needed, that scientific knowledge used in policy-making has gone through independent peer reviews by qualified experts.
7. Proper handling of uncertainty and diversity
   Scientific advisers shall provide policymakers with clear explanations of uncertainties and diversity of views associated with scientific knowledge. The government shall respect such uncertainties and diversity of views.
8. Free disclosure of scientific knowledge
   In principle, scientific advisers are free to make their scientific knowledge public. They shall do so responsibly, however, in awareness of the large influence that scientific knowledge can have on policy-making and public opinion as well as on society as a whole.
9. Even-handed treatment of scientific advice by the government
   The government must treat with fairness the scientific knowledge it acquires. It must not approach scientific advice with any preconception, distort scientific knowledge when making it public, or intentionally add wrong interpretations when using advice in policy-making.The government should explain how scientific advice was considered when drawing up policy. It is especially important for the government to explain the rationales when making policy decisions that are in conflict with the scientific advice obtained.
10. Ensuring transparency of the scientific advice process
    To improve the quality and reliability of policy-making based on scientific advice, the government shall ensure transparency of the scientific advice process.

A salient point in CRDS's draft codes of conduct is that it underlines the value of integrated scientific advice. In "(6) Ensuring the quality of advice and integrating viewpoints" can be found the sentence: "The Science Council of Japan and academic societies shall, where appropriate, endeavour to present high-quality scientific advice by integrating views of the nation's scientific community". This sentence reflects Japan's experience with the Great East Japan Earthquake and the Fukushima nuclear disaster, which triggered scientists to make public a spate of diverse views on evacuation, food safety and cleanup activities, sometimes causing confusion among the public. The idea of CRDS's draft codes of conduct is that the scientific community can maximize their contributions to the government and society by supplying consensus voice of scientists. This of course does not mean that minority views should be disregarded. In cases where differences in views remain, such differences should be lucidly explained in scientific advice, which is as a whole subject to consensus by scientists.

However, it is difficult to assert that pursuing the consensus of scientists is definitely the right direction. On one hand guidelines in Germany, for example, support the idea that it is desirable for committee members to reach consensus advices (BBAW, 2008). On the other principles set out by the UK government emphasize that "Scientific advisers are free to publish and present their speech" (BIS, 2010). One can also find advocacy for "plural and conditional" advice (Stirling, 2010), although it can seem to be consistent with consensus (or integrated) advice, if minority views are given due respect as part of the consensus. In Japan, SCJ took the position close to CRDS in 2013, as shown in the next section (SCJ, 2013), but one of its committees reported in 2014 that in some cases presenting diverse viewpoints from a variety of standpoints could be more valuable than presenting consensus advices (SCJ, 2014). It appears that the issue of the consensus voice of scientists will require further examination and discussion in Japan as well as internationally.

Other items in CRDS's draft codes of conduct are generally found in foreign examples, except "(4) Awareness of responsibility as scientific advisers". This item was included also in view of various problems seen after the Great East Japan Earthquake. In addition, CRDS urged the government to promote initiatives to effectively mobilize scientific knowledge in preparing for, and responding to, emergencies. Finally, CRDS recommended both the government and the scientific community to draft principles or guidelines of scientific advice on their own.

SCJ's code of conduct

CRDS's policy proposal, published in March 2012, won considerable attention in Japan's science policy community.

Later this year, *the Science and Technology White Paper*, annually published by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), featured problems surrounding the Great East Japan Earthquake and the Fukushima Nuclear Disaster, covering the issue of scientific advice extensively (MEXT, 2012). However, concrete actions by MEXT or other ministries did not follow for a while. No codes of conduct were drafted; no organizational reform was carried out.

Meanwhile, the scientific community started to move. SCJ set up a committee on 25 May 2012 to discuss its own reform, incorporating examination of the issue of scientific advice in its mandate, too. After several meetings, the committee authorized a revision of the "Code of Conduct for Scientists" on 25 January 2013. The first edition of the Code of Conduct, established on 3 October 2006, had dealt with such issues as research integrity, scientists' relations with the public, repudiation of discrimination and conflicts of interest. In the revised version, the items concerning scientific advice and dual-use technology were explicitly added (SCJ, 2013).

SCJ's Revised Code of Conduct for Scientists (25 January 2013) (excerpt)
III. Science in Society
(Dialogue with Society)

1. Scientists shall participate actively in dialogue and exchange with citizens, for better mutual understanding between society and the scientific community. They shall also strive, to resolve various social issues and realize social welfare, to provide policymakers with effective scientific advice. In doing so, they shall aim to give advice based on consensus among scientists; in cases where differences in views exist, they shall explain them lucidly.
(Scientific Advice)
2. Scientists shall conduct research with the objective of contributing to public welfare, and offer sound advice based on objective and scientific evidence. Recognizing the great impact that their statements can have on public opinion and policy-making, they shall be well aware of their responsibility and shall not abuse their authority. They shall also make their best efforts to ensure the quality of their scientific advice, and at the same time clearly explain the uncertainty associated with scientific knowledge as well as the diversity of opinions.
(Scientific Advice to Policymakers)
3. When scientists provide policymakers with scientific advice, they shall recognize that while scientific knowledge should be duly respected in the process of policy-making, it is not the only basis for decision-making. In the event where a policy decision diverging from the advice of the scientific community is made, scientists shall request, as necessary, that policymakers explain about the decision to society.

Entering global debate

Just as Japanese policymakers and scientists came to take interest in scientific advice, similar trends were gaining momentum in the international community. In April 2013, OECD's GSF started an international study on scientific advice. GSF is a general-purpose, inter-governmental science policy committee set up under the Committee for Science and Technology Policy (CSTP) of OECD. Scientists as well as policymakers from participating countries discuss various issues regarding science and technology and issue reports containing recommendations for governments or international bodies.

What triggered GSF's activity on scientific advice was a controversial judicial action in Italy. On 22 October 2012, several scientists, who were in official scientific advisory capacities, were sentenced to prison for failing in their duties to assess risks of earthquake properly and providing with the public with correct information before the L'Aquila earthquake on 6 April 2009 killed 309 people. This event caused enormous repercussion worldwide,[4] and posed serious questions on the roles and responsibilities of scientific advisers. If scientists can be subject to civil or even criminal penalties for providing honest scientific advices, would they still be willing to act as scientific advisors? Even if they take such responsibility, would not their advice be affected in some way by their fear of incurring penalty? The Italian delegation raised such questions in the GSF meeting held just after the verdict.

In January 2013, a scoping group for an international study on scientific advice was formed, and the project formally started in April. The expert group was co-chaired by the Netherlands, Japan, Germany and Italy. Members of the expert group conducted literature survey and interviews, and had frequent teleconferences. A major international workshop was held in Tokyo in October 2013. In this workshop, Marcia McNutt, Editor-in-Chief of *Science* magazine, asserted that the most critical foundation of scientific advice was trust among scientists, policymakers and the public. Another workshop was held in Berlin in February 2014, specifically to discuss the issue of legal liability of scientific advisors. After 2 years of intensive study, the final report was published in April 2015 (OECD, 2015).

OECD–GSF's final report presented a well-balanced international landscape of scientific advice. First, it showed a general structure of scientific advisory organizations and processes. From an organizational viewpoint, scientific advisory bodies of nations can be roughly categorized into four groups: (1) science policy advisory committees or councils, (2) permanent or *ad hoc* scientific/technical advisory structures (government advisory committees), (3) academies, professional societies and research organizations and (4) individual scientific advisors/counsellors (including GCSA-type individuals). There are also international scientific advisory organizations such as the World Health Organization (WHO), the Intergovernmental Panel on Climate Change (IPCC) and the International Council for Science (ICSU).

Meanwhile, from a procedural standpoint, the process of scientific advice can be roughly divided into four stages:

1. *Framing of the question*: End-users of scientific advice should ideally be involved together with scientific experts in framing the question at the outset.
2. *Selecting the advisors*: Involving the right experts and avoiding conflicts of interest is critical for the quality and legitimacy of any science advisory process.
3. *Producing the advice*: The independence of scientific advisors should be ensured, and uncertainties and the diversity of scientific views must be properly treated; the quality of the advice should be assured through peer review where time permits.
4. *Communicating and using the advice*: Individual and institutional responsibilities in regard to internal and external communication should be fully defined and mutually understood; policymakers should be transparent in their use of scientific advice.

OECD–GSF's report also discusses such issues as the means to minimize risks of legal liabilities of scientific advisors, the need for governments to establish scientific advisory mechanisms for emergencies, the importance of better coordination of national and international science advisory bodies and the involvement of civil society in the process. Such considerations resulted in four policy recommendations for governments (see below).

Four Policy Recommendations by the OECD report
Recommendation 1: Governments and responsible institutions should define clear and transparent frameworks and rules of procedure for their advisory processes and mechanisms.
Recommendation 2: Governments should establish effective mechanisms for ensuring appropriate and timely scientific advice in crisis situations.
Recommendation 3: Governments should work with international organizations to ensure coherence between national and international scientific advisory mechanisms related to complex global societal challenges.
Recommendation 4: Governments and responsible institutions should implement measures that build societal trust in science advice for policy-making.

This OECD-GSF study exactly coincided with the timing of surging interest in scientific advice in the international community. In October 2013, the United Nations announced the creation of a Scientific Advisory Board for its Secretary General. The Board, composed of 26 eminent scientists from all over the world, held its first meeting in Berlin in January 2014 and started providing policy input mainly on issues related to sustainable development. Then, in August 2014, ICSU held the first global meeting of high-level scientific advisers in Auckland, New Zealand, led by Peter Gluckman, CSA to the country's Prime Minister. About 200 participants from 40 countries engaged in intensive discussion on varied aspects of scientific advice for 2 days. Similar meeting in the Asia-Pacific region had started in June 2013, and that in Europe in June 2014.

In such a trend, OECD might build on GSF's report to more actively engage in international cooperation on scientific advice, which was one of main agenda items of the OECD-CSTP ministerial meeting, held in Daejeon, Korea, on 20–21 October 2015. The Daejeon Declaration, adopted at the meeting, recommended OECD to "explore ways to improve science advisory processes, including mechanisms for international coordination and exchange of good practices, and the associated engagement of civil society, and examine the possible development of a Recommendation of the Council on Scientific Advice".[5] Apparently, the need for international collaboration on the issue of scientific advice is increasingly recognized at high levels of governments.

Science diplomacy perspective

In Japan, there was little development with regard to scientific advice for some time after SCJ's revision of its Code of Conduct for Scientists in January 2013. Virtually no effort was made on the side of the government to formulate principles or guidelines on the process of scientific advice. Nor was any chief science advisor position was set up (Arimoto and Sato, 2014). Then a breakthrough came from a diplomatic sector.

On 28 July 2014, the Ministry of Foreign Affairs (MOFA) created a roundtable on science diplomacy. The roundtable met five times to discuss how to utilize Japan's scientific and technological capacities for diplomacy and how to promote international cooperation for scientific research and innovation. The final report, published on 8 May 2015, contained an array of recommendations, one of which was to appoint Science and Technology Advisor to the Minister for Foreign Affairs on a trial basis. The aim of such an appointment was "to develop institutional schemes for timely input to the minister, so that the information on updated domestic status in science and technology and trend in foreign countries will be well reflected to the policy-making of high-level bilateral and multilateral diplomacy". The report also recommended constructing a supporting structure for the Science and Technology Advisor. Specifically, it asked for establishing an advisory group comprising of experts in a variety of fields, holding regular meetings among relevant ministries, and promoting collaboration among think-tank institutions in the field of science and technology (MOFA Advisory Panel on Science and Technology Diplomacy, 2015).

On 24 September 2015, Teruo Kishi, Professor Emeritus of the University of Tokyo, was appointed the Science and Technology Advisor to the Minister for Foreign Affairs. Kishi is a renowned material scientist, former president of the National Institute for Materials Science and former vice president of SCJ. Kishi started to operate with the ministry-wide backup of MOFA, and the supporting system also began to take shape. Kishi has actually made great contributions to the agenda-setting of the G7 Summit held in May 2016.

Why did appointment of the Science and Technology Advisor for the Minister for Foreign Affairs materialize, whereas that for the Prime Minister or other minister has not in Japan? Clearly, the importance of science and technology in diplomatic issues has dramatically increased in recent years. In such areas as climate change, biodiversity and foreign aid, science and technology is deeply embedded in diplomacy. As a host country of G7 Summit in May 2016, and the Japanese government sorely needed input from science and technology perspective. As MOFA traditionally did not have strong capacity in science and technology, the need for the position of Science and Technology Advisor and associated supporting structure was thus imminent. Whether MOFA's move will spread to other ministries or the whole cabinet remains to be seen.

The changing landscape of science and technology and international politics

The current global trend to ascribe ever-larger roles to scientific advice is clear. Most national, regional and global problems cannot be solved without scientific inputs. Effective, robust scientific advisory systems will be essential at not only national but also regional and international levels. For this reason, countries all over the world have begun dialogue on scientific advice. As mentioned earlier, a global meeting of scientific advisors was held for the first time in Auckland in 2014. The second meeting will be held in Manchester in 2016, and then the third meeting in Tokyo in 2018. Regional equivalents of such meetings have already begun in Asia-Pacific Economic Cooperation (APEC) region and in Europe, and will begin in Africa in 2016. Utilizing such fora, countries can exchange their views and experiences to improve each other's scientific advisory systems; they can also endeavour to construct effective international scientific advisory mechanisms to address global and regional problems.

In recent years, there has been a remarkable growth in the number and diversity of organizations related to international scientific advice. For example, in addition to such UN-related bodies as the WHO, the World Meteorological Organization and Food and Agriculture Organization, all of which were founded soon after World War II, IPCC and the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services were created in 1988 and 2012, respectively, to supply scientific advices in specific fields. As for organizations for general scientific advice, ICSU, whose history dates back to 1899, was complemented by a multinational network of academies called Inter-Academy Panel in 1993 and its associated organization InterAcademy Council (IAC) in 2000. In addition the Third World Academy of Sciences (now the World Academy of Sciences) was established in 1983. Other organizations, such as UNESCO, OECD's GSF (founded in 1992) and the Global Research Council, which was founded in 2012 as a global network of funding agencies, also have aspects as scientific advisory bodies. International fora on science policy hosted by NGOs, such as the American Association for the Advancement of Science, the EuroScience Open Forum, the World Science Forum, Japan's Science Agora and the China Association for Science and Technology, are expanding their activities beyond national boundaries.

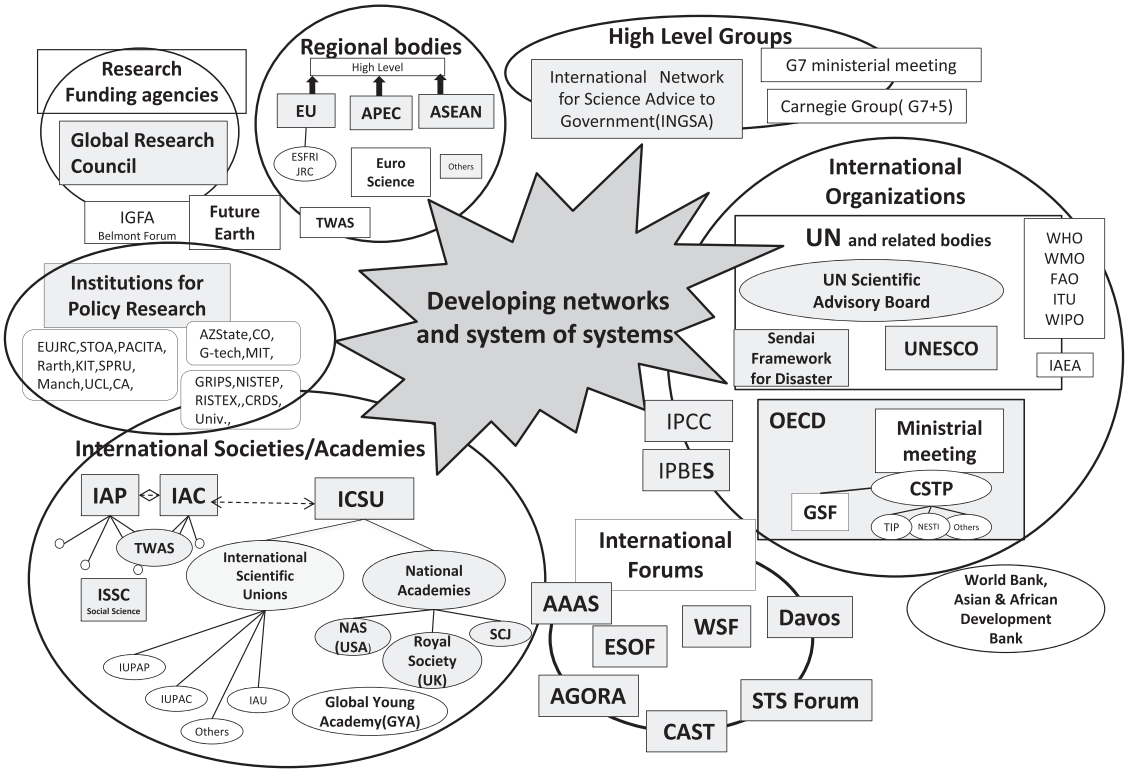

Figure 2 | Organizations related to scientific advice.
***Source*: Modified from Arimoto (2014).**

The authors' view is that, for all these international bodies to best achieve their objectives, some form of coordination will be necessary. They should form a reasonably flexible, yet effective, "system of systems" for scientific advice in the world, as shown in Fig. 2. Towards that goal, they should first pursue mutual understanding and recognition, and then formulate and share a joint vision for scientific advice. On the basis of such a joint vision, they can collectively address pressing issues that the world is facing now or will face in the future. That seems to be exactly what is needed of science and technology in today's globalized society (Sato *et al.*, 2014).

Japan is aware of such important global trends of scientific advice. Aside from the appointment of Science and Technology Advisor to the Minister for Foreign Affairs mentioned earlier, the Fifth Science and Technology Basic Plan, published in January 2016, for the first time featured a section on scientific advice. Drafted every 5 years, the Science and Technology Basic Plan is the most fundamental policy document in the field of science and technology policy in Japan. The document recognizes growing role of scientific advice in contemporary society, and points out the need to enhance Japan's scientific advisory system, referring to recent international trends.

The authors also believe that it is important for Japan to be actively involved in international studies on scientific advice. Case studies and conceptual studies should be accumulated. Also, such studies should be translated to more easily comprehensible, general books, so that many people can access them. That is necessary exactly because the issue of scientific advice is not easy for government officials, politicians and the public to understand and familiarize with.[6]

Academic efforts in this field must be constantly upgraded, for scientific advice will and should be changed, as the world, and science and technology itself, is rapidly changing. How should the mechanisms of scientific advice change in the age of "open science" and "citizen science"? What kind of scientific advice is needed to encourage "inclusive innovation"? Such questions can be answered only through deep insights into the nature of scientific advice and the new environment in which it operates, combined with careful discussion among stakeholders. As novel, powerful technologies such as artificial intelligence and genome editing are emerging to have enormous positive and negative impact to the humankind, the roles and responsibilities of scientific advice and scientific advisors are becoming overwhelmingly large. Thus, there is now a real necessity to earnestly seek ways to improve and upgrade the mode of scientific advice, mobilizing academic insights as well as political and administrative capacities of as many nations as possible. That will become increasingly possible, as more and more nations will be engaged with the issue of scientific advice both at academic and policy levels, as Japan has in the last 5 years, in addition to quite a few nations those that already have.

Notes

1 Another organization in Japan, the Japan Academy, is an honorary organization, without scientific advice function.

2 Great East Japan Earthquake Task Force, SCJ, emergency recommendations, 25 March, 4 April, 5 April, 13 April, 15 April 2011.

3 Among the codes of conduct analysed were: The White House, "Memorandum for the Heads of Executive Departments and Agencies, Subject: Scientific Integrity", 9 March 2009; John P Holdren, "Memorandum for the Heads of Executive Departments and Agencies, Subject: Scientific Integrity", 17 December 2010; US Federal Advisory Committee Act (1972, amended 1997); UK Department for Business, Innovation and Skills, "Principles of Scientific Advice to Government", 24 March 2010; UK Government Office for Science, "The Government Chief Scientific Advisor's Guidelines on the Use of Scientific and Engineering Advice in Policy Making", June 2010; UK Government Office for Science, "Code of Practice for Scientific Advisory Committees", November 2011; Berlin-Brandenburgische Academie der Wissenschaften, "Leitlinien Politikberatung", 2008; Commission of the European Communities, "Communication from the Commission on the Collection and Use of Expertise by the Commission: Principles and Guidelines", 2002; IAC, "Rules of Procedure", 2005.

4 For example, President of the US National Academy of Sciences and President of the Royal Society of the United Kingdom issued a joint statement on 25 October 2012, protesting the verdict in Italy. Meanwhile, the German National Academy of Sciences *Leopoldina* and the French Academy of Sciences also issued a joint statement on 12 November 2012, calling for thorough investigation and analysis of what had happened.

5 "Daejeon Declaration on Science, Technology, and Innovation Policies for the Global and Digital Age", 21 October 2015.

6 The authors plan to publish such a book in Japanese in Summer 2016, explaining key concepts, problems and trends of scientific advice, and illustrating them in case studies in such fields as food safety, drug approval, earthquake prediction and global warming. (Arimoto *et al*., forthcoming)

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Data availability

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Additional information

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