Coordination matters: Puzzles of science, technology, and innovation policy implementation

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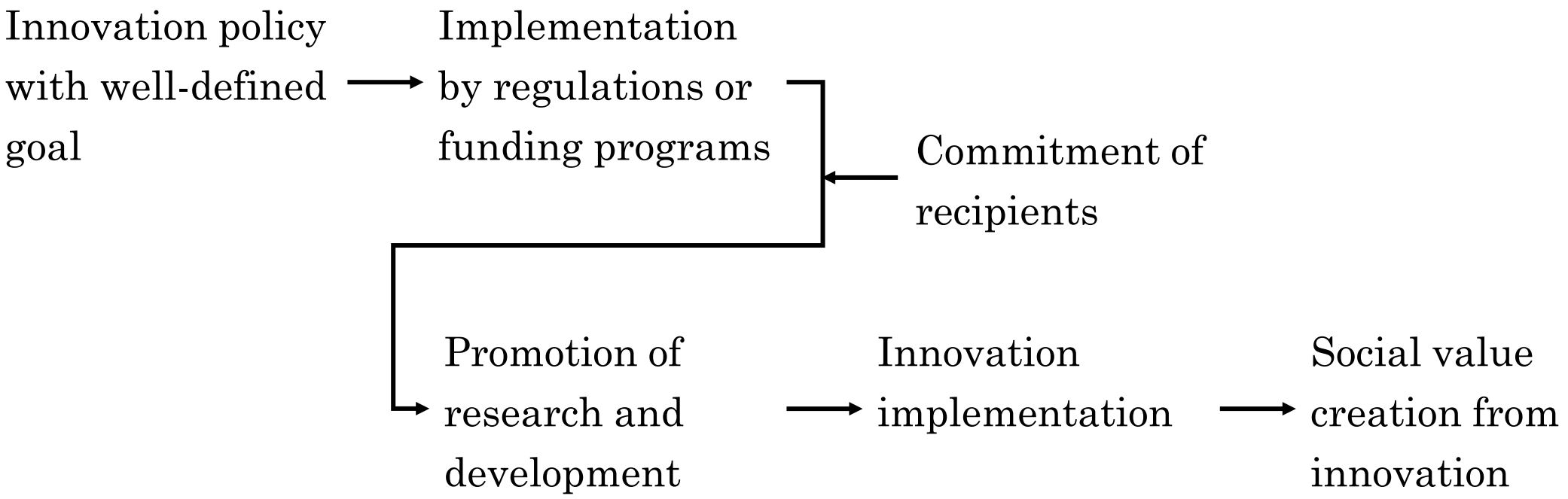
An ideal causal model of science/technology-led innovation policy



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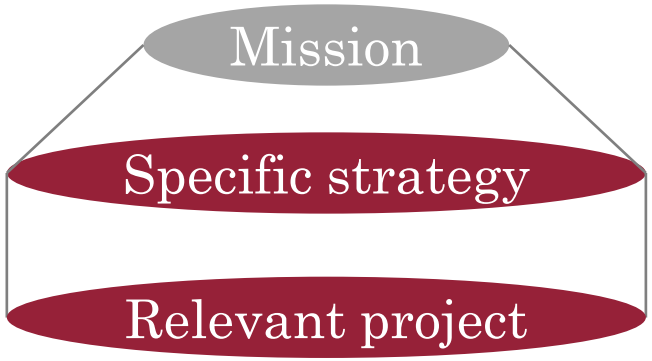
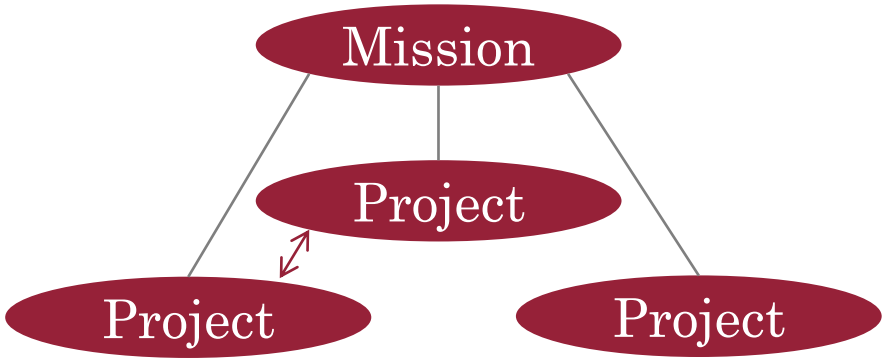
A puzzle of innovation policy implementation: A level of targeting

Concentrated model



Portfolio management model



• Concentrated investment (bigger resource allocation)	Pros	• Minimization of uncertainty risk
• **Necessity of coordination** of (or selection from) interest groups • Risks of complete failure	Cons	• Potential conflicts among projects • **Redundant investment**

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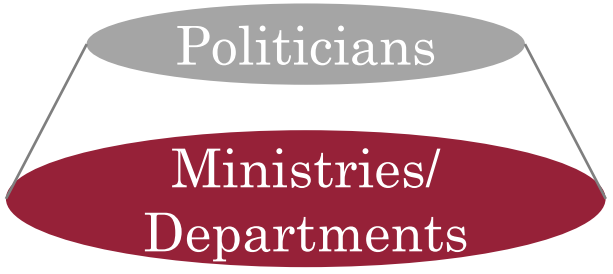
Another puzzle of innovation policy implementation: A key actor of coordination/portfolio management

	Top-down approach	Agency approach	Private-led approach
			
Pros	• Bigger resource allocation • Legitimacy	• Certain expertise	• Expertise • Flexibility
Cons	• Transparency • **Expertise** • **(Fixed design)**	• Transparency • **Amount of resource allocation (or political power)**	• Legitimacy (or anti-trust issue) • **Conflicts of strategy**

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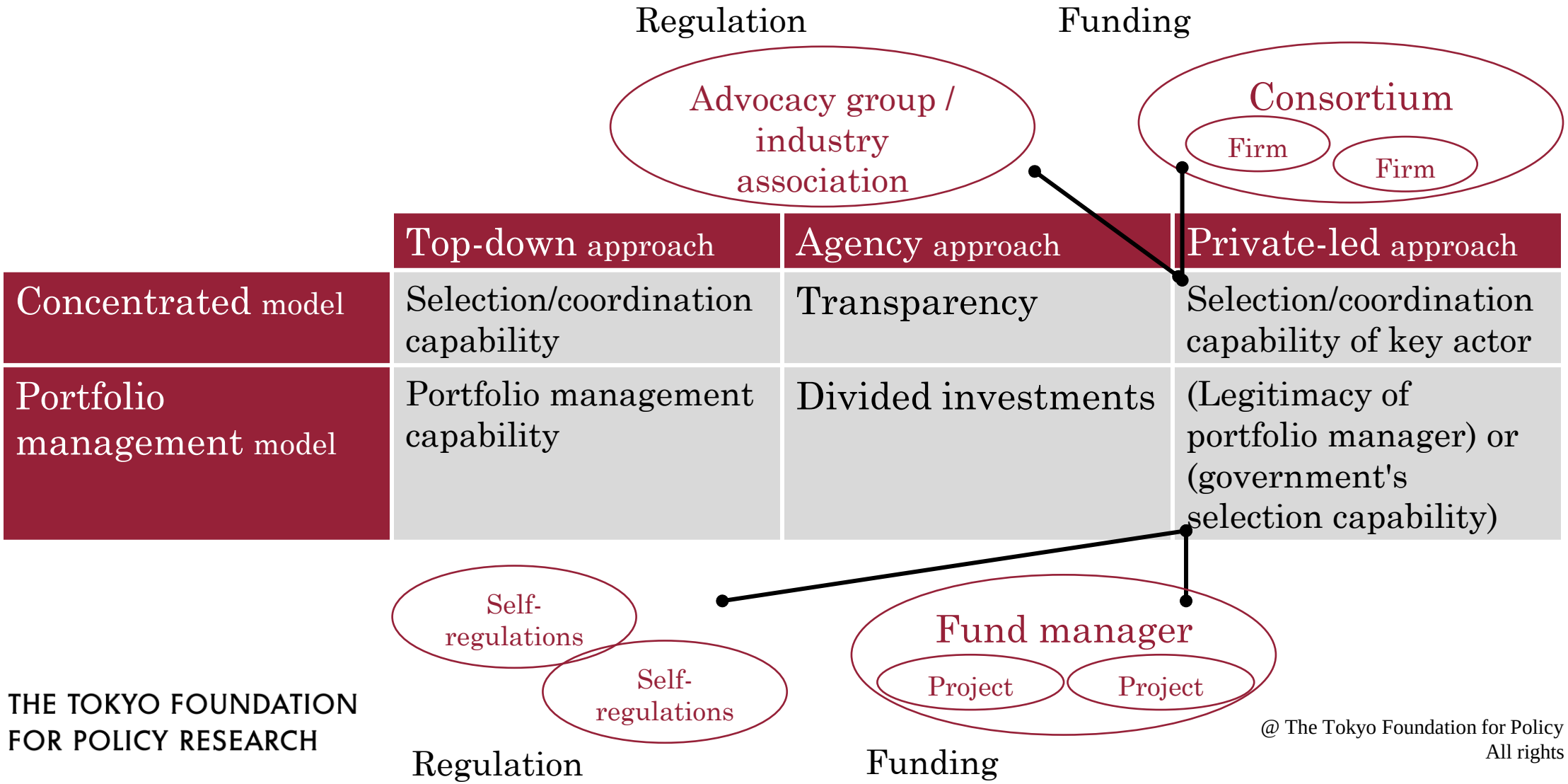
Challenges of innovation policy implementation by combinations of models and approaches



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An underlying issue in selection/coordination
(from multi-disciplinary perspectives)

- Objections to high uncertainty / highly technical challenge
  - ...often leads compromise (i.e., safe and acceptable goal) (Takeishi et al., 2010: Innovation study)
  - ...are raised by taxpayers and/or auditing agencies (Lerner, 2012: Public policy study)
- Peer pressures under collective decision making process
  - ...often leads acceptable, well-known, and myopic targes (Stephen & Zubcsek, 2015; Creativity study)

Takeishi, A., Aoshima, Y., & Karube, M. (2010). Reasons for innovation: Legitimizing resource mobilization for innovation in the cases of the Okochi Memorial Prize Winners. In Dynamics of knowledge, corporate systems and innovation (pp. 165-189). Springer, Berlin, Heidelberg.; Lerner, J. (2012). Boulevard of Broken Dreams: Why Public Efforts to Boost Entrepreneurship and Venture Capital Have Failed and What to Do About It.; Stephen, A. T., & Zubcsek, P. P. (2015). People offer better ideas when they can't see what others suggest. Harvard Business Review, 24.;

Another underlying issue in selection/coordination: Conflict of business strategies

- One goal with multiple paths
  - Example: Autonomous driving

Intelligent transportation system approach

...requires large infrastructure investments

Cloud computing approach

...requires secure and fast wireless telecommunication technology (e.g., 5G)

Edge computing approach

...requires high performance battery and semiconductor, and smart AI software.

(Source of illustrations) Freepik from flaticon

Consequences of two underlying issues

Concentrated model

Safe and acceptable goal → Red ocean (as a business goal)

Hard to coordinate → Weak commitment

Portfolio management model

Lack of quality identification capability → Inefficiency

Divided investment → Insufficient investment

These issues can be resolved by a development of quality identification capability

(Source of illustrations) Freepik and surang from flaticon

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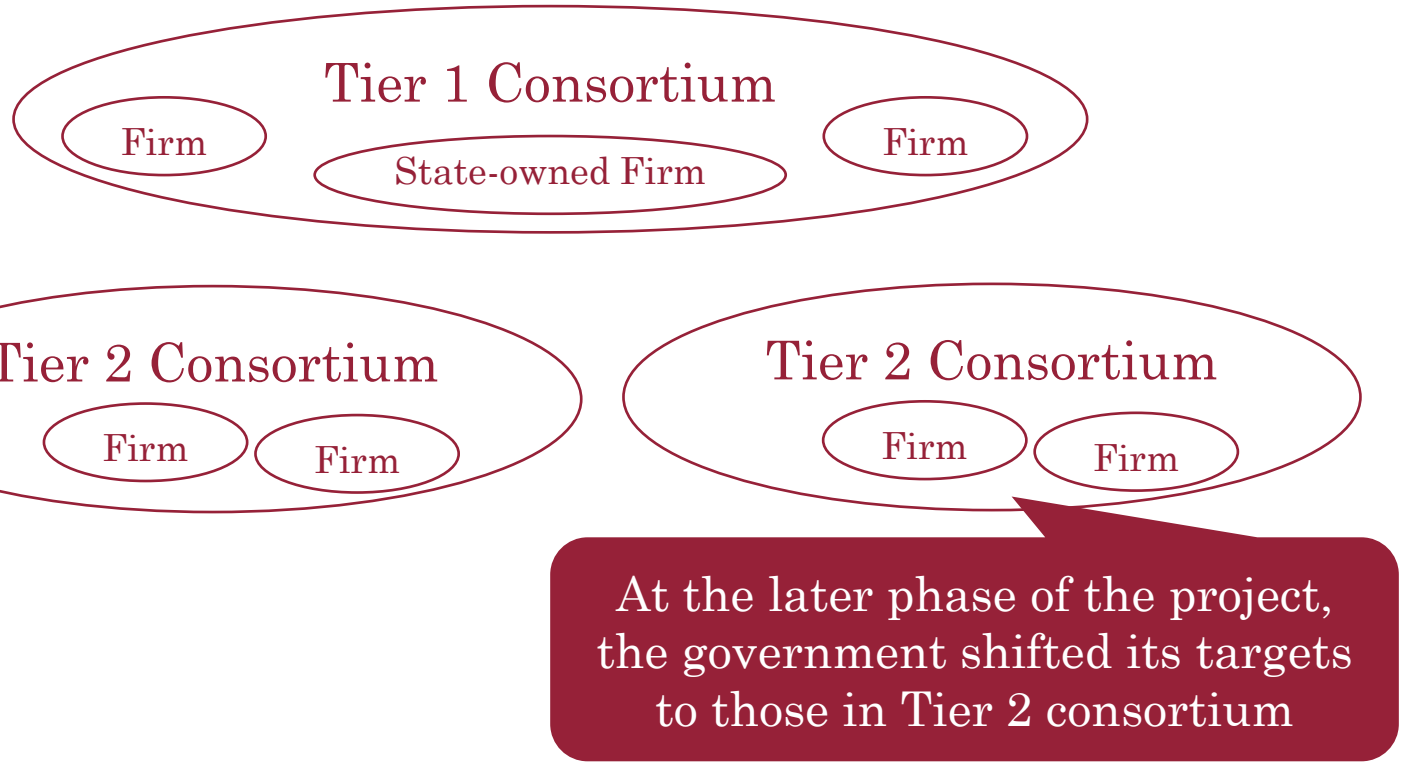
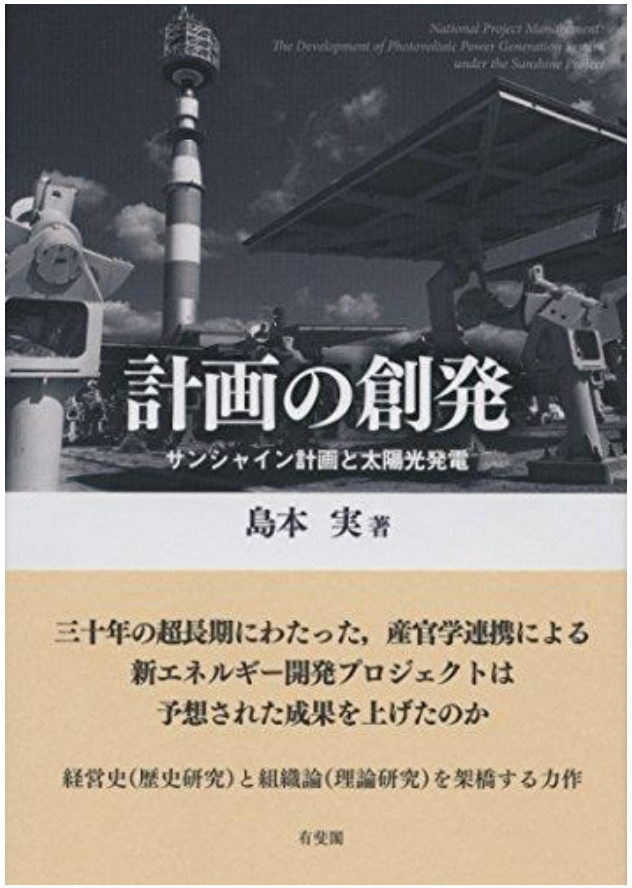
Learnings from Japanese national project in 1970s/80s

- They took hierarchic portfolio model





Shimamoto, M. (2014). *Keikaku no Sohatsu: Sunshine keikaku to taiyoukou hatsuden* [Co-creation of Innovation Project: Insights from Solar Energy R&D in Sunshine Project]. Yuhikaku.

Questions for discussion

- How do the private sector coordinate their strategic behavior in the collaborative regulation design or R&D activities?
  - Trade-off: Strategic isomorphism (with competitors)
    vs Decreased necessity for coordination
    Poor competitiveness potential as a business

- How do both the government and private sector maintain legitimacy of private sector-involved regulation or innovation program?
  - Trade-off : Flexibility vs legitimacy

Case Study: AI medical device

- Medical devices using AI technology have unique characteristics such as the black box nature of the deep learning algorithm and the possibility of constant performance changes due to automatic learning.

- The following issues need to be addressed during the regulatory approval review:

i. How to verify performance on an ongoing basis

The performance of AI medical devices must be specified and verifiable in a medically and statistically valid manner.

ii. Quality assurance in the event of performance changes

It is necessary to specify the factors that affect the performance of AI as a medical device, as well as the range and limitations within which effects may be confirmed.

iii. Approaches to regulatory procedures

The issue of application to medical devices; if that's outside the current definition of a medical device, how should the rules be changed?

iv. Responsibility

In the event of a serious accident, is it the responsibility of the medical practitioner, equipment manufacturer or program designer?

Features of the introduction of regulations on AI medical devices

The most fundamental Question

How to regulate product groups with new functions and capabilities?

- The process of introducing regulations for AI medical devices was roughly as follows.
  i. Regulators attempted to apply the existing regulatory framework, SaMD (Software as Medical Device), to AI medical devices.
  ii. However, it was found that it could not be properly evaluated due to functions beyond what was expected for a programmed medical device.
  iii. Therefore, the regulators decided to apply the rules of the current system for the time being while developing new rules.

- In the absence of appropriate regulatory measures, there is no alternative but to take provisional measures in the form of applying the existing rules.
  - The result was that any SaMD with even a slight change in functionality would have to be approved as a new and different product.
  - Even if the products concerned were to enter the market, it would be practically impossible to approve them.

The process of introducing new regulations in Japan

	Major Events
Oct 2015	PMDA restructures its consultation and review system for medical devices in light of technological innovations in robotics, ICT, etc.
Mar 2016	Ministry of Health, Labour and Welfare (MHLW) published guidance on issues related to the review of medical device programs that support diagnosis.
Dec 2016	Ministry of Health, Labour and Welfare (MHLW) helds opinion exchange meetings with diagnostic imaging device manufacturers and others regarding the use of AI.
Jun 2017	The Ministry of Health, Labour and Welfare (MHLW) released a report on the results of a roundtable discussion on promoting the use of AI in the healthcare sector.
Dec 2017	PMDA's Scientific Committee AI Subcommittee compiled "Issues and Recommendations on AI-Based Medical Diagnosis Systems and Medical Devices 2017
May 2018	The report of the PMDA's Scientific Committee on AI was also published in an English-language academic journal. Chinzei K, Shimizu A, Mori K, Harada K, Takeda H, Hashizume M et al. Regulatory Science on AI-based Medical Devices and Systems. Adv Biomed Eng. 2018; 7: 118—123.
Dec 2018	Ministry of Health, Labour and Welfare (MHLW) issued a notice on the relationship between the use of programs to support diagnosis and treatment using artificial intelligence (AI) and the provisions of Article 17 of the Medical Practitioners Act.
Mar 2019	The Ministry of Health, Labour and Welfare (MHLW) published a report on next-generation evaluation indicators for medical imaging diagnostic support systems using artificial intelligence technology.
Sep 2020	The Pharmaceutical and Medical Devices Law was amended to introduce a new system for approval of medical devices using AI technology according to their characteristics.

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A major turning point

- In December 2017, the AI Expert Committee of the Scientific Committee established by the Pharmaceuticals and Medical Devices Agency (PMDA) compiled the ***"Issues and Recommendations on AI-based Medical Diagnostic Systems and Medical Devices 2017"*** (PMDA Report).

- The PMDA report outlined the challenges in applying AI to medical devices from the perspective of regulatory science.
  i. Necessity of evaluation methods and systems in line with the characteristics of AI
  ii. Necessity of considering evaluation index for diagnostic imaging devices using AI technology
- With this report as a starting point, concrete progress was made in the formation of rules for AI medical devices in Japan.


ＡＩを活用した医療診断システム・
医療機器等に関する課題と提言 2017

平成２９年１２月２７日

ＡＩ専門部会
部会長　光石　衛
副部会長　大江　和彦

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Revision of the Pharmaceutical and Medical Device Act

- An approval system has been introduced to address the characteristics of AI medical devices, whose performance is constantly changing.
- There is no longer a need to obtain a new approval as a separate product when the functions change.

- **Change plan confirmation procedure system**: advance notification system for performance changes
  - AI medical devices can be subject to confirmation by the Minister of Health, Labor and Welfare regarding the plan for changes in performance, manufacturing method, etc., among the approved items (how to collect and manage data and learning in the future when first approved, etc.), making it possible to submit a plan for the part of performance and process that is expected to improve the device in advance.
  - In the case of an application for approval of a change in accordance with the confirmed plan, the review will include an investigation into whether the change is in accordance with the plan (whether the device has sufficient performance after being improved in accordance with the plan submitted in advance), instead of an investigation into quality, efficacy, or safety.
  - This will shorten the review period from about six months to about one to two months.

Trends in the United States

- Similar to Japan, the U.S. Food and Drug Administration (FDA) also took a lot of time to establish and institutionalize a method for evaluating medical devices with continuous performance changes.
  - The FDA divided AI medical devices into two categories, **"adaptive"** and **"locked",** defining the former as those that continuously collect, analyze, and learn data through use of the device, and whose algorithms constantly adapt and change to the environment, and the latter as those that can lock in the algorithms learned by the AI, so that once the algorithms are locked in place, their functions do not change.

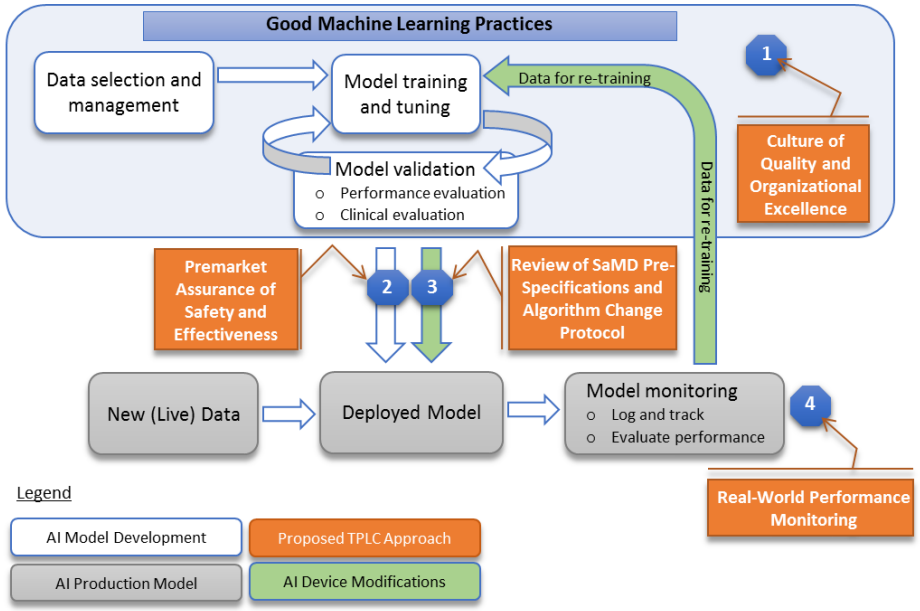
- The FDA's regulation took a major step forward with the release of a discussion paper titled ***"Proposed Regulatory Framework for Modifications to Artificial Intelligence/Machine Learning-Based Software as a Medical Device"*** in April 2019. In this paper, the FDA proposed a basic regulatory framework for "adaptive" AI medical devices.
- In February 2020, the FDA approved the marketing of an adaptive product that had been submitted under the new "Predetermined Change Control Plan," after coordinating with stakeholders through a series of public workshops.
  - In other words, all AI medical device products approved before February 2020 were "locked".

Source: FDA, "Proposed Regulatory Framework for Modifications to Artificial Intelligence/Machine Learning-Based Software as a Medical Device" available at https://www.fda.gov/files/medical%20devices/published/US-FDA-Artificial-Intelligence-and-Machine-Learning-Discussion-Paper.pdf

Trends in the United States

FDA's new regulatory approach

- The FDA proposed a new quality control concept called **"Good Machine Learning Practice (GMLP)"** for the introduction of AI medical device regulations.
  - The GMLP is a policy that requires a high level of quality control on the part of development and manufacturing companies at each stage of the product (Data selection and management, model training and tuning, model validation, etc.) in order to ensure high quality in compliance with the regulations.
  - This approach is quite unique and qualitatively different from that in Japan, as it includes not only the performance of the device itself, but also the quality control aspects of the product lifecycle, such as the appropriateness of the data used and the reasonableness of program updates.



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Findings from the case study:
（Ⅰ）Introduction of regulations in each country and international harmonization

- Difficulties in introducing regulations for emerging technologies in a timely manner
  - In both Japan and the US, it took a lot of time to introduce regulations for AI medical devices.
- Domestic review process in each country
  - As for new regulations for emerging technologies, it seems that each country has established its own domestic rules while checking international trends.
  - Therefore, it seems that the regulatory trends in the US did not directly trigger the formation of rules in Japan.
- Future development of harmonization
  - Harmonization is expected to proceed after the development of domestic rules in each country has been completed.
  - The FDA is already working with regulatory authorities in several countries to accelerate the standardization of GMLP.
    - January 2021, FDA releases action plan for AI and machine learning based SaMD.
    - In October 2021, the U.S. Food and Drug Administration (FDA), Health Canada, and the U.K.'s Medicines and Healthcare products Regulatory Agency (MHRA) issued new guidance, “Good Machine Learning Practice for Medical Device Development: Guiding Principles”.

Findings from the case study:

（Ⅱ）Regulatory lag and lack of technology forecasting for regulation

- In Japan, unlike other technological fields, funding and regulation of R&D in the medical field has not been planned and implemented based on proper technological forecasting.
  - The PMDA report was the trigger, and the research for regulations on AI medical devices was not started early on.

- The delay in the introduction of regulations for emerging technologies such as AI medical devices is a problem of **“regulatory lag”.**
- In order to avoid delays in regulations for emerging technologies, it is necessary to accurately forecast technology trends and invest in R&D related to evaluation technologies based on the forecasts at the right time.
  - In September 2019, the PMDA established the Horizon Scanning Implementation Guidelines. The PMDA has introduced horizon scanning on a trial basis.
  - AMED, Japan's version of NIH, plans to establish a new strategic division(SCARDA) that will be responsible for strategic budget allocation.

Findings from the case study:
（Ⅲ）Limitations of the regulator's capability

- Limitations in the ability of the MHLW
  - In designing new regulations for emerging technologies, it is difficult for even the MHLW's technical officers to fully understand the technical characteristics and plan evaluation methods for a highly specialized set of knowledge and technical information, including AI.
- Limitations of street-level capacity of agencies
  - It is not possible to evaluate emerging technologies simply by applying existing frameworks, standards, and procedures to them. They can't deal with anything that isn't clearly defined in the rules.
- Dependence on external resources
  - The PMDA, which is only an agency (the entity that implements regulations, not the entity that plans them), is doing the actual agenda-setting for regulations.
  - PMDA itself does not have research capacity, so it mobilizes experts as external resources in the form of scientific committees.

*The National Institute of Health Sciences is primarily responsible for research on regulatory science.

Findings from the case study:
(Ⅳ) Low commitment from the private sector

- Rule making led by academia
  - " Academia" such as the PMDA Scientific Committee played a major role in the regulation review process. The private sector's commitment to the regulatory review process was extremely low.
- Potential asymmetry of information
  - There should be a clear information asymmetry between the regulation review side and the development side. It is not "academia" that develops the actual products and services related to AI, but private companies that own the products.
- Consideration of regulations through industry-academia-government collaboration
  - In the process of developing regulations related to regenerative medicine, Forum for Innovative Regenerative Medicine（FIRM） and The Japanese Society for Regenerative Medicine（JSRM） participated in the collaborative design of regulations, but in the case of AI medical devices, the process was very different.
  - Now is the time for industry, government, and academia to seriously consider ways to design regulations in a more coordinated manner. Such an approach also needs to be introduced on a trial basis and reviewed as necessary.

Corporate Participation in the Regulatory Planning Process

- There are a number of concerns regarding the participation of companies in the regulatory drafting process.
  - Intellectual property confidentiality needs to be protected in the provision of information and knowledge about emerging technologies from companies. Otherwise, companies will not be able to participate.
  - On the other hand, it is also essential to consider how to control the possibility that companies will try to design regulations in their favor. For example, there is a potential incentive on the part of companies to reduce the level of evidence required to assess safety and efficacy in their favor.
- Even with the participation of corporations, **legitimacy** is required in the design and implementation of regulations.
  - To ensure legitimacy, a **transparent process and evidence-based review** under government initiative is needed.
  - In order to go beyond the knowledge and position of one company, it may be necessary to adjust horizontally as an **"industry".**
- The challenge will be how to design regulations in a transparent process while protecting the intellectual property of companies.