4.1 Framework for Understanding the Policy Impact of STI Policies

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Abstract

Science, technology, and innovation policies should be pursued strategically in order to solve social issues through a consistent understanding of the effects of policies on the promotion of research in basic science, applied science, and technology development, as well as the impact of implementing the results of such research on the creation of new social value. This is also why the creation of a “science of science policy” is required to ensure that science, technology, and innovation policy has an objective and scientific basis. Solving contemporary social issues requires a clear recognition that modern scientific fields and disciplines have complex linkages, with scientific progress and its adoption within society possessing the potential to not only affect the natural environment, but the very environment in which the values of the people who make up society are formed. As such, the ex-ante and ex-post evaluation of the socioeconomic impact of the implementation of various science, technology, and innovation policies is an extremely important issue. In this paper, we summarize the framework for and issues involved in assessing the socioeconomic impact of science, technology, and innovation policies based on the awareness of such issues.

Keywords

Policy options, coevolution of policy formation mechanisms and policy science

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1 What are policy options?

When deciding on a particular issue and trying to execute that policy topic, several policy instruments for achieving that goal can be considered according to the policy scenario. The degree of policy goal achievement and the socioeconomic impact of policy implementation are expected to differ depending on the policy measures selected. While there is no disputing that government authorities and administrations bear ultimate responsibility for policy formation and implementation, it is also the responsibility of those implementing such policy to provide an explanation to the public to ensure public understanding and consent for implementation. In this respect, they should present evidence to the public demonstrating that there will be differences in the extent to which the policy goals will be achieved and the social impact they will have depending on the policy measures selected in the course of policy formation and implementation. Here, we use the term "policy options" to refer to the proposals made to clarify the policy implications of available policy measures for the ex-ante and ex-post evaluation of the degree of goal achievement and the socioeconomic impact of policy measures for solving problems. Of course, we must also consider the need for greater meta-evaluation, which assesses the validity of the very procedures used to formulate the "policy options" proposed here. As Figure 1 shows, we must keep in mind that the PDCA cycle system is considered a superordinate concept in evaluating the suitability of policy issue setting.

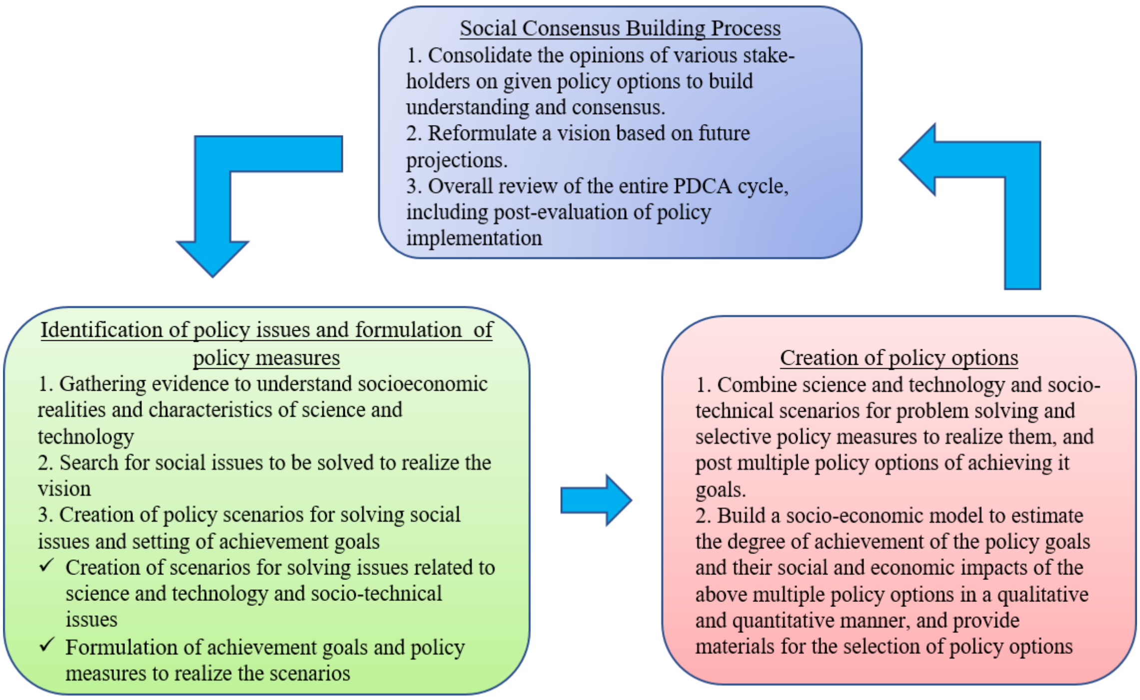

Figure 1. A conceptual diagram of policy options and policy processes.
Source: Created by the author.

2 The significance of policy option creation in the science of science, technology, and innovation policy

Many historical studies have traced the evolution of human philosophical thought over the seventeenth and eighteenth centuries, showing how philosophical thought was freed from the frame of "deciphering God's creation" and evolved to become so-called "curiosity-driven" science seeking to satisfy human curiosity, bringing with it revolutionary developments in the natural sciences and greatly contributing to human development. Moreover, the paradigm shift that took place in the nineteenth and twentieth centuries from classical physics to the modern physics of Maxwell, Planck, Einstein, Bohr, and others has led to rapid progress across basic science, applied science, and technological development in fields as broad as electromagnetism, quantum mechanics, biochemistry, information science, materials science, physiology, and medicine.

Revelations on the structure of matter at the end of the nineteenth century gave rise to new materials in the twentieth century, namely, the spread of information technology and the development of the computer, which made it possible to process large volumes of data at high speed. This was the information revolution. Entering the twenty-first century, this data processing technology was combined with communication technologies, leading to the further revolutions in various fields, including the creation of the Internet, a new technology for the global transmission and processing of data, and subsequently the development of AI (artificial intelligence) and advances in quantum computing. At the same time, the deepening of basic science and the spread of its applied technologies throughout society is having new effects on humanity, including destructive impacts on the environment and ecosystems, and even our social structures, giving rise to the so-called "Trans-Science Age," in which scientific developments invariably create unforeseen challenges that can no longer be solved simply by using the wisdom of the natural sciences.

Indeed, the focus of human scientific analysis no longer stops at satisfying the simple curiosity of "unravelling the mysteries of nature." While scientific advances aimed at explaining natural phenomena and the introduction of technologies based on that knowledge have accelerated changes in the development of human society, the reaction of natural phenomena to these changes is creating a shift in the balance of the natural environment. This has created inescapable cycles whereby we must restructure the sense of ethics and legal principles that humanity has developed, and create new sciences to address unsolved problems. Therefore, we are compelled to expand our perspective to comprehensively analyze the chain of action-reaction phenomena involving humans and nature within scientific and technological development. To accommodate this comprehensive analysis, science is undergoing a complex transformation—shifting beyond individual discipline-based science to become both "issue-driven" and "issue-solving," based on inter-disciplinary and multi-disciplinary ideas.

In response to these changes in the fields and subjects of scientific analysis, science and technology policy must also be multifaceted, no longer simply promoting linear progress from basic science to applied science to development science as has been the case in the scientific fields of the past, but instead proactively seek social issues, integrate scientific knowledge across scientific fields to solve them, nurture technology, and strategically guide innovation in social systems. In this regard, states are promoting the "science of science, technology, and innovation policy," with the aim of promoting the planning of objective evidence-based policy and their evaluation, reflecting the results of their evaluation and verification in policy, as well as establishing a process for evaluating the preconditions for policies and reflecting them in policy planning.

Launched in 2011, Japan's "Science for RE-designing Science, Technology and Innovation Policy" (SciREX) project is intended to promote the examination of scientific methodologies for the creation of evidence-based science, technology, and innovation policy and its establishment as a scientific discipline. The pursuit of a science of science, technology, and innovation policy has revolved around the following issues: (1) providing an overview of science and technology in modern society and an understanding of its scientific characteristics; (2) identifying and clarifying issues to be solved in modern society; (3) selecting science, technology, and innovation policy measures, including changes in social technologies and systems, to solve identified issues and evaluate their impact, as well as create so-called selectable policy options; (4) ensuring public accountability for policy intentions and fostering understanding among all stakeholders; (5) nurturing talent for science, technology, and innovation policy; and (6) the development of a data and information system to systematically accumulate evidence across these issues. The basic concept behind the advancement of this project can be summarized as follows.

1. Problem-solving science, technology, and innovation policy: To promote stronger inter-disciplinary links across basic, applied, and developmental science and technology, and the creation of new value (innovation) through the implementation of their results in society, with the goal of contributing to the resolution of problems facing society.
2. The search for a "science of science policy": The project for the promotion of such policy should be advanced with scientific rationality and based on objective observations (i.e., evidence and facts) concerning the discovery of social issues and the scientific recognition of the characteristics of modern science.
3. Transparency in the policymaking process and public accountability in the implementation of policies: Scientists, who play the role of scientific advisors in policy formation ,and the political and administrative bodies responsible for formulating and implementing policies based on that advice are charged with ensuring transparency in the policy formation process and its explanation to the general public. Accordingly, scientists and relevant political and administrative bodies should work together in a complementary relationship to ensure the scientific neutrality of policy.
4. Ex-ante and ex-post evaluation of policy assessment: To scientifically ensure the transparency of the policymaking process by providing multiple options for policy formation and implementation, assessing their socioeconomic impacts, and presenting them as options for policy selection. The ex-post evaluation of chosen policies should also be conducted to establish a PDCA cycle for policy implementation.
5. Establishing standards of conduct for scientists, policymakers, and policy implementers: Academia, government, and politics must each act from the standpoint of the people, enact their own norms, and respect one another's positions and roles in order to promote innovation in society.

3 A framework for setting policy topics

As illustrated by the block on the left side of Figure 2, "A framework for setting policy topics," the issues to be solved by science, technology, and innovation first need to be set. The first step in setting topics involves clarifying our understanding of science and technology and the social economy by taking a top-down view of the current state of science and technology, understanding its characteristics, and making a holistic observation of the current socioeconomic situation. The bottom block on the left reads, "Understanding the current situation through evidence," in which "An overview of the characteristics of science and technology by natural scientists" involves taking a top-down view of the structural characteristics of science and technology by consolidating scientists' findings in each domain, including understanding the current level of science and technology, interdependence between fields, and the characteristics of each scientific field. When viewing the characteristics of Japan's science and technology structure, it may be possible to clarify Japan's characteristics by comparing them with those of other advanced countries, using such countries as benchmarks. In doing so, bibliometric data provide an effective means of linking the allocation of research funds to each scientific field and the results of R&D. In addition to the number of papers and patents, understanding the state of human resource development in each field may be an important indicator when measuring results. In this respect, another observation in Figure 2 is, "Holistic observation of the current state of society and economy and its structure."

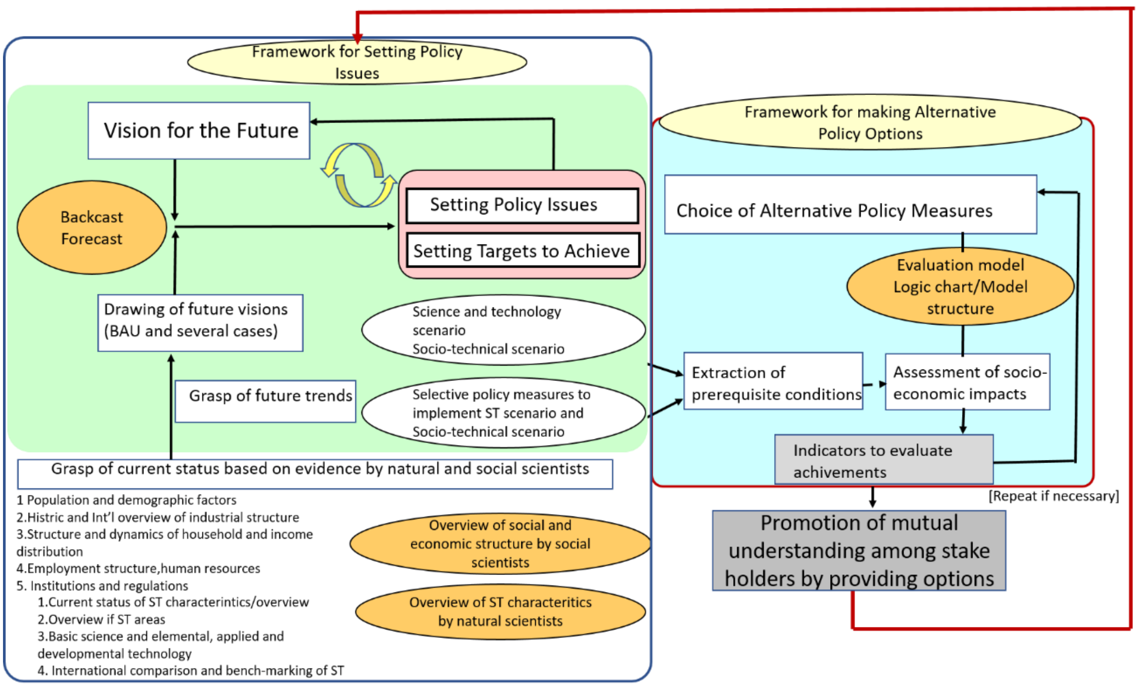

Figure 2. Framework for creating selectable policy options in "science for policy."
Source: Created by the author: Reference JST-CRDS (2010)

This framework is intended to aid the identifications of both apparent and latent issues faced by the social economy today. In this respect, we may be able to identify issues by paying attention to the simple feelings of citizens or by analyzing data produced by natural and social scientists and academics in the humanities. For instance, a global warming phenomenon may be discovered through a meteorologist's observations, issues in the labor market may be discerned by inferring changes relating to labor supply and demand in industries and companies from changes in the population structure, while other issues may be uncovered by examining international competitiveness and the structure of industries in the global economy. In order to understand the current state of the social economy, it is essential to collect systematic data on the current state of the social economy from sociology, economics, demographics, and other fields; examples include the availability of production factors like capital, population (labor), energy, and resources, as well as changes and trends in the supply and demand of goods and services, productivity of industries and companies, and people's values.

As Figure 2 shows, the next step involves the process of clarifying issues to be solved in the future in response to present issues identified through "an overview of the characteristics of science and technology" and a "holistic view of the current state of society and economy and their structure." What kind of society do we want to create for the future? What kind of society does the public want? These questions stand in contrast to the vision of the future of Japan, and the task and goal of policy is to bridge the gap between the image of the future based on that vision and the current image of society. This process involves determining whether the measures to bridge the gap are issues that should—or even can—be solved by strengthening science and technology and their introduction to social systems. If the problem is identified as one that can be solved using science and technology, a point in time at which the future vision is to be realized should be set, the functions required of science and technology should then be clarified, and the level of science and technology able to satisfy those functions determined as a natural trend from today's level. In instances where there appears to be a gap between the current and desired level of technology, the question becomes: What policy measures can be used to fill the gap? In contrast to forecast analysis, which compares a future forecast based on the current state with a future ideal state, a retrospective analysis can be used to measure the gap between a hypothetical ideal technology level and the current technology level by comparing the actual technology level with the desired future technology level, and determining how the current state should be changed to fill this gap and achieve the ideal future state.

In any case, targets will be set charting a path for the strengthening of science and technology so as to close the gap between the current level of science and technology and the goals for achieving a future level of technology. We can refer to this the "science and technology scenario" for solving a problem. There will be several policy measures to choose from in order to realize this science and technology scenario. Whether the implementation of the chosen policy instrument will promote the advancement of science and technology and bring about the desired scientific and technological progress can be envisioned as a roadmap over time, including the accuracy of the strategy for the allocation and development of resources between fields and the probabilistic factors affecting the success or failure of development. Additionally, a "socio-technical scenario" for social systems and their design must also be prepared in order to implement this "science and technology scenario" in society. The procurement and source of funds for the development accompanying scientific and technological research and development—whether conducted by the government or private economic agents—must be designed as a social system. In many cases, the social implementation of a developed technology will require changes in the social system. It is also important to recognize that both scenarios contain probabilistic elements of uncertainty in the process of their realization.

4 The structure of selectable policy option creation

The "science and technology scenario" and "socio-technical scenario" roadmaps, both of which contain probabilistic elements, as well as the policy measures adopted to realize them, will be depicted as multiple selectable options. In this respect, it is necessary to provide materials for discussions concerning the process of building understanding and consensus through discussions with various stakeholders in society on the question of which option to select from the multiple options that can be considered as available policy measures. Materials for discussion must be able to provide evidence on whether the implementation of the policy instruments of each policy option can achieve the policy objectives and the socioeconomic implications of the choice of policy instruments. Figure 2 illustrates this in the block labelled "Structure of policy option creation."

In the first block, "setting policy topics," the goals of the agenda, the "science and technology scenarios" and "socio-technical scenarios" for achieving these goals, and the multiple policy options for realizing these scenarios are presented as options. Policy option creation involves presenting a set of policy goal attainment and socioeconomic impact assessments for multiple options. There are many methodologies for creating policy options, including model simulations using econometric methods, agent model simulations that measure the impact of policy measures by probabilistically representing the diversity of decision-making among various stakeholders, verification methods using economic experiments, and descriptive evaluation methods such as impact assessment surveys. Regardless of the methodology used, the evaluation of the socioeconomic impact of the implementation of a policy instrument will be presented through quantitative and qualitative impact assessment indicators premised on systematic consistency, so as to evaluate the strengths and weaknesses of the multiple options available, clarify the implications of those choices, and provide material for discussion to advance the policy selection process in a transparent manner. As shown in the bottom row on the right side of Figure 2, policy options should contribute to building understanding of and consensus on the policy among the various stakeholders. If the socioeconomic impact assessments show that the policy options have additional effects in light of the future vision beyond those anticipated at the time they were first set, it is possible that reconsidering the choice of policy instruments and the setting of topics may be necessary.

Figure 3 presents the PDCA cycle process, which anticipates collaboration and co-development between academia—that is, those responsible for the science of science policy—and administrators, who are responsible for planning and implementing policy based on the advice received from academia (i.e., "policy for science"). It is important to ensure persuasive, clear explanations and transparency throughout the process, as well as co-ownership between the state and the public. See Figure 3 below.

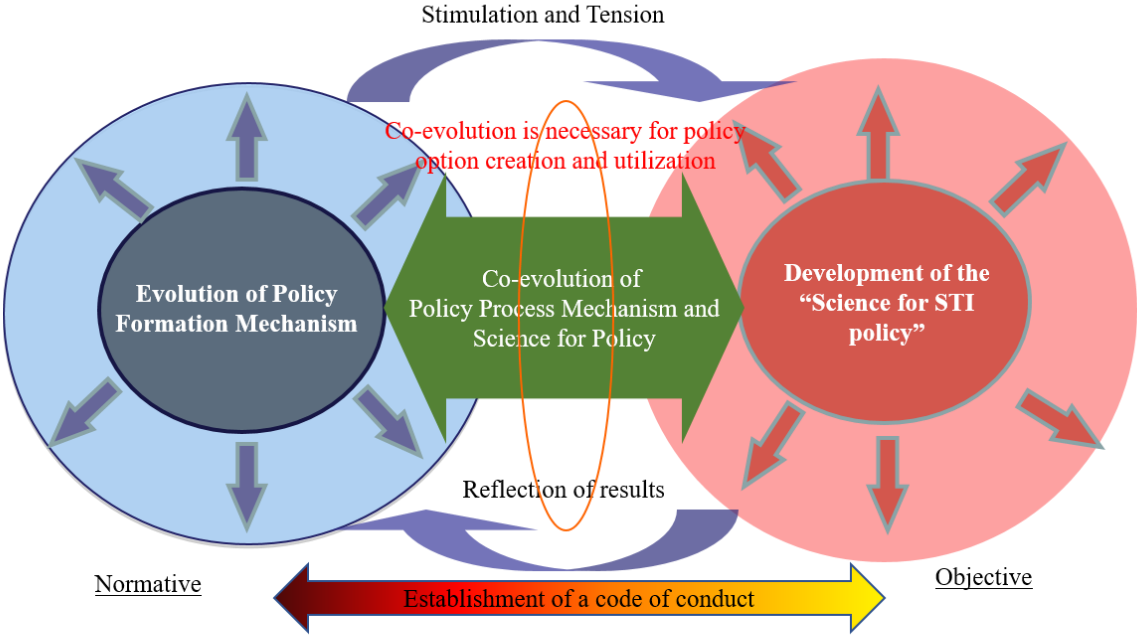

Figure 3. Co-evolution through new linkages between policy formation mechanisms and science of policy. Source: JST-CRDS (2010)

The science of science, technology, and innovation policy considers the policymaking process, which consists of an overview of science, technology, and socioeconomic conditions obtained through observation and analysis; the setting of policy issues based on this overview; the presentation of policy goals and "science and technology and socio-technical scenarios" as well as multiple policy options through which to achieve them; policy evaluation through policy options; and policy implementation through the process of understanding and building consensus for policy decisions. The accuracy of the scientific methodology of rational science and technology policy will be enriched with the addition of ex-post assessment of the impact of policy implementation. The process also requires collecting data for evidence accumulation under a theoretical framework for observation and analysis and experimental design at each stage of discovering and identifying the social issues to be solved, creating science and technology scenarios, socio-technical scenarios, extracting policy instruments, and creating policy options. This is summarized in Table 1.

Table 1 Data structures for identifying policy issues, creating science, technology, and socio-technical scenarios, identifying policy instruments, and creating policy options: Creating selectable policy options and reflecting them in the policymaking process

	Issue Discovery and Identification - Scientific and Socio-Technological Scenario Creation and Policy Option Development		**Creation of Policy Options**
	Overview and characteristics of science and technology /Science and technology scenario	Overview and characteristics of socioeconomics /Socio-technical scenarios	
Current situation and Observation type	Understanding Linkage of Science and Technology by Science knowledge map: Current Status and Benchmark Grasping the current development stage of science and technology by bibliometric analysis of science and technology Grasping the results of input-output of science and technology funding, papers, patents, etc. Distribution of human resources in science and technology	Understanding the current socio-economic status: population distribution, resource distribution, competitive market conditions, industry supply characteristics, consumer demand characteristics, production efficiency and international competitiveness, income distribution and disparity Structure of social institutions: current status of legal regulations and various institutional designs Social implementation of science and technology and current status of institutional design	
Current structure and Analysis type	Characterization of the stock of scientific and technological knowledge Strengths and Weaknesses of the Level of Science and Technology: Discovery of Current Issues through Time Series and Cross-Sectional Analysis Science and Technology Roadmap Funding system issue discovery issue discovery Human resources development Identification of the potential of science and technology to solve problems	Identification of socioeconomic characteristics and structure Identification of socioeconomic issues and the possibility of solving them by improving and reforming social systems and institutions Discovery of public expectations of the socio-economy	Time-series data such as national accounts and industry input-output-table Tangible and intangible fixed asset flow and stock data Simulation modeling for policy option formation Government R&D investment (science and technology related statistics) Simulation experiments of socioeconomic impact assessment of policy instrument selection Relevant data for policy option creation
Assumption-based forecasting type	Future Prospects for the Development of Science and Technology Roadmap for Science and Technology Development Identification of strategic focus areas for the deepening of science and technology	Projection of the future demographics Projection of future resource availability International socioeconomic geopolitical projections	Science and technology scenarios Socio-technical scenarios
Extraction of policy instruments	Selection of Strategic Priority Areas for Science and Technology Funding System Framework and Recommendations Framework for scientific human resource development programs	Socio-economic policy measures for social implementation of science and technology: Framework for deregulation, tax incentives, etc. Framework for intellectual property management system, etc.	

Source: Created by the author

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