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University–industry cooperation and the transition to innovation ecosystems in Japan

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Abstract

This article looks at the evolution of university–industry collaboration (UIC) policies in Japan since the mid-1990s to the present and analyses their role in shaping the country's innovation ecosystem. UIC policies are examined within a multidimensional innovation policy framework that encompasses five Science and Technology Basic Plans and a vast array of support measures for venture business, intellectual property, innovation networks and business promotion, all reflecting an extensive top-down government intervention with ambitious goals. A dense network of UIC centres has been established throughout the country, mostly in universities, and these centres are tightly embedded in regional innovation structures. In spite of the sustained government policy intervention, Japan lags behind the United States and Europe in a ranking of the top 20 global ecosystems and has some of the world's lowest entrepreneurial indicators, as defined by the Global Entrepreneurship Monitor. The authors argue that a likely cause for the lag is Japan's slow and still incomplete transition from a 'traditional' innovation system to a modern innovation ecosystem with a strong entrepreneurial spirit and culture, effective intermediaries between university and industry, high absorptive capacity in companies using academic research, cross-boundary mobility of workforce and ideas and global outreach. The experience of Osaka University and Hokkaido University, two UIC leaders in Japan and internationally, supports this hypothesis.

Keywords

Abenomics' third 'arrow', Japan Revitalization Strategy, innovation ecosystem, university–industry cooperation

Japan has a unique position among both Asian nations and the industrialized wealthy countries of 'the West'. Alone among Asian nations, it was never colonized by the West, yet it managed brilliantly to learn from it, on its own terms. Twice in its history, Japan modernized its industry and institutions with impressive results: first after the Meiji Revolution and again after the destruction of the Second World War. Uniquely too, Japan is still the only non-Western nation to have developed world-class science to a level recognized by the 24 Nobel prizes it has received since 1949. Japan's spectacular growth during the quarter century following the American occupation was based on effective government planning and guidance, a potent industrial system, prosperity and lifetime employment in its companies and broad technology transfer from the West through licencing and then systematic improvement and upgrading in Japanese companies. This transfer was the basis for incremental innovation that worked well and sometimes gave birth to authentic new products and processes.[1]

Japan's rapid economic growth started to slow down in the 1970s, as many of its support factors were no longer at work. The country faced difficulties in adapting its

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economy from a catch-up mode to a mature, innovation-based economy, in which growth was no longer possible just by imitating or importing new technologies from advanced economies. The use of undervalued currency was no longer sufficient to stimulate exports because of globalization pressures and a rapidly aging population that slowed down labour force growth (Hamada et al., 2011). The asset price bubble that started in the mid-1980s culminated with a collapse of asset prices in the early 1990s, marking the beginning of the 'Lost Decade' (Hayashi and Prescott, 2002). This period originally encompassed 1991–2000 but was later extended to the 'Lost Two Decades' as it expanded into much of the 2000s.

This declining economic competitiveness was attributed by the Japanese government to drastic changes in business operations during the 1990s.[2] Japanese industry was slow to react to these challenges, lacking a dynamic refocusing of the traditional organizational and business practices, as well as strong leadership to introduce strategic managerial reforms. Also, the adoption of new policies to accelerate the structural economic reform and create an industrial structure with strong world-class corporations was considered slow (METI, 2002). Others saw the extended stagnation not so much as a consequence of the financial system's breakdown, since financing for corporate investments was still available, but as a result of a fall in productivity, a reduction of the length of the working week between 1988 and 1993 further to a revision of the Labour Standards Law and financial intermediation problems (Hayashi and Prescott, 2002). Other causes were identified in the high tolerance of the banking system for zombie banks supporting zombie firms (Caballero et al., 2008; Onaran, 2011), monetary policies leading to prolonged deflation and fiscal policies that created massive debt by excessive spending on ineffective programmes.

Some weak signs of recovery emerged in the mid-2000s under the reform-oriented Koizumi government but these were stifled by the global financial crisis of 2008, which pushed the country back into recession and reignited the debate on growth-oriented policy changes. New attempts to revitalize the economy started in December 2012 under Prime Minister Shinzo Abe's three-part reform plan dubbed 'Abenomics', which introduced structural reforms of unprecedented scope. The first two parts ('arrows') of the reform programme refer to a bold monetary policy and flexible fiscal policy, while the third arrow, also known as the Japan Revitalization Strategy (the New Growth Strategy), promotes deep economic reform, productivity growth and raising living standards based on three action plans, including an Industry Revitalization Plan with a comprehensive innovation dimension (see Appendix 1). While the first two arrows have generally been credited with positive results (Cabinet Office, 2014, 2016), the third has had mixed results so far. Some credit it as key to the ultimate success of Abenomics reforms (e.g. OECD, 2015; McBride and Xu, 2016), while others consider that it lacks a clear direction for some measures and causes persisting challenges to the private sector through a rigid employment system and high taxes (Egawa, 2014).[3] At the same time, since the third arrow's growth strategy requires 5–10 years for full implementation, it is still too early to assess its success, which will depend extensively on the political will to continue pursuing it (Dourille-Feer, 2015).

In spite of the sustained and ambitious top-down government policy intervention, Japan lags behind the United States and Europe in a ranking of the top 20 global ecosystems, in which nine are in North America, six are in Europe and the remaining five are in Asia, but none are in Japan (Tsarchopoulos, 2017). Furthermore, with a total of 3.8% early-stage entrepreneurial activities, Japan has the lowest share of early-stage entrepreneurs in its adult population and it also has the lowest share of respondents with entrepreneurial intentions (2.5%). Only 31% of the adult population in Japan see entrepreneurship as a good career choice, 7.3% perceive the existence of opportunities in their surroundings and only 12.2% think they have the abilities to start a business, while 54.5% expressed fear of failure (GEM, 2014).

What is the cause of this lag? The hypothesis we put forward in this article is that a likely cause is Japan's slow and still incomplete transition from a 'traditional' innovation system, focused on the optimization of Science and Technology/Research and Development (S&T)/R&D) agendas, budgets and public policy mechanisms, human resources and knowledge flows between the academic, business and public sectors, to a modern innovation ecosystem, in which these elements are complemented by a strong entrepreneurial spirit and culture, effective intermediaries between university and industry, high absorptive capacity in companies using academic research, the cross-boundary mobility of workforce and ideas and openness to international opportunities and change. This hypothesis builds on several insights drawn from the literature, a detailed analysis of key university–industry collaboration (UIC) policies in Japan and their transformative power and the experience of two leading national universities (Osaka University and Hokkaido University) that are at the forefront of UIC in Japan.

The remainder of the article is organized as follows. The second section, below, looks at several reasons why UIC policies in Japan, although significantly influenced by the US experience, have often differed in effect. The third section provides an overview of UIC policies in Japan within a complex innovation policy framework that has been consolidated in the country since the mid-1990s. The fourth section documents the impact of these policies with insights from two case studies of Hokkaido University and Osaka University. The fifth section concludes with a discussion of findings and final remarks.

UIC in Japan: Strong imprint of US experience but differing framework conditions

UIC started to get increasing policy attention in Japan in the context of the economic recession of the 1990s, when universities were considered a driver of innovation and economic growth (Nagaoka et al., 2009). Inspired by the US experience of economic recovery, which was significantly influenced by federal support to university research and a strong intellectual property rights (IPR) regime, since the mid-1990s, the Japanese government has initiated specific UIC policies that have grown in complexity over time, covering all the key links of the innovation chain and leading to some significant increases in specific UIC indicators (see Appendix 2). In spite of a strong imprint of US policies, the effect of the Japanese UIC policies differed in many instances due to the different structure of the Japanese innovation system and framework conditions for innovation.

For example, Japan's R&D landscape is dominated by large companies that lead in high-tech fields (mainly in the automobile, electronic and medical sectors) and pursue an innovation strategy based on research performed in-house or in affiliated companies. Large companies have preferential access to university discoveries but, in general, do not absorb a significant volume of new technology emanating from university start-ups. This comes at the cost of depriving high-tech ventures of niches in which to grow, skilled personnel and a natural customer base (Kneller, 2007). Although some of this dependence on large companies' in-house R&D is gradually being reduced by the involvement of technology-intensive small and medium-sized enterprises (SMEs) in UIC and other networks among innovation players, the dynamic is rather slow because the growth of Japanese start-ups, especially in high-tech fields, is hindered by labour market rigidity and a scarcity of venture capital (VC) for start-up projects (Motohashi, 2005, 2008, 2016).

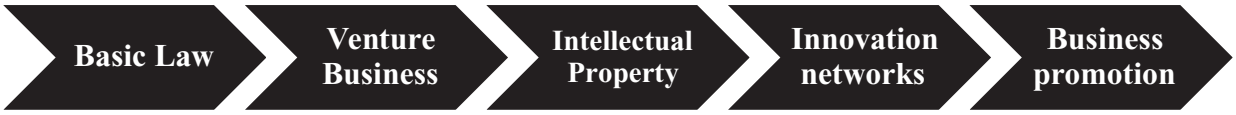
On the academic side, one can note the presence of some large government research labs and universities performing world-class basic science research, particularly in nanotechnology, physics and chemistry, but overall the Japanese academic system conducts relatively little applied research and remains in relative isolation from industry. This contrasts with the US system, where there is less government–business interaction but much closer cooperation between business and academia. Also, new industrial sectors driven by small-scale science-based entrepreneurs in specialized markets, such as those observed in the United States, have not been reported in Japan (Foray and Lhuillery, 2010; Mowery, 2009). Furthermore, Japanese universities often pursue an aggressive and rigid IP policy that is not always flexible enough to suit the needs of the industrial partner firms (Okamuro and Nishimura, 2013). All these factors result in weaker links between patents and commercial activity, a high level of publication secrecy, and reduced participation in open science by academic entrepreneurs (Walsh and Huang, 2014). Japanese UIC continues to be dominated by informal ties and gift-exchange, and the expanding UIC activities are thought to be more a reflection of academics' responsiveness to the new policies and their wish to demonstrate productivity and compliance with the new expectations, rather than of a genuine increasing trend of research commercialization (Walsh et al., 2008).

Venture companies in Japan play a much more limited role in technical and economic progress than in the United States. VC levels in Japan are approximately 50 times lower than in the United States – about $960 million were invested in VC in Japan in 2014[4] versus $48 billion in the United States (NVCA, 2015). These low VC levels are explained by Japanese investors' much higher risk aversion and insufficiently high returns to change that aversion. The source of VC in Japan is also different from that in the United States: In Japan, it is mainly corporate capital, coming both as corporate VC and as independent funds, whereas in the United States, most of the VC comes from institutional investors, such as pension funds, endowments or fund of funds (Riney, 2015).

UIC policies in the broader context of innovation policies in Japan

Innovation policies in Japan have been developed over the last two decades primarily by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which provides most of the funding for universities and some of the national labs and supports basic S&T policies, and by the Ministry of International Trade and Industry (MITI), renamed in 2001 as the Ministry of Economy, Trade and Industry (METI), which is mostly responsible for industrial competitiveness and industrial technologies but also oversees some human resources measures. Other ministries involved in innovation are the Ministry of Health, Labour and Welfare, the Ministry of Internal Affairs and Communications, which promotes numerous policies related to information and communications technologies (ICT), and the Ministry of Defence. Key funding bodies are the Japan Society for the Promotion of Science, the Japan Science and Technology Agency (JST) and the New Energy and Industrial Technology Development Organization (Woolgar, 2011).

The innovation policy framework has developed as an interplay of five main co-evolving components (Figure 1): one based on five S&T Basic Plans, elaborated since 1996 on the foundation of the S&T Basic Law, and four others focused on venture business, intellectual property, innovation networks and business promotion, respectively. These components are rooted in MITI's *Creation of the 1980s Vision,* a technology-driven industrial policy for economic



1995: S&T Basic Act				
1996: 1st S&T Basic Plan				
	1998: Technology Transfer Promotion Act			
	2000: Industrial Technology Enhancement Act		2000: Industry Cluster (METI)	
2001: 2nd S&T Basic Plan	2001: Hiranuma Plan 1000 venture businesses by 2004		2001: Knowledge Cluster (MEXT)	
		2002: Intellectual Property Basic Act		
		2003: Improvement of the Centre for Intellectual Property in University (MEXT)		
2004: Incorporation of National Universities				
2004: Improvement of 'Basic act on Education'				
2006: 3rd S&T Basic Plan				
			2007: Innovation 25 (Cabinet Office)	
				2009: Innovation Network Corporation of Japan (INCJ) (METI)
			2010: Selection of the Global Special Zones (Cabinet Office)	
2011: 4th S&T Basic Plan 2011: 'University Research Administrator'			2011: Regional Innovation Strategy Support Programme (MEXT)	
				2012: Public-Private Innovation Programme (University Investment Programme) (MEXT)
			2013: Centre of Innovation, Science and Technology-based Radical Innovation and Entrepreneurship Programme (COI STREAM (MEXT)	
				2014: Enhancing Development of Global Entrepreneurship Programme (EDGE) (MEXT)
2015: Research Support Systems				
2016: 5th S&T Basic Plan				

Figure 1. Innovation policy framework in Japan. *Source*: Based on information from Tsunehisa Araiso, personal communication, 2016.

growth that proposed the concept of Japan as a technology-intensive nation moving from catching-up with the advanced economies of the West towards new industrial patterns and playing an international role commensurate with its power as a country accounting for 10% of the global economy (METI, 2009a). This was an ambitious task in the context of increasing oil prices, the long-term economic recession of the 1990s and the stronger yen that determined many manufacturing industries to shift production overseas.

Some of the most important policies of the five components are discussed briefly below, highlighting specific UIC policies and their embeddedness in this integrated innovation framework.

The S&T Basic Plans

The S&T Basic Law, the foundation of Japan's S&T policy, was enacted by MEXT in 1995, in pursuit of the fundamental policy goal set in 1980 to become a 'nation based on the creation of science and technology' (Harayama, 2001). Realizing this goal required a costly and long-term government engagement at a time of transition for the country from catching up with the West's S&T policies to developing its own S&T fields and strategies. UIC emerged as an intrinsic part of the law, due to a growing social pressure on academia in the 1990s to increase efficiency and accountability, which made closer ties with industry a good argument to justify public support for research activities (Harayama, 2001). Based on the law, five five-year S&T Basic Plans have been formulated from 1996 to the present and have been implemented by the JST.

Each of the S&T Basic Plans addressed specific challenges of its time. For example, the first (1996–2000) and second (2001–2005) plans were carried out in a period of prolonged economic stagnation after the collapse of the bubble economy and addressed stringent issues of that time such as the promotion of R&D for social and economic needs, the promotion of S&T education and strategic priority-setting in basic research, increasing government R&D expenditure, and structural reforms of the R&D system, including a reorganization of national research institutes and national universities into corporations. The Incorporation of National Universities Act (April, 2004) introduced a partial privatization of the national university system, turning national universities into 'national university corporations' with increased operational autonomy and new managerial structures, which was a turning point for UIC. The Act allowed the establishment of intellectual property headquarters in universities, gave universities the right to their own inventions by revoking professor privilege and increased the budget autonomy of universities to stimulate them to seek industry funding (Walsh and Huang, 2014).

The third S&T Basic Plan (2006–2010) came at a time when the Japanese economy was showing signs of recovery from prolonged stagnation, so that continuing to increase government R&D expenditure and reform the R&D system appeared to be natural priorities. The plan also prioritized the development of world-class researchers (the autonomy of young researchers and attracting talented foreign researchers), strategic S&T priorities for basic research and R&D and closer links to society and broader societal participation in S&T activities (Council for Science and Technology Policy, 2010).

The fourth S&T Basic Plan (2011–2015) was in operation at the time the Japan Revitalization Strategy (the New Growth Strategy) was issued and specifically aimed to give 'greater depth and concrete form to the New Growth Strategy'.[5] The plan acknowledged several deficits that its predecessors had not managed to correct[6] and, in response, introduced three key policy principles: (i) a shift from S&T policy to science, technology and innovation (STI) policies and from conventional R&D to problem-solving; (ii) a higher priority for human resources and their support organizations; and (iii) the implementation of an 'STI policy created together with society'. These principles were pursued through specific initiatives that introduced a stronger systemic perspective of innovation (e.g. building regional innovation systems) and a stronger emphasis on UIC by enhancing knowledge networks among industry, academia and government; creating new open innovation centres to promote collaborations among these sectors; and promoting intellectual property and international standardization strategies (see Appendix 3 for an overview of UIC policies in the fourth S&T Basic Plan). The Cross-Ministerial Strategic Innovation Promotion Programme (SIP), adopted in 2013 under the plan, introduced new measures to foster collaboration between academia, industry and government and improve the entire path from basic research to commercialization. Ten programme directors selected from industry and academia were appointed to run three of the SIP's four fields (energy, next-generation infrastructure and regional resources).

The current and fifth S&T Basic Plan (2016–2020) brings STI policy to the next level. It guides Japan to become 'the best suited nation to innovation in the world', by promoting a 'super smart society' and the expansion of partnerships between industry, academia and government (Council for Science, Technology and Innovation, 2015). This plan appreciates that UIC still has a long way to go before reaching full maturity and large-scale operations because of obstacles such as: the low mobility for researchers across organizations and sectors, the limited capacity of venture companies to induce structural transformations in industry, an insufficient match between company needs and university knowledge and technology, the declining confidence of the population in S&T and the stagnating government R&D investment. To address these weaknesses and

reform the STI system, the fifth S&T Basic Plan introduced four pillars of STI policy until 2020, including one that promotes stronger UIC and more university spin-offs.

The venture business component

This component addresses primarily the challenges faced by the country's SMEs: a continuous decrease in number, from 4.84 million in 1999 to 3.81 million in 2014, in the context of population decline and aging, the aging of business managers (the highest proportion of business managers is in the 70+ age bracket) and labour shortage, the aging of facilities, sluggish capital investment, the increasing number of business closures and company dissolutions caused mainly by aging and health problems of business managers (but also by anxiety over the business future), insufficient use of the opportunities provided by IT and the new technologies and so on (Small and Medium Enterprise Agency, 2016).

Japan's current set of SME policies is very comprehensive, including a wide range of monetary, promotion and organization policies, all building on the provisions of the SME Basic Act enacted in 1963 and revised in 1999 and 2013 to adjust to the changing economic conditions, to rectify the gap between SMEs and large enterprises in terms of labour productivity and trade conditions and to encourage business innovations and start-ups (Small and Medium Enterprise Agency, 2013).

The design and content of SME policies are closely related to the key role Japanese SMEs play both politically and economically as a large employment source in a system with minimal welfare provisions for structural unemployment. This explains much of the country's unique approach among major industrialized nations to designing SME support policies, especially in the form of compensatory measures for disadvantages arising from the strong focus of the national industrial policy on large enterprises. Such policies helped Japanese SMEs survive during nearly two decades of economic slowdown but did not do much to stimulate innovation or high performance as they were intended mainly as a safety net for large numbers of SMEs. As a result, after the 1990 burst of the economic bubble, many SMEs became largely dependent on public funds and protective policies for survival, while only a few managed to remain globally competitive (Shimizu, 2013).

Some of the SME policies are also relevant to UIC, such as the establishment of the Organization for Small and Medium Enterprises and Regional Innovation (2004), the 2011 revision of the Industrial Revitalization Act, as well as the Industrial Competitiveness Enhancement Act (December, 2013), which came to correct three notable distortions (over-regulation, underinvestment and delay in consolidation), for successfully implementing the Japan Revitalization Strategy of June 2013 (METI, 2013). The implementation of the Act was accelerated by the Industrial Competitiveness Enhancement Action Plan[7] (January, 2014), which promotes crowdfunding and small business, the protection of regional brands, the relaxation of immigration rules to allow entry of highly skilled foreign professionals and the increased use of IT, big data, and so on to establish Japan as a 'technology-driven nation'. Also, several White Papers on SMEs in Japan[8] have been elaborated by the Small and Medium Enterprise Agency since 1997 to the present (latest edition in 2016). These documents identify key obstacles to SMEs' sustainability and growth and provide measures to improve their operation (e.g. encouragement of entrepreneurship education at all school levels and contacts with entrepreneurs to increase people's awareness about starting a business, a consulting system involving existing entrepreneurs and private support organizations to reduce the costs and procedural burdens of start-ups, crowdfunding, etc.)

The intellectual property component

Central to the intellectual property component is the 1999 Act on the Promotion of Technology Transfer from Universities to Private Business Operators (also known as the Japanese Bayh–Dole Act, amended in 2005 and 2011), which was part of the Industrial Revitalization Special Law and aimed to revive the Japanese economy. Largely inspired by the US 1980 Bayh–Dole Act, the Japanese Act shares many similarities with its US equivalent but there are also differences, such as the broader coverage of subject matter. The Act gave ownership to universities and inter-university research institutes of the technological research results obtained with government funding, allowing their transfer to and commercialization by private business operators and retention of the IPR. Prior to the Act, university professors (inventors) owned the IPR generated by government-funded research, but technology commercialization and the exploitation of IPR were at low levels because of the high patenting costs and IPR bureaucracy. In order to change that, the Japanese Bayh–Dole Act was followed by three other laws, also enacted as part of the Industrial Revitalization Act: (i) the Law for Promoting University–Industry Technology Transfer (also known as the TLO Promotion Law), which introduced Technology Licensing Organisations (TLOs) in universities for academic research commercialization and IPR management and granted several advantages to TLOs established by METI and MEXT; (ii) Improvement of the Deduction System of Incremental R&D Tax Credits (1999); and (iii) the Law of the Small and Medium-Sized Business Innovation Research System (also known as the Japanese SBIR), which exempted SMEs from the investments made to commercialize technology transferred from universities (Takenaka, 2005).

The Japanese Bayh–Dole Act had a positive effect on the commercialization of university research, but it was not

sufficient, according to the Japanese government which initiated an extensive review of the Intellectual Property Basic Act of 2002, followed by several revisions of IP laws in subsequent years. Japan's IP Basic Act related the country's IP policy to its national strategy and set forth the roles of government, industry and academics in executing the strategy, while indicating specific measures for accomplishing the missions of the individual groups. The Act also triggered a review of the educational system for IP professionals (Takenaka, 2009).

Another relevant element of the IP component is the Hiranuma Plan for the Creation of New Markets and New Jobs (May 2001), which considered the economic stagnation a result of 'shrinking demand driven by anxiety about the future and the insufficient innovation preventing the development of potential demand' (METI, 2001). In response, in a drastic shift of public and private sector resources to programmes designed to make innovation a self-sustainable process, the plan introduced 15 policy measures to create new markets and jobs, build innovation systems and foster venture businesses to create new industries. The Plan had a strong UIC focus, as five of its 15 proposals focused on UIC – for example, consolidating innovation infrastructure by doubling the number of new start-ups in 5 years and creating 1000 university spin-offs in 3 years; reform of universities and technology transfer from academia to industry; increasing investment and UIC in strategic areas such as the environment, biotechnology, data transmission, nanotechnology and materials; implementing a support programme for venture businesses; promoting the formation of industrial clusters; and building local human networks. While the plan was successful in creating 1000 academic spin-offs in 3 years (Harada and Mitsuhashi, 2011), the other goal of doubling the total number of start-ups in 5 years was not achieved. An important strength of the plan was the promotion of systemic reforms to replicate the system of creating businesses from academic research as observed in Silicon Valley and of various reforms regarding the IP of universities and technology transfer organizations (Dasher et al., 2015).

The innovation networks component

The innovation networks component supports the formation of clusters as innovation networks and elements of regional innovation systems. Two interrelated cluster programmes are highly relevant for this component:

- The Industrial Cluster Plan (METI), which was launched in 2001 to enhance Japan's competitiveness through new technology-driven businesses by local firms 'utilizing seeds from universities and other research institutions' (METI, 2009b). The Plan consists of three phases spread over 20 years, from 2001 to 2020: (i) *launch (2001–2005),* when some 20 cluster projects were started and worked in collaboration with the existing clusters developed autonomously by local governments, as the foundations for industrial clusters; (ii) *development (2006–2010)*, which focused on reforms in corporate management and start-up creation, while continuing to foster network formation and develop specific businesses; and (iii) *autonomous growth (2011–2020)*, which focuses on the financial independence and autonomous growth of the industrial clusters, while also continuing the network formation and development of specific businesses. Since 2009, 19 industrial clusters have been launched, involving 10,200 regional SMEs and a total of 560 universities and technical colleges (Dasher et al, 2015). At present, the industrial clusters are managed as regional clusters by private organizations and local governments.
- The Knowledge Cluster Programme (MEXT), which is rooted in the regional R&D and innovation policies promoted by the early S&T Basic Plans, especially the third one (2006–2010), which set the goal of 'building regional innovation systems and creating vital regions' through enhancement of R&D and technological innovation in regional universities (MEXT, 2006). The Knowledge Cluster Programme was based on local governments' cluster plans in areas with a high concentration of knowledge and industry, involving universities or other public research institutions, firms and other related entities. The programme aimed to stimulate university–industry–government joint research, patenting, incubation, forums and the dissemination of research results. The process started in May 2001 with the selection of 30 candidate regions, and 18 clusters were created from late 2002 to 2004. The MEXT Knowledge Clusters Programme cooperated from the start with the METI Industrial Cluster Plan through several committees for regional cluster promotion, local implementing organizations, and joint conferences to announce project results. Subsequent evaluation of the programme's impact for the period 2001–2006 confirmed a significant increase in the number of collaborative R&D projects and networking between universities, research institutes and the development of various regional initiatives (Saeki, 2007).

Another measure supporting the formation of innovation networks is Innovation 25, initiated in 2007 by the Abe administration as a long-term strategy with a time horizon of 2025. To realize the initiative, a minister in charge of innovation was appointed, and the Innovation 25 Council was set up, liaising with the scientific community, industry and the public. Five national government policies to launch

the Innovation 25 strategy have been defined, including one focused on university reform and a review of innovation regulations for creating social systems, norms and rules that encourage service innovation, infrastructure for innovation and entrepreneurship (Prime Minister of Japan and His Cabinet, 2007).

The Regional Innovation Strategy Support Programme (MEXT) was adopted in 2011 to help the development of intellectual assets and human resources in regions benefiting from MEXT's support for their regional innovation strategies. The programme was designed along four main axes, targeting (i) researchers who play core roles in regional innovation strategies, (ii) the development and implementation of human resource programmes for regional innovation strategies, (iii) the establishment of knowledge networks of universities and research institutions and (iv) support for sharing research facilities and equipment among local universities and other research institutions (MEXT, 2011).

The Centre of Innovation Science and Technology-Based Radical Innovation and Entrepreneurship Programme (COI STREAM)[9] was launched in 2013 by MEXT to encourage radical innovation and establish innovation platforms in Japan. The programme supports basic, multidisciplinary and interdisciplinary high-risk and high-gain R&D performed by UIC teams. COI activities are carried out at specific sites, where the companies involved can make financial, human and other in-kind contributions throughout the joint R&D period, and the structure of their collaboration with the university can be flexible and optimized subject to the overall circumstances. COI sites are funded by the JST to a maximum of ¥1 billion per year for up to 9 years, so that, at the end of the funding period, the COI site can become a self-sustaining and industry-centred innovation platform and continue to create radical innovation.

The business promotion component

A key element of the business promotion component is the government supply of public VC, to compensate for the low levels of private VC on the market. The Tokyo-based Innovation Network Corporation of Japan (INCJ) was established in 2009 for a 15 year-period as a public–private partnership between the Japanese government (METI) and 26 major corporations. The partnership operates as a government-sponsored private equity firm which promotes open innovation and innovation ecosystems through funding, capital, managerial support and technological expertise from the public and private sectors for Japanese companies in green energy, electronics, IT, biotechnology and infrastructure-related industries. Most of the ¥300 billion INCJ budget comes from the Japanese government (¥286 billion) and the rest from the 26 private corporations (¥14 billion). The government also guarantees INCJ investments in new ventures up to ¥1800 billion, or support, through a combination of VC and buyout funds, to the growth of SMEs or the consolidation of large companies to help them become global leaders.[10] The INCJ has also created Open Innovation Platforms, which operate independently from investment activities and bring together companies, venture capitalists and entrepreneurs.

Also noteworthy is the Programme for Enhancing the Development of the Global Entrepreneur (EDGE), adopted in 2014 by MEXT to develop ventures based on university R&D and to create innovation ecosystems in Japan. The programme provides entrepreneurship and commercialization skills to graduate students and young researchers and builds human and organizational networks through collaboration with venture-related institutions, overseas institutions and private companies. Since 2014, the programme has secured the involvement of 13 universities, which are sharing knowledge and networks while also improving their educational programmes independently.[11]

UIC at work: The experience of Osaka University and Hokkaido University

This section presents two case studies – Osaka University and Hokkaido University – that provide insights into the current state of UIC in Japan and exemplify the implementation of the innovation policy framework discussed in the previous section. The choice of the two universities was based on their high innovative potential, as reflected, for example, by the 2015 edition of Thomson Reuters' *World's Most Innovative Universities* ranking, which places Osaka University 18th and Hokkaido University 98th in the world.[12] Also, the *Nature Index 2017 Innovation Tables* ranks Osaka University 31st in the world, making it the top-ranking Japanese university on the list, and Hokkaido University 116th.[13] Both universities are part of Japan's National Seven Universities.

From a methodological point of view, the case studies are based on desk research and interviews conducted in December 2015 with leaders and research managers of key UIC structures at the two universities (at Osaka University: Office for University–Industry Collaboration, Institute for the Promotion of Business–Regional Collaboration, Centre for Innovation and Business Promotion; Northern Advancement Centre for Science and Technology; at Hokkaido University: Centre for Innovation and Business Promotion, Office for Enhancing Institutional Capacity). The interviews, which lasted about 60 min on average, consisted mainly of open-ended questions, which were preferred for exploring in more depth the respondents' views, attitudes and understanding of the dynamics and key features of UIC in the two universities since the mid-1990s.

Osaka University

Osaka University is the largest of the national universities, with 23,412 students and 10,052 faculty and staff (as of 1 May 2016), and 11 schools, 16 graduate schools, 27 research institutes and centres and 2 university hospitals. In FY2016, it devoted ¥25.7 billion to UIC out of its ¥136.4 billion revenue (Ogawa, 2017). The first UIC facilities were established in 1995 on a small scale, with only one professor and one associate professor, and were renewed in the academic year 2008–2009. The Office for University–Industry Collaboration was created in April 2011 and was renamed in April 2017 as the Office for University–Industry Co-Creation, operating as a hub for industry–university links in a networked structure that goes beyond the traditional UIC patterns. The 'University–Industry Co-Creation' concept itself is an innovative one and aims to create open innovation from the stage of basic research. The concept stands as a third stage in the evolution of UIC philosophy at Osaka University, the first stage having centred on comprehensive UIC started from basic research, and the second centred on nurturing innovative researchers through UIC (Ogawa, 2017).

The Office operates through four divisions:

i. The *Innovative Co-creation Division* works on organizational industry–university co-creation with a societal dimension, addressing key social challenges. It coordinates government-sponsored research and joint/commissioned research with industry partners on campus or in the satellite labs, facilitates companies' investment in the university, promotes new research lines and research monitoring, collects information on industry and supports university spin-offs.
ii. The *Technology Transfer Division* coordinates intellectual assets (patents and licences), directly or in collaboration with a technology management company (TLO), and the Invention Committee, with the aim of creating societal and economic value.
iii. The *Co-creative Education Division* focuses on the development of human resources with appropriate skills for creating innovation and connecting the university and society by means of Joint Research Chairs and Research Alliance Laboratories.
iv. The *Venture Incubation Division* uses government-sponsored projects to create an innovation ecosystem. The Division manages the Osaka University Venture Capital Co., Ltd (OUVC), a wholly owned VC firm created in December 2014 with ¥10 billion capital from MEXT. OUVC funds the university's own spin-offs formed by faculty and students in fields related to regenerative medicine, cancer treatment, early diagnostics, robots and artificial intelligence, ICT and big data and energy saving. Thus, Osaka University became the first university in Japan to establish a VC firm. The Division coordinates incubation activities and the Global Technology Entrepreneurship and Commercialization (G-TEC) Programme for entrepreneurship education, initiated in 2011. Other activities focus on the development of people to become industry leaders, the evaluation of innovation activities, and support for early-stage collaboration with industry.

A university trademark is the 'Industry on Campus' concept that is being implemented through several initiatives. The early Joint Collaborative Laboratories were expanded in 2006 into a Joint Research Chair system, which consists of independent research structures devoted entirely to cooperative research: These are established within the university for periods between 2 and 10 years with sponsorship from external corporations and other entities as well as from researchers.[14] The Chair is staffed by at least one professor or associate professor and an academic researcher and, from the business side, a corporate researcher, postdoctoral fellow and so on. University researchers and the sponsoring corporations' researchers stand on equal footing in their joint endeavour and consult with each other in defining the research agenda and deciding on the Chair management. The IP and the research results are jointly owned for a fixed period agreed for completing the research targeted for commercialization. The ultimate purpose of the Joint Research Chair system is to create a long-term research platform that will strengthen the university's research capacity and realize the societal dimension promoted by the Japanese government.

The Research Alliance Laboratories, introduced in 2011, expanded the Joint Research Chair concept by inviting corporate research groups to Osaka University to conduct advanced research jointly with the university researchers, develop UIC projects, commercialize research achievements and start-up new businesses. Currently, the university has six Joint Research Chairs, six Research Alliance Laboratories and a Research Alliance Unit, which are all located in the TechnoAlliance Building – a vast lab space for lease opened in 2011 to facilitate UIC interactions.

The UIC activities of Osaka University have been highly successful, looking at indicators for 2002–2015.[15] For example, the number of joint research contracts increased nearly fourfold, from 265 in 2002 to 993 in 2015, and the income they generated tripled, reaching US$35.7 million in 2015. Similarly, the number of commissioned research contracts nearly tripled, from 388 in 2002 to 950 in 2015, and the income they generated also tripled, reaching US$154.4 million in 2015. Research donations followed the same ascending trend, nearly doubling from 2705 in 2002 to 6263 in 2015, and bringing income amounting to US$47.8 million in 2015. The number of new inventions (disclosures) was 354 in 2015. The number of licences

increased from 0 in 2002 to 89 in 2015, reaching a licencing income of US$1.2 million. In addition, the university's G-TEC Programme was successful in facilitating knowledge exchange between university students and practitioners, the acquisition by students of managerial skills and an entrepreneurial mindset and the acquisition by practitioners of academic knowledge and entrepreneurship frameworks (Nakagawa et al., 2017).

Hokkaido University

At the core of Hokkaido University's UIC philosophy lies a shift from providing university-led social contributions to generating new industries and becoming an active component of Japan's industrial machinery. This implies overcoming the usual hurdles that companies face in the commercialization of university research and ensuring a quick and effective commercialization process from the companies' standpoint. Hokkaido University thus aims to pioneer new ways of business creation through UIC, by defining clear roles for each of the parties involved.[16]

The UIC network of the university is concentrated in the Northern campus area and is very dense,[17] consisting of several specialized units initiated in the mid-1990s and significantly expanded in subsequent years. For example, the Centre for Advanced Science and Technology was set up in 1996 to liaise between university researchers and industry, conduct joint research, provide lab space for that research and offer consulting services for industry. Hokkaido Venture Capital was created in 1998 and was followed in 1999 by Hokkaido TLO Co. Ltd, and in 2000 by Collaboration Hokkaido, an institution founded by the Northern Advancement Centre for Science and Technology, a regional foundation under the direction of the Hokkaido Economic Federation that promotes UIC and provides funding for innovative research and lab space for new industrial products. Also, the Hokudai Business Spring (a business incubation facility founded by the Agency for SMEs under the Ministry of Economics, Trade and Industry, then MITI) was created to carry out product development research.

In 2001, two other structures came to life: the JST Innovation Plaza, for the same purpose of offering research labs for new collaborations with industry, and the Hokkaido Platform Entrance (HoPE), established by the Hokkaido SME Association, the Centre for Advanced S&T of Hokkaido University and the Hokkaido Research Organization to support the launch of new business ventures. In 2010, it was awarded the MITI Minister's Prize for University–Industry–Government Cooperation in recognition of its success.

In 2002, the Hokkaido University Research & Business Park (HU R&BP) was established by the Hokkaido Economic Federation as a core research and business centre in charge of research commercialization, to be performed in cooperation between the local government bodies of Hokkaido Prefecture, financial/economic circles and academic institutions. The Park aims to utilize the IP of universities and other academic institutions to develop innovative technologies and new products, create new business ventures and contribute to the economic vitality of Hokkaido.

In 2003, the Creative Research Institution was set up as a university-wide interdisciplinary research organization with the mission to implement priority research programmes based on the university's strategic research policy, to create new academic disciplines and advanced research areas, to develop high-quality human resources and to return the results to society. Also in 2003, a Centre for the Management of Intellectual Property was established in the university by MEXT; it was renamed in 2007 as the Centre for the Management of Intellectual Property and Innovation, which systematically integrated UIC collaborations. This centre was further reorganized in 2009 as the Institute for the Promotion of Business–Regional Collaboration, which supports interaction with local SMEs and operates in close coordination with the HU R&BP and HoPE.

Hokkaido University was also selected as a Centre of Innovation (COI) for the COI STREAM Programme run by MEXT and the JST. A Master's Programme in Innovative Food and Healthcare was started as a COI site in partnership with the University of Tsukuba, Kitasato University and more than 30 companies and institutions, which work together to introduce a healthier life style for women, children and the elderly through diet and exercise.[18]

Hokkaido University has also been involved since 1995 in the creation of industrial clusters, primarily in three priority domains for the region: food, housing and recreation (tourist industry). There are currently 23 regional industrial cluster research associations operating in Hokkaido. In April 2000, the Hokkaido Centre of Collaboration among Government, Industry and Universities (Collabo Hokkaido) became the nation's first facility to be established within a national university by the private sector, with the support of the Hokkaido Government and the Sapporo Municipal Government. In conjunction with METI's Industrial Cluster Plan, METI Hokkaido selected IT and biotechnology as key areas for regional clusters (the IT industrial cluster is also known as the Sapporo Valley) and, in April 2001, launched the Hokkaido Super Cluster Promotion Project as an innovative form of collaboration with the business sector and regional governments (Hokkaido Bureau of Economy, Trade & Industry, 2002).

The success of UIC activities at Hokkaido University is reflected in its position in Japan's top 10 universities in terms of several UIC indicators (Abe, 2015):

- 8th for patent applications (with 1165 patent applications during 2009–2013);
- 9th for revenue from joint research (with ¥3.96 billion during the same period); and
- 10th for start-ups (with 47 start-ups in 2009).

However, interviews with local managers and UIC experts highlighted the fact that, although Hokkaido University undertakes a broad range of UIC activities, the actual output of these activities is of relatively low relevance and usefulness to the products and processes developed by companies, because there are too many differences between university research and real-life processes in industry. As a result, the income generated by the commercialization of university IP remains very limited, and this shortage needs to be compensated by government subsidies – suggesting a relatively immature stage of UIC and dependence on public subsidies.

Discussion and conclusions

After the burst of the bubble economy, Japan went through a 20-year period of deflation and economic stagnation. In response, since 1995 the government has introduced successive waves of growth-inducing policies that have co-evolved and gradually covered all the key links of the innovation chain. Our analysis identified a continuous expansion of innovation policies from an initial focus on S&T priority-setting and reform of the R&D system to the development of framework conditions for innovation, consolidation of technology transfer, research commercialization and related infrastructure, innovation networks, links with business firms and stronger UIC, regional innovation and greater responsiveness to societal needs. The innovation landscape in Japan thus became increasingly complex, with a sophisticated set of policies and implementing programmes, demonstrative of strong top-down government intervention with highly ambitious goals.

UIC policies have been a central element in the innovation policy framework from the early stages. They have been promoted in all the Basic S&T Plans since the mid-1990s and in other components of the innovation policy framework as a form of increasing responsiveness to social needs and contribution to social reform. As a result, a dense network of UIC centres has been established throughout the country, mostly in universities, which are firmly embedded in regional innovation structures. The two case studies of Osaka and Hokkaido universities exemplify this sustained effort and the broad range of initiatives implemented by Japanese universities to intensify their cooperation with business partners and with regional and national government agencies. The Osaka University case shows a relatively successful UIC system and the key elements in this success, although it is still behind the best world-class systems. The Hokkaido case shows an in-progress development of creative UIC which uses Japanese tactics of networking (*nemawashi*) to create a new ecosystem that will impact the region.

The hypothesis put forward in this article, which attributes Japan's relative lag behind other innovation world leaders, such as the United States and Europe, to a slow and still ongoing transition from a 'traditional' innovation system to a global innovation ecosystem, is supported by several factors. One factor that emerged from our interviews at the two universities relates to the *financial support* received by the universities: the funding for university start-ups comes mainly from METI, while the funding for joint/contract research comes mainly from MEXT, and universities have difficulties combining the two types of subsidies because of the different policies of the two ministries. Another factor is related to the still early development of *entrepreneurship support* in universities. This is hindered by a limited range of incentives in the labour laws for academics to start their own businesses and for entrepreneurs to sell their companies to large corporations; bankruptcy laws that make it difficult for entrepreneurs to put an end to failing start-ups and penalize unsuccessful entrepreneurs; a low social acceptance of the entrepreneurs; and the low VC levels, with capital coming mostly from government sources rather than private investors. Under these conditions, it is still unclear whether Japanese entrepreneurship is working (Ito et al., 2016).

Yet another factor is the lack of or early development stage of *intermediary support mechanisms and resources* for fostering innovation that are present in more advanced innovation ecosystems such as Silicon Valley. In addition, in spite of a strong US imprint on Japanese UIC policies, their effect has often been different due to the different structure and balancing of the Japanese innovation system, as discussed in the second section of this article.

A recent Stanford Silicon Valley–New Japan Project[19] suggests that the Japanese are fully aware of United States's dominant importance in start-up ecosystems and are trying to benefit more from it – as demonstrated by a new wave of start-ups in Silicon Valley in recent years by Japanese entrepreneurs, whose interest is not necessarily in learning how to create a Silicon Valley-like ecosystem in Japan, but to understand how large firms, fast-growing large start-ups and emerging start-ups can benefit from the Silicon Valley ecosystem. Moreover, some argue that the Japanese government could assist the transition to an innovation-based growth economy by helping Japanese firms and entrepreneurs use Silicon Valley institutions (Dasher et al., 2015).

Interviews with Japanese UIC experts revealed that a similar process of reliance on the United States has been going on in relation to UIC. Large Japanese companies prefer to collaborate with leading US research universities rather than with Japanese ones, while the value of Japanese contracts with US universities is usually an order of magnitude higher than those with Japanese universities, even for contracts carried out under various forms of government support. While this does not mean that Japan attaches less importance to developing strong and mature innovation ecosystems inside Japan, it may suggest a departure from the traditional inward-looking approach of the country and

an increasing openness to collaboration with top international players, such as those in the United States, to increase the performance and competitiveness of domestic players. Indeed, evidence from Japan shows that UIC policies have the greatest impact and achieve the strongest results (as measured by licencing revenue) among the largest and strongest universities that can attract significant funding from the private sector.

If the 'old' Japanese innovation system had served well enough the country's need to catch-up with the West and was not called into question for several decades, its transition to an innovation ecosystem is now equivalent to a paradigm shift, with wide-ranging policy implications. In part, this transition points to the need for government policies with a broader global outlook and stronger support for partnerships with leading international actors for domestic benefits. It also points to the need for the local universities, companies and government agencies to continuously strengthen and redesign their innovation networks by expanding both internationally and locally, by involving more local entrepreneurs in their education, research and business plans and by consolidating their entrepreneurial focus.

Authors' note

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Notes

1. For example, Sony's Walkman or the full implementation of the lean manufacturing system with total quality management, which has since become standard best practice around the world. Many Japanese technologies have been adopted by new, low-cost industrial powers, such as China, which started their rise to technology prowess in parallel with the slow decline of Japan's powerful tech industry. This is a good example of how continuous improvement of manufacturing skills and infrastructure can generate economies of scope and competitive advantages that were not envisaged by traditional strategic management and operations management theories (Flynn and Flynn, 1996).
2. Such factors included a shift towards equity finance that emphasized returns to investors, a global industrial restructuring in response to increasing integration of world markets and a shift in the source of competitiveness from production efficiency to uniqueness and differentiation (METI, 2002).
3. Further to criticisms that the original version of the Japan Revitalization Plan of June 2013 included too many reform ideas with no clear focus, and repeated some policies that had been already proposed by METI and other ministries in the past, two updated versions were issued in June 2014 (which specifies ten focus areas, one of which was innovation) and in June 2015 (which adds some new directions, especially for policies promoting local economies, while keeping innovation policies at the core of the third arrow reforms).
4. See http://entrepedia.jp/reports/67
5. See http://www.mext.go.jp/component/english/__icsFiles/afieldfile/2012/02/22/1316511_01.pdf
6. For example, insufficient consideration of social challenges, declining share of scientific papers and low levels of citations in international rankings, slow growth rate of government R&D investment, insufficient university jobs for young researchers, obstacles to maintenance and management of S&T facilities and insufficient awareness about and support for S&T in society.
7. See details at http://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/housin_gaiyou_140124en.pdf
8. See details at http://www.chusho.meti.go.jp/sme_english/whitepaper/whitepaper.html
9. See details at http://www.jst.go.jp/tt/EN/platform/coi.html
10. http://www.incj.co.jp/english/
11. http://edgeprogram.jp/about/?locale=en
12. http://www.reuters.com/most-innovative-universities/profile
13. https://www.natureindex.com/supplements/nature-index-2017-innovation/tables/top200-institutions-lens
14. A Joint Research Chair can be established in any field of humanities, social science or natural science, or in interdisciplinary fields integrating any or all of them, by any school/institute, including graduate schools, university research institutes and university hospitals. The Chair holder may indicate the sponsoring corporations at the Chair inception. The duration of the Chair can be extended subject to the availability of funding, which is partly covered by university overheads.
15. http://www.uic.osaka-u.ac.jp/old/en/strength/data.html#data
16. See details at: http://www.mcip.hokudai.ac.jp/cms/cgi-bin/index.pl?page=contents&view_category_2&view_category=1003
17. See details at: http://www.mcip.hokudai.ac.jp/cms/cgi-bin/index.pl?page=contents&view_category_2&view_category=1005
18. https://www.fmi.hokudai.ac.jp/en/about_coi/
19. http://fsi.stanford.edu/research/silicon-valley-new-japan-project

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Appendix 1

Table 1A. The third 'arrow' of Abeconomics: Japan Revitalization Strategy (New Growth Strategy).

Industry Revitalization Plan
Accelerating structural reforms to speed up industrial restructuring
Reforming the employment system and reinforcing human resources capabilities
Promoting STI (including through a Strategic Innovation Programme and an Innovative R&D Programme, by enhancing national research institutes and research funding, increasing R&D investment in the public and private sectors, strengthening intellectual property and standardization)
Becoming the world's leading IT society

(continued)

Table 1A. (continued)

Further strengthening Japan's international competitiveness as a business hub
Innovation of SMEs
Strategic Market Creation Plan in four strategic new growth sectors
Health and life expectancy
Energy
Next-generation economic infrastructures
Regional communities
Strategy of Global Outreach
Attraction of global talent, goods and funds to Japan through proactive entry to overseas markets
Support for SMEs
Strategic public–private joint initiatives and infrastructure for human resources
Strategic trade and economic partnerships

Source: Selected from Japan Revitalization Strategy (Cabinet Office, 2014).
Note: STI: science, technology and innovation; SME: small and medium-sized enterprise.

Appendix 2

UIC indicators (2003–2014)

- 2.6 times increase in the number of joint research contracts, to approximately 23,000 and revenues of approximately ¥55 billion in 2014;
- 2.2 times increase in the number of certified researchers, to approximately 24,000 in 2014;
- 3.7 times increase in the number of patent applications, to 9159 applications in 2014, of which 2572 were foreign applications and 6587 domestic applications;
- doubling of revenue from licenced patents between 2008 and 2013, amounting to ¥2.2 billion; and
- significant increase in the number of university start-ups from 9 in 1995 to 252 in 2005, followed by a drop since 2005, to 52 in 2013.

Source: MEXT Statistics (http://www.mext.go.jp/en/publication/statistics/index.htm).

Appendix 3

Table 3A. Selected UIC measures introduced by the Fourth S&T Basic Plan.

Realization of sustainable growth and societal development into the future
System reforms directed at promoting STI:
(1) *Enhancement of strategic systems for promotion of STI*
(i) Enhancement of knowledge networks among industrial, academic and government sectors
(ii) Creation of new places to promote collaboration among industrial, academic and government sectors (formation of open innovation centres, etc.)
(2) *Building new STI systems*
(i) Improvement of commercialization support
(ii) Building of regional innovation systems
(iii) Promotion of IP strategies and international standardization strategies
Enhancing basic research and human resource development
Development of S&T-related human resources
(1) Development of human resources that can be actively involved in a variety of places
(i) Creation of new places for dialogue between industrial and academic sectors
(ii) Support for doctoral students and diversification of career paths
(iii) Development and vocational training of engineers
(2) Development of creative and outstanding researchers
(i) Creating fair and highly transparent evaluation systems
(ii) Improving researchers' career paths
(iii) Promoting active involvement of female researchers
Formation of an international-standard research environment and foundations
(1) Improvement of R&D at universities and public research institutions
(i) Promoting development and shared use of advanced research facilities and equipment
(2) Improving intellectual infrastructure
(3) Improving research information infrastructure

Source: Selected from the Fourth Basic S&T Plan of Japan (see http://www.mext.go.jp/component/english/__icsFiles/afieldfile/2012/02/22/1316511_01.pdf).
Note: UIC: university–industry collaboration; S&T: Science and Technology; STI: science, technology and innovation.