The Architecture of Innovation System for the Commercialization of Science

- The Incentive Structure for the Decisions of Financial Resource Allocation -

Kanetaka M. Maki*
Keio Research Institute at SFC, Japan
kanetaka@kanetaka-maki.org

Emi Miyachi[1]
Keio Research Institute at SFC, Japan
emi.miyachi@mmip.co.jp

Satoshi Kabasawa
Graduate School of Media and Governance, Keio University, Japan
kabasawa@kiep.ne.jp

*Corresponding author

Abstract: The commercialization of science research often fails due to the lack of an appropriate architecture to bridge the financial gap between science researches and commercialization. The gap has created by characteristics of science researches such as high risk of uncertainty, long term of researches (10-30 years) and difficulty in creating the market of know-how (difficulty of M&A). One of the primary reasons of these failures is that most of the outputs of science researches are in too-early stage for industry to get interests in their value. In this research, with taking the research theories based on previous studies, we will show an empirical study by classification of innovation systems to bridge the financial gap for the commercialization of science research, and conduct new innovation process models.

Keywords: innovation system; finance structure; science; commercialization; incentive structure;

1. Introduction

Innovation is becoming one of the most important elements for both the economic prosperity of countries and improvement in the quality of life for people. Given the recent termination of research institutes in some large enterprises, universities have taken a key role as the engine of innovation, especially in terms of scientific research for clean technology, biotechnology, and communication technology, all of which are key elements of creating new businesses.

However, commercialization of science researches often fails due to the lack of a viable financial incentive architecture to bridge the financial gap between science researches and commercialization. We view that such the lack has been created by characteristics of science researches such as high risk of uncertainty, long term of researches (10-30 years) and difficulty in creating the market of know-how (difficulty of M&A). One of the primary reasons of these failures is that most of the outputs of science researches are in too-early stage for industry to get interests in their value.

We have been viewing that a viable financial flow for a successful commercialization of science researches is not enough due to the following three reasons;

Firstly, the proof of "Open Innovation" by Henry Chesbrough[1, 2] is widely recognized, but designing the appropriate financial incentive structure to collaborate among the different entities are still in challenge. Some previous studies prove that "Open Innovation" works effectively in some industries with high modularity such as IT industry. In open innovation concept, each entity focuses on its own core competence. This means, the empty space (gap) that no entity will work occurs. Baldwin[3] explained the characteristics of vertical integration and horizontal integration. In comparison with vertical integration model, it is extremely difficult to create incentive structure for financing the empty space in horizontal integration model. Nelson[4] described the concept of "national innovation system", and Porter[5] illustrated the proof of "clusters" as a regional innovation system that could accelerate the collaboration. Etzkowitz[6] described the concept of "Triple Helix" which explains the importance of universities as the source of innovation and linkages among universities, industry, and government. There is huge gap to transfer university knowledge to industry. Start-ups and venture capitalists are taking key roles in the innovation value chain in some regions.

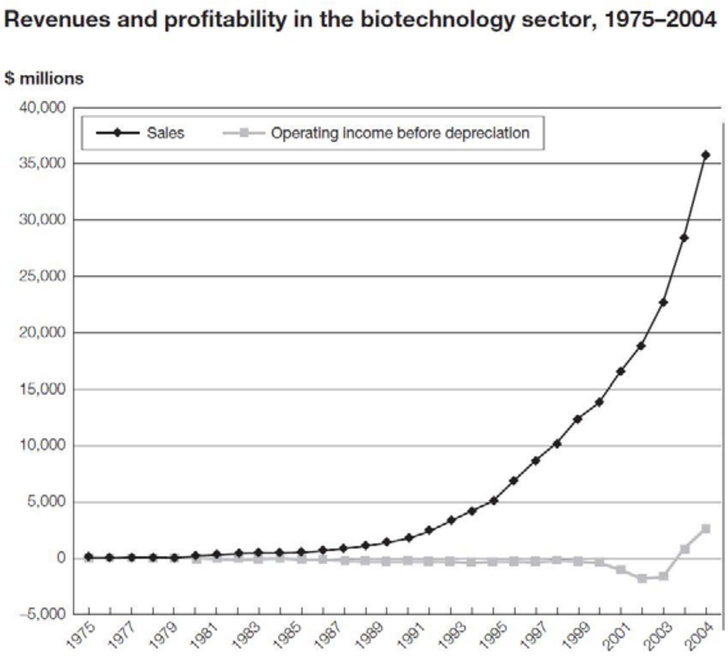
Secondly, the main research field for innovation is changing. Previously, information and communication technology was key role for innovation. In 21st century, more and more science related research is becoming essential to create competitive advantages for all countries, regions, and enterprises. Fleming[7] described the importance of science as a map for technological innovation. Science is especially useful in fields such as medicine or biotechnology, which include "the difficulty of the inventive problem".

Thirdly, the financial system in the world is rapidly changing. The financial engineering developed a huge market of financial products. However, overachievement of financial engineering deployment caused bubble economy and financial crisis. Still, financial engineering is necessary for future social system to operate individual assets, but we have to redefine how to use the financial engineering as a tool. It is hard for us to find enough budgets for science research for two reasons; 1) government based fund are not enough, and 2) according to financial methodology, science research is too early and high risk for industry to see any prospective outcomes. However, using financial engineering for promotion of innovation is one of the best solutions, even though it is challenging to achieve.

In this research, with taking the theories based on previous researches, we will show an empirical study by classification of innovation systems to bridge the financial gap for the commercialization of science research, and conduct new innovation process models.

2. State of the art about the topic

Baldwin[3] explained difference between vertical integration model and horizontal integration model by using the concept of modularity. In Baldwin's concept, horizontal integration is becoming better strategy for corporations to accelerate the innovation. However, in comparison with vertical integration model, it is extremely difficult to create incentive structure for financing the empty space in horizontal integration model.
Hounshell in the literature edited by Rosenbloom and Spencer[8] provides a historical overview of industrial research laboratories evolution in the United States in the 20th century, and described such the industrial laboratories as a distinctive scientific institutions have reshaped due to the end of the cold war and increasing fiscal constraints on public funds around the end of the century.
Chesbrough[1,2] illustrated the concept of "Open Innovation", which is one of the horizontal integration models, and the concept became mainstream in innovation system. Some previous studies prove that "Open Innovation" works effectively in some industries with high modularity such as IT industry. However, in "Open Innovation" concept, each entity focuses on its own core competence. This means, the empty space (gap) that no entity will work occurs.
Etzkowitz[6] described the concept of "Triple Helix" which explains the importance of universities as the source of innovation and linkages among universities, industry, and government. Nelson[4] described the concept of "National Innovation System", and Porter[5] illustrated the proof of "Clusters" as a regional innovation system that could accelerate the collaboration among different entities.
Shane[9], and Bygrave and Timmons[10] proved academic startups and venture capitals are the vehicles of executing innovation to fill the gap.



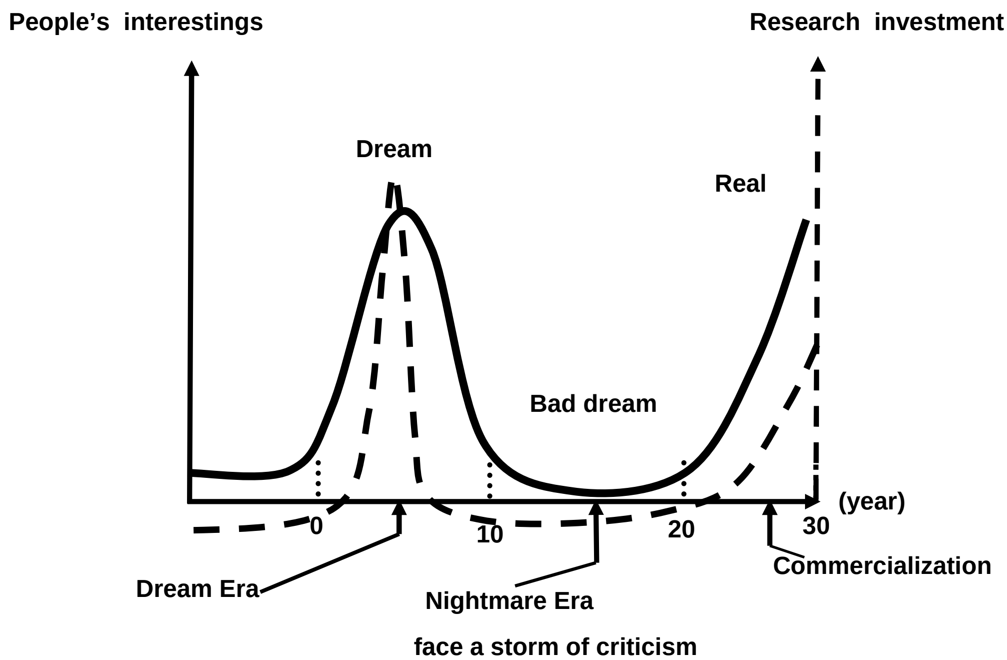
Source: Pisano, Gary P. "Science Business", Harvard Business School Press, 2006.

Figure 1: Revenues and profitability in the biotechnology sector, 1975-2004

All of these previous research outputs describe characteristics of Silicon Valley's Innovation Model. The model fits to IT sector, and we believe that this model works in many of innovation-related sectors. However, as the Figure 1 below shows, some data of biotechnology industry[11] describes that sales are increasing every year but profits (=Operating income before depreciation) stays almost zero for thirty years. This shows that the capital intensive Silicon Valley's Innovation Model may not work for such as biotechnology industry.

Pisano[11] declared that the innovation process of the commercialization of science is not effectively working, based on his studies on biotech start-up industry. However, this failure is not because of the potentiality of the commercialization of science, but more because of the lack of appropriate organizations and financial incentive structures. The science industry has several specific characteristics; he explains reasons by "high risk", "difficulty of integration", "the degree of information asymmetry", "the need for investments in specialized assets", "the tacitness of the know-how", and "the degree to which the relevant intellectual property can be protected legally". All of these problems are caused by the lack of translational research[12] that creates the gap between sciences research and commercialization, which is extremely difficult to be funded.

Yoshikawa and Naito[13] analysed science research process, showed that there are two stages; a front-stage of scientific discovery and/or scientific solution and a following stage of fusion and/or application of the outcome from the front-stage, and there is a need to provide continuously enough resources not only the front-stage but the following-stage. Kokuryo[14] has been also discussing especially that Type2 basic research[15] has a strong need of the financial resource. The figures below depict such the financial needs by Yoshikawa's[15] and Kokuryo's[14] discussion.



Modified"Type2 Basic Research",Yoshikawa Hiroyuki,P16, fig5

Figure 2: Yoshikawa's Model

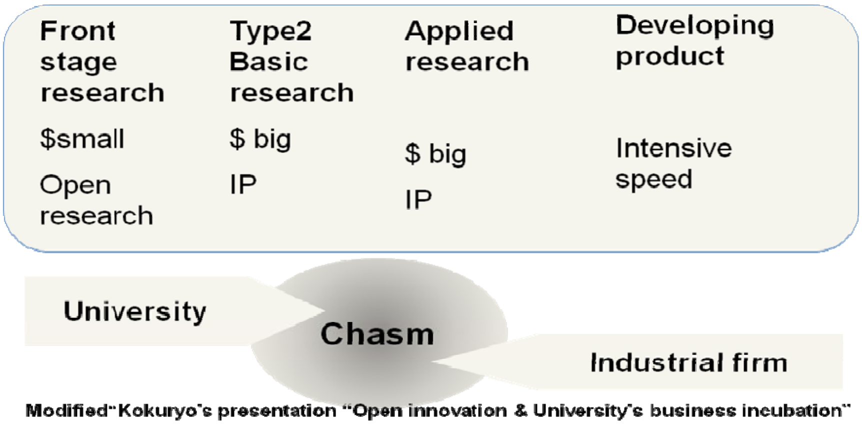


Figure 3: Kokuryo's Model

The paradox between belief based on previous studies and the reality of biotechnology sector's performance, new research topic and research questions emerge.

3. Research goals and questions, methodologies and findings

3.1 Research goals and questions

Our research goal is to design the appropriate architecture of innovation system for the commercialization of science. To achieve our goal, we have two research questions;

1) What are the emerging innovation systems and their structures?;

2) What is the effect of information processing model and incentive structure for the decisions of the financial resource allocation?

3.2 Methodologies

Our research conducted the hypothesis that explains new innovation model. Our hypothesis was conducted by analyzing sixteen innovation systems shown in the Table below, which table is in chronological order to emphasize how the innovation systems have evolved over the years. The sixteen innovation systems were defined base on literature review of architecture and innovation theories and were selected by interviews of innovation researchers and categorized by previous researches. We analyzed sixteen models using secondary sources including webpage, books, and reports. In addition, we conducted pre-interview for seven organizations, National Science Foundation (http://www.nsf.gov/), CALIT2(http://www.calit2.net/), CITRIS(http://www.citris-uc.org/), National Venture Capitalist Association Venture Philanthropy (http://www.nvca.org/), True Bridge Capital Partners (http://truebridgecapital.com/), Industry Innovation Network Corporation of Japan (http://www.incj.co.jp/english/), IPS Academia Japan Inc. (http://ips-cell.net/e/index.html), to deepen the understandings of innovation systems. Furthermore, we analyzed all sixteen models. In each system, we analyzed the causal relationships between the architecture and solutions for difficulty of science. Explanatory variables are based on previous studies of innovation and architecture theories to explain incentive structure. Dependent variables are based on Pisano's framework (difficulty in the commercialization of science).

Table 1: Models of Innovation Systems to Bridge the financial gap

Type	Model of innovation system	Case	Architecture						Solution for Difficulties of Characteristic of Science		
			History	Model	Sponsor	Incentive	Term	Covering Phase	High Risk	Longer Term	Market of Know How
Type 1	Debt finance for enterprises	The Petroleum Production Company Nobel Brothers, Limited	classic	vertical	bank	interest	10 years	all	P	G	F
Type 2	Central research institute operated by large enterprises	Bell Labs.	classic	vertical	capita stock + profits	profit	10 years	basic research, applied research	P	G	F
Type 3	Government-based grants for research institutes	National Science Foundation	classic	horizontal	tax income	research outcome & economy prosperity	5 years	basic research, applied research	P	P	P
Type 4	National research project with initiative of the government	Japan National Projects such as main-frame computer developme nt	classic	horizontal	tax income	economy prosperity & profit	10 years	basic research, applied research	P	G	F
Type 5	Sogo-Shosha	MITSUBIS HI Corp, MITSUI& CO.,LTD	classic	vertical / horizontal	profits	profit	5 years	applied research	P	P	F
Type 6	Start-up and venture capitalists	Silicon Valley Venture Capitals	classic	horizontal	equity	capital gain	7 years	applied research	G	F	P
Type 7	Angel investment	Viinod Khosla, Guy Kawasaki	classic	horizontal	equity	capital gain, excitement	7 years	applied research	G	F	P
Type 8	Collaborative grants of government and industry	National Science Foundation	classic	horizontal	tax income & profits	economy prosperity & profit	5 years	translational research, applied research	F	P	F

Type 9	Translational research mechanism in government-based research institute	RIKEN (a large natural sciences research institute in Japan), Calit2	emerging	horizontal	tax income & profits	deployment of research & profit	7 years	translational research	G	F	G
Type 10	License free & donation	CITRIS at UC Berkeley	emerging	horizontal	tax & profits	economy prosperity & profit	7 years	translational research, applied research	G	F	G
Type 11	Equity based intellectual management structured for private benefits	Intellectual Ventures	emerging	horizontal	capital stock	profit	10 years	translational research, applied research	G	G	F
Type 12	Venture philanthropy	Bill Gates Foundation	emerging	horizontal	individual profits	philanthropy & capital gain	20 years	translational research, applied research	G	G	F
Type 13	Alumni based fund	Georgia Tech Alumni Fund	emerging	horizontal	equity	compassion & profit	15 years	translational research, applied research	G	G	F
Type 14	Venture capital fund with platform of track-recorded managers	TrueBridge Capital Partners	emerging	horizontal	equity	capital gain	15 years	translational research, applied research	G	G	F
Type 15	Government-based Fund	Industry Innovation Network Corp. of Japan	emerging	horizontal	equity	economic prosperity & capital gain	15 years	translational research, applied research	G	G	F
Type 16	Equity based intellectual management structured for public benefits	IPS Academia Japan, Inc.	emerging	horizontal	equity	deployment of research & profit	15 years	translational research	G	G	G

In the table 1 above, we assess the solution for difficulties of characteristic of science as good (G), fair (F) or poor (P) according to a measurement shown in the table 2 below.

Table 2: Measurement of Solution for Difficulties of Characteristic of Science

	Solution for Difficulties of Characteristic of Science		
	High Risk	Longer Term	Market of Know How
Measurement	Mechanism of risk distribution and return	Expected term for return	Existence of platform to collaborate players for different functions
Good	Organized	more than 10 years	Organized
Fair	Partially organized	5-10 years	Partially organized
Poor	Not Organized	less than 5 years	Not Organized

3.3 Findings

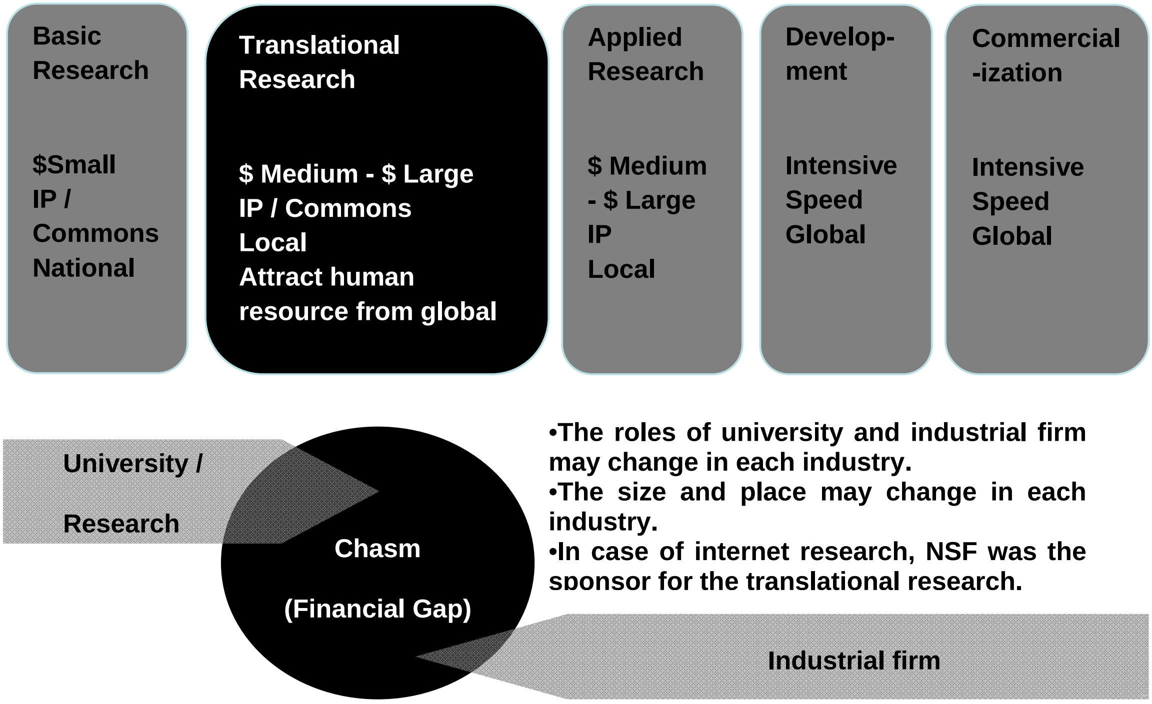
Several new findings came out from the analysis in the table 1.
Emerging models have several similar characteristics. Emerging models focus on 1) deepening new science findings, 2) transforming from “illusions” (high uncertainty) of scientists to applied research fields with lower uncertainty, 3) providing longer-term finance, 4) providing networks to related industry to share tacitness, and 5) educating researchers for emerging research field. As a method, 1) they create translational research organizations or systems and 2) conduct finance research with grants of local government or equity-based finance. As a result, emerging models try to solve the difficulties of the commercialization of science which Pisano clarified[11].
There are three types of methods to create incentives for investors for the translational research.

1) First method is to use the cluster: Translational research is essential phase to create new cluster for regional government and large enterprises in the region. They aim to attract talented human resource and create startups.
2) Second method is to use the financial incentives. Equity based investment with IP protection is high risk and high return business model.
3) Third method is venture philanthropy. Their incentives are the contribution to the society by solving social issues with financial return. First method is quite common in many cases.

4. Some implications and conclusion

According to our analysis, we created new innovation model shown in Figure 4. By putting “translational research” between basic research and applied research, the problems of commercialization of science Pisano described may solve. There is a chasm at the stage of translational research, because scientists propose “illusion” that is too uncertain for industry to be interested. As a definition, translational research is to find new applied research fields to reduce uncertainty.

In this research, there are several achievements. In academic perspective, the outcome of this research can explain why current Silicon Valley innovation model, which is combination of previous studies, does not work, by defining new innovation process model using theory of “translational research”. In addition, the outcome will clarify the incentive structure of “translational research” to fill the financial gap. In practical perspective, there are several contributions. Firstly, researchers can find new way to fundraise and deploy their research outputs. Secondly, investors can find new business chance. Thirdly, large enterprise can find new business chance with lower risk. Fourthly, research outcome supports policy makers to accelerate the innovation.



Definitions

Basic research:	Find new theorems in complex phenomenon
Applied research:	Finding solutions for social needs by using theorems
Translational research:	Find new applied research fields to reduce uncertainty (The word is cited from medical research)

Figure 4: A Translational Research Based Innovation Process Model

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