

Dynamics of Innovation Policies and Ecosystems in Japan

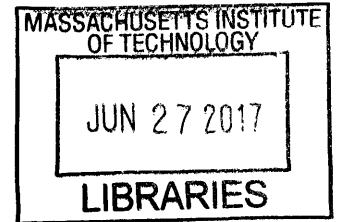
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ARCHIVES

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Abstract

Many public policies related to innovation have been implemented in Japan, especially focusing on promoting startups from universities, aiming at economic growth from technology. However, innovation ecosystem is complicated and dynamic that make difficult for policymakers to understand the system and evaluate policy effect. In this study, we analyze innovation ecosystem around a university and build a system dynamics model to have policy implications. We study the University of Tokyo and MIT, major universities for a large number of spinoff startups in each country, as cases of ecosystems.

The study begins with policy and literature review of innovation and entrepreneurship, to understand present studies and policies. Next, stakeholders, system boundary, and causal relationships are analyzed to frame the system. Then, we build a system dynamics model of innovation ecosystem around a university. We included several causal loop structures in the model. For example, an *Entrepreneur boom* loop is a reinforcing loop which accelerates foundation of university spinoff startups and conversion of students to become entrepreneurial. A *Risk capital depletion* loop is a balancing loop which decelerates growth of startups when too many startups look for investment. Multiple loops and stakeholders interact closely in the systems, and the interrelated structures cause delay and side effects in simulation runs of our model.

Results of the simulation infer policymakers need to consider combinations of policies rather than implement a single policy. Another interpretation from simulation runs is that patient policy implementation can lead to better outcomes because time delays in the loops make it difficult for policymakers to observe the effect of policies in the short term. Although additional data points are required for further calibration of the model, insights from this study and the model contribute to better understanding of innovation ecosystems around a university.

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1. Introduction

In Japan, a significant amount of national budget has been spent on science and technology research, and there have been numerous successful research outcomes produced. Since 2000, seventeen Japanese researchers have been awarded a Nobel prize,¹ and it is the number two country for the number of PCT (Patent Corporation Treaty) applications over the world in 2015, following the United States.² With recognitions of those achievements, the Japanese government has been focusing on innovation policy for several years, aiming at economic growth from research outcomes, and some of the governmental programs focus on innovation from universities. For example, Ministry of Education, Culture, Sports, Science and Technology (MEXT) distributed budget to four major national universities to establish their Venture Capitals (VCs) in 2012 supplemental national budget.³ The four universities, Tohoku University, the University of Tokyo, Osaka University, and Kyoto University, received 120 billion JPY(appx. 1.2 billion USD) in total, and this budget is exclusively for investment for startups from those universities.⁴

Despite public policy efforts and potential of technologies, Japan is not regarded as an innovative country by some researchers. The Global Innovation Index 2015 ranks Japan as the 19th country for innovation.⁵ A report from Global Entrepreneurship Monitor shows early stage entrepreneurial activity in Japan is lowest among 29 innovation-driven economies.⁶ We should not conclude that Japan is not innovative only from those reports because those reports investigated limited aspects of national productive capability. However, from those reputations, analysis of innovation policy and understanding of innovation ecosystem in Japan are interesting subjects to study, for future development of innovation policies.

¹ Nobel Media AB, “All Nobel Prizes.”

² World Intellectual Property Organization, “Who Filed the Most PCT Patent Applications in 2015?”

³ Bureau of Higher Education, Ministry of Economy Trade and Industry, “About Public-Private Innovation Program(Investment to National Universities).”

⁴ Ibid.

⁵ Dutta, Soumitra, Bruno Lanvin, and Sacha Wunsch-Vincent, “The Global Innovation Index 2016: Winning with Global Innovation.”

⁶ Slavica Singer, Jos. Ernesto Amor.s, Daniel Moska Arreola and Global Entrepreneurship Research Association (GERA), “GEM Global Entrepreneurship Monitor,” 201.

On the other hand, the Greater Boston Area is a region in which universities and high-tech companies accumulate, and they collaborate each other, that forms the ecosystem of innovation. For instance, Bloomberg ranks Massachusetts as the most innovative state in the United States.⁷ There are not only research and development facilities but also other facilities and players related to innovation in the area. Cambridge Innovation Center is one of the largest office space for startups, and Lab Central is a shared laboratory for biotech startups. MassChallenge is one of the largest accelerator programs in the world that awards \$1.65 million USD to startups annually. Besides, recently MIT has been focusing on programs that promote innovation from its community members and contributes to the regional innovation ecosystem. The MIT Sandbox program provides educational programs and funding to students by supporting their challenges.⁸ MIT Engine supports startups in the region by providing office, investment, and maker spaces.⁹ The ecosystem in the Greater Boston Area is different from Japan, and it keeps developing.

Innovation ecosystems are complicated because there are numerous types of players and cultures involved to be analyzed. For example, national and municipal governments, universities, VC firms, entrepreneurs, established companies, and other stakeholders take roles to establish and facilitate growths of startups. Therefore, understanding dynamics of the systems focusing on generation and growth of startups is crucial to plan effective policies to improve innovation ecosystems in Japan, and system dynamics and other techniques from related to systems engineering will work for this purpose. As well as the analysis of Japan, it may give us insights on this subject if we analyze Boston. In addition to modeling, it is also important to understand the cultural background behind the ecosystem. An ecosystem which works in the United States may not work in Japan, because of differences in culture and social systems. Therefore, not only modeling of the ecosystem but also discussions for entrepreneurship and innovation cultures will be carried out in this study. To be specific in analysis and policy proposal, this study focuses on the University of Tokyo and MIT and ecosystem surrounding those universities, because those two universities are leading both in technological invention and creation of startups in the areas. First, research questions are discussed to shape the research, in chapter two. Second, innovation

⁷ Jamrisko and Lu, “Here Are the Most Innovative States in America - Bloomberg.”

⁸ Massachusetts Institute of Technology, “MIT Sandbox.”

⁹ Massachusetts Institute of Technology, “The Engine.”

policies and players around the University of Tokyo and MIT are reviewed with the purpose of understanding components of the system. Third, a literature review is carried out to understand existing theories and discussions related to innovation system and entrepreneurship in section four. This section also includes research about the business culture that affects innovation system. Fourth, in section five, the problem and the system will be framed with stakeholder analysis, system breakdown, and causal loop analysis. In section six and seven, system dynamics model is built on several assumptions that are based on discussion in prior sections. Finally, findings from the system dynamics model are summarized and policy implementations are discussed in section eight.

2. Research question

In this section, research questions are discussed to shape the focus of the research. As discussed in the previous section, purposes of this study are to understand innovation ecosystem for better implementation of the policies. We analyze and model innovation ecosystems around the University of Tokyo and MIT as examples. Therefore, the first research question is directly related to the purpose.

Q1: What are potential policy levers for public policymakers to efficiently promote innovation from a university?

The Q1 is about public policy levers, that policymakers can implement. Our focus is on policies that have potential to impact ecosystem and leads to more innovation produced from the ecosystem. The University of Tokyo is the top university in a number of spinoffs startups¹⁰ and research outcomes¹¹ in Japan. Therefore, understanding of the ecosystem around and potential policies for The University of Tokyo will provide insights for future challenges other universities will meet. The next question is how to determine the potential policy levers.

Q2: How can the innovation ecosystem around a university be modeled for policymakers to select potential and effective policy levers?

System engineering methods, especially modeling methods have been employed to analyze systems for various public policy issues.¹² However, existing research using system modeling of innovation ecosystems was not found. Therefore, this research seeks to discuss how the innovation ecosystem around a university can be modeled to determine policy levers. This question can be divided into three sub-questions to approach.

¹⁰ Nomura Research Institute, “Industrial Technology Research Program 2016(Research for Situation of University Spinoff Startups).”

¹¹ Quacquarelli Symonds, “QS World University Rankings 2016.”

¹² Sterman, *Business Dynamics*.

Q2-1: What are major elements and structure (including feedback loops) that consists the innovation ecosystem?

Q2-2: How can the model of the innovation ecosystem be validated and what data sets are necessary for the validation?

Q2-3: How will the modeled be used to discuss the policy levers and by whom?

The first sub-question approaches to the basic structure of the modeling. Understanding of the system begins with understanding elements, such as stakeholders, valuables, and relations. Sometimes dynamics of a system can be explained by existing of reinforcing and balancing feedback loop.¹³ The second sub-question is about validation of the model. Since the model in this research isn't based on an existing model, careful argument of validation along with clarification of assumptions and further data acquisition are necessary. This is because currently available data may insufficient for validation. The third sub-question is about a use of the model. Who uses the model, how it is used, and what is the limitation of the model, are the questions we approach.

¹³ Ibid.

3. Innovation Policies and players around the U. Tokyo and MIT

In this section, public policies, public agencies, major private entities, and programs in universities related innovation are reviewed, to explore the innovation ecosystem surrounding both the University of Tokyo and MIT.

3.1. Public Policies and Public Players around the University of Tokyo

(1) Overview of policies of Japanese government and Tokyo Metro Government

For the national level, Japanese government promotes innovation and entrepreneurship mostly for economic growth of the country. In Japan Revitalization Strategy, one of the most important national strategy of Japanese government, innovation and startups are expected to contribute to the national economy.¹⁴ Under the strategy, several ministries promote innovation and entrepreneurship. MEXT supports university spinoff startups, focusing on benefiting from academic research outcomes. Ministry of Economy, Trade and Industry (METI), supports both research oriented and not oriented startups to vitalize Japanese economy. Besides, Ministry of Internal Affairs and Communication(MIC) supports startups related to telecommunication. As incorporated administrative agencies, Japan Science and Technology Agency (JST) under MEXT and New Energy and Industrial Technology Development Organization (NEDO) under METI also plan and execute programs related to innovation and entrepreneurship.

(2) Innovation Network Corporation of Japan

Innovation Network Corporation of Japan(INCJ) is an investment company founded by the Japanese government and private companies. The government invested 286 billion JPY, and the private companies invested 14 billion JPY to establish INCJ in 2009.¹⁵ INCJ invests in various companies to vitalize Japanese economies and industries, and it also invests in venture funds to supply risk capitals to VC firms. INCJ has directly invested in 101 companies including 79 startups, and venture funds which received investment from INCJ have invested in 124

¹⁴ Cabinet Secretariat, “Japan Revitalization Strategy 2016.”

¹⁵ Innovation Network Corporation of Japan, “Innovation Network Corporation of Japan | Introduction.”

startups by end of 2015 fiscal year.¹⁶ Total investment for startups is 197,8 billion JPY(1.978 billion USD).¹⁷

(3) Organization for Small and Medium Enterprises and Regional Innovation

Organization for Small and Medium Enterprises and Regional Innovation (SME Support), an independent governmental agency under METI, provides comprehensive supports to small and medium companies, including startups. One of the major supports from SME support related to startups is an investment in venture funds. In the first half of 2016 fiscal year, SME support invested in 13 venture funds as limited partners (LP), that is 16.5 billion JPY in total.¹⁸ Since 1998, when SME support started the investment, it has supported 242 funds and 234.5 billion in total.

(4) Japanese Small Business Innovation Research

Japanese Small Business Innovation Research (Japanese SBIR) is a national governmental program, started in 1999, that is similar to Small Business Innovation Research (SBIR) in the United States. Seven ministries participate in Japanese SBIR, and they subsidize small and new enterprises to carry out research. Besides this research funding, there are commercialization supports, such as patent filing fee exemption, a loan with a low-interest rate from governmental agencies, and opportunity for investment.¹⁹ However, those commercialization supports are not utilized well, and a limited number of funded projects have resulted in commercialization, which caused a criticism that Japanese SBIR is used for old small and medium enterprises but not for startups.²⁰

¹⁶ Ministry of Economy, Trade and Industry, “Performance evaluation of Innovation Network Corporation of Japan for 2015FY.”

¹⁷ Ibid.

¹⁸ Organization committee of cabinet for promoting public-private funds utilization, “Sixth Verification Report for the Guideline for Public-Private Funds Management.”

¹⁹ Basic Policy Working Group, Council for Science and Technology Policy, “Outline of Science and Technology Basic Policy Planning.”

²⁰ Administrative Evaluation Bureau, Ministry of Internal Affairs and Communication, “Investigation Report for Promotion of Innovation Policy.”

(5) START Program

Program for Creating Start-ups from Advanced Research and Technology (START program) is a research funding program of JST that supports university research which has potential to be commercialized by spinoff startups. VC firms and investment companies are actively involved as “Project Promoter,” and they discover technology seeds from universities, propose new projects to be funded, and manage selected projects.²¹ START program started in 2012, and MEXT has selected 16 projects per year in average. As of November 2016, 18 VC firms and investment companies are selected as Project Promoter, and 18 startups are founded from 81 projects. Some of 18 startups raised more than \$1 million investments.²²

(6) SUCCESS

Support program of Capital Contribution to Early-Stage Companies(SUCCESS) is a JST’s program that invests in and support startups which are founded based on science and technology. The aim of SUCCESS is to maximize social benefit and economic impact from technologies developed by JST research funding. Different from other JST research funding programs, JST takes equity of startups through an investment of SUCCESS. Since the beginning in 2014, JST has invested in 12 startups as of March 2017.²³

(7) EDGE program

Enhancing Development of Global Entrepreneurs (EDGE program) is MEXT’s entrepreneurship education program that funds selected universities to carry out new entrepreneurship educational program for graduate students and young researchers, and build innovation ecosystems. EDGE Program started in 2014, and 13 universities have been funded for three years.²⁴ Selected universities are required not only to carry out educational program but also collaborate with industries and oversea institutes to build innovation ecosystems.

²¹ Japan Science and Technology Agency, “Program Outline | START(Program for Creating Start-Ups from Advanced Research and Technology).”

²² Japan Science and Technology Agency, “Pamphlet of START Program.”

²³ Japan Science and Technology Agency, “Introduction | SUCCESS.”

²⁴ Ministry of Education, Culture, Sports, Science and Technology, “Result of organization selection for Enhancing Development of Global Entrepreneurs Program(EDGE Program) in 2014FY.”

(8) Awards for Academic Startups

Awards for Academic Startups is an annual competition to award university spinoff startups, and JST and NEDO have been hosted the award since 2014. Startups that are based on university research technology and less than ten years from foundation can apply for the award.²⁵ Not only technology and business but also collaborations with external organizations are taken into account for judges, aiming encouraging support from large companies to startups.

(9) Startup Innovator

Startup Innovator is NEDO's program to support entrepreneurs who started and are planning to start a technology-focused business. NEDO selects entrepreneurs and funds their salary (up to ¥6.5 million per year) and costs for startup (up to ¥35 million per year).²⁶ Professionals, such as venture capitalists, experienced entrepreneurs, lawyers, and accountants, support entrepreneurs as "business catalyzer."²⁷

(10) Support for Seed Stage Technology Based Startup

Support for Seed Stage Technology based Startup is NEDO's program to support seed stage startups by subsidizing. NEDO subsidize startups with an amount of 85/15 of investment of selected VC firms.²⁸ There are 19 selected VC firms as of July 2016 who can invest in startups and get equity of the startups, and NEDO adds 85/15 (5.7 times of the investment from firms) non-dilutive subsidy to support commercialization. Before application to this funding, startups need to negotiate with the VC firms to sign up a term sheet or get investment, and then startups can apply to NEDO for a subsidy.

²⁵ Japan Science and Technology Agency, "Summary 2016|Japan Science and Technology Agency."

²⁶ Innovation Promotion Division, New Energy and Industrial Technology Development Organization, "Startup Innovator Call for Applications."

²⁷ Ibid.

²⁸ Innovation Promotion Division, New Energy and Industrial Technology Development Organization, "Call for Application Technology Based Startup Supporting Progra/Support for Seed Stage Technology Based Startup in 2016FY."

(11) Sido Next Innovator and Hiyaku Next Enterprise

Sido Next Innovator is METI's educational program for entrepreneurs who have a business idea. Selected 120 entrepreneurs participate in a domestic curriculum for seven weekends (12 days in total), then limited participants visit Silicon Valley for one week, after another round of a selection.²⁹ The domestic curriculum includes lectures, mentorings, business plan makings, and pitches. The Silicon Valley program includes lectures, site visits, and pitches.

Hiyaku Next Enterprise is also METI's program to send startups and small companies to 4 cities(Silicon Valley, New York, Austin, and Singapore) for a week, aiming to connect startups to ecosystem oversea.³⁰ In 2016FY, 15 startups are selected for each course, and they participate in lectures and advice sessions with professionals who provide professional services to startups locally. For example, business incubators, law firms, and entrepreneurs are involved in the Silicon Valley program.

(12) The Nippon Venture Award

The Nippon Venture Award is an annual competition to award startups and entrepreneurs who can be role models for young entrepreneurs. The award started in 2015, and around six startups and their supporters are selected annually.³¹ The highest award is the Prime Minister's Prize, and the Prime Minister attends the ceremony for the award.

(13) Public-Private Innovation Program

MEXT provided funds to four major national universities to establish their VC firms to spin off companies from their research outcomes. In total, 100 billion JPY were funded to Tohoku University(12.5 billion JPY), the University of Tokyo(43.7 billion JPY), Kyoto University(27.2 billion JPY), and Osaka University(16.6 billion JPY) in 2014³². By January 2016, the four universities established their VC firms, and all of them started investing in startups that spinout from their "mother" universities.³³

²⁹ Ministry of Economy Trade and Industry, "Foster Innovator'Sido Next Innovartor 2016."

³⁰ Ministry of Economy Trade and Industry, "Hiyaku Next Enterprise|Ministry of Economy, Trade and Industry."

³¹ Venture Business Creation Council, "The 2nd Nippon Venture Award."

³² Bureau of Higher Education, Ministry of Economy Trade and Industry, "About Public-Private Innovation Program(Investment to National Universities)."

³³ Mayumi Usui, "Current situation and challenges for public-private funds."

(14) I-Challenge

I-Challenge is MIC's research funding program to foster innovation in information and communication technology (ICT) field. MIC funds universities and small businesses to carry out research and commercialization of ICT. Selected VC firms review applications(1st round selection) from universities and small businesses.³⁴ If there is a promising technology, a selected VC firm drafts an application with a business model for the technology for research funding from MIC. Then MIC reviews 2nd round applications to decide projects to be funded (2nd round selection).

(15) Tax Deduction for Angel Investors

Investors can benefit from income deduction or capital gain deduction for tax when they invest in small companies that have been in business for limited years.³⁵ Investors can choose to have either income deduction or capital gain deduction. For the income deduction, investors can reduce an amount equal to investment minus 2,000 JPY from their income, when they invest in a small company that is in business for less than three years. For the capital gain deduction, investors can reduce amount equal to the investment from capital gain when they invest in a small company that is in business for less than ten years.

(16) Incubation HUB promotion project

Incubation HUB promotion project is Tokyo Metropolitan Government's program to fund coalitions of business incubators.³⁶ The government subsidizes labor cost and operation cost to establish coalition and organizer events to foster new businesses. The subsidy is up to 15 million JPY. The government started this program in 2013 and selected seven coalitions. Only coalitions of multiple organizations can apply but single incubator cannot.

³⁴ Technology Policy Division, Global ICT Strategy Bureau, Ministry of International Affairs and Communications, "ICT Innovation Create Challenge Program(I-Challenge!) Introduction."

³⁵ Ministry of Economy Trade and Industry, "Introduction to Tax Reduction for Angel Investors."

³⁶ Bureau of Industrial and Labor Affairs, Tokyo Metropolitan Government, "Incubation HUB Promotion Project."

(17) Subsidy for Incubation Facility and Activity

Tokyo Metropolitan Government subsidizes business incubators to renovate the incubators' facility, and the subsidy can also be used for limited operation expenses. The subsidy can cover construction, interior and operation costs for three years. Cost covered by the subsidy is up to 50 million JPY for renovation and 20 million JPY annually for operation expenses. The program started in 2015, and 15 companies have been subsidized by March 2017.³⁷

(18) Starting New Business Support Program

Tokyo Metropolitan Government supports entrepreneurs who are planning to start business and companies which are founded in last five years. The government subsidizes labor, rent, professional service, advertisement, and equipment costs. The subsidy is up to 3 million JPY per one company. The program started in 2015, and 90 entrepreneurs/businesses have been supported through 2015 and 2016.³⁸

(19) Tokyo Metropolitan Government Small and Medium Business Program Loan for New Business

There is a loan for new business up to 25 million JPY with seven or ten years maturity by Tokyo Metropolitan Government. The interest rate is 1.9-2.5% annually.³⁹ Debtors can use it for either operation cost or equipment cost. A person who is planning to start a business, a company which started in last five years, and a company which is willing to spin out a startup, can apply for this loan.

(20) Women, Youth, and Senior startup support program

There is another loan for women, youths (younger than 40), and seniors (elder than 54), who are planning to start a business. Individuals who already started a business in last five years can also apply.⁴⁰ Under collaboration with Metropolitan Tokyo Government, private banks lend

³⁷ Tokyo Metropolitan Small and Medium Enterprise Support Center, "Subsidy | TOKYO Startup Station."

³⁸ Tokyo Metropolitan Small and Medium Enterprise Support Center, "Past Awards for Starting New Business Support Program."

³⁹ Bureau of Industrial and Labor Affairs, Tokyo Metropolitan Government, "Incubation HUB Promotion Project."

⁴⁰ Bureau of Industrial and Labor Affairs, Tokyo Metropolitan Government, "Introduction to Women, Youth, and Senior Startups Support Program."

up to 15 million JPY for up to 10 years, without collateral. Annual interest rate is fixed at 1 %, that is lower than the nominal rate. Also, mentoring services are provided from local professionals for debtors of this loan.

(21) Tokyo Startup Gateway

Tokyo Startup Gateway is an annual business plan contest sponsored by Metropolitan Tokyo Government. The government provides 1 million JPY for the first prize and 500,000 JPY for the second. Also, sponsoring companies provide business supports for finalists, such as accounting services and mentoring.⁴¹ Through the contests, lectures and mentoring are provided to applicants to improve their business plan by the final pitch event. Individuals who are planning to start a business, from 15 to 39 years old can apply.

(22) Incubation Offices operated by Tokyo Metropolitan Government

Tokyo Metropolitan Government owns six incubation offices, Tokyo Contents Incubation Center, Venture KANDA, Time 24, SIOS SUMIDA, Incubation Office TAMA, and Shirahige Nishi R&D Center.⁴² They have 6-65 office rooms where small enterprises can rent. Some of the incubation offices are equipped with small makers spaces, studio, or experiment equipment.

(23) Aoyama Startup Acceleration Center

There is an acceleration center in Aoyama area own by Tokyo Metropolitan Government, which provides educational programs for entrepreneurs, eight office spaces for startups, accommodations for visitors, and event spaces.⁴³ The main acceleration program is a five months program includes pitches, lectures, mentoring, and demo days. It opened 2015 and Tohmatsu Venture Support operate it.

⁴¹ Tokyo Metropolitan Government, “Startup Contest to Foster Entrepreneurs and Business That Change The World | TOKYO STARTUP GATEWAY 2016.”

⁴² Tokyo Metropolitan Small and Medium Enterprise Support Center, “Incubation Office Information | Tokyo Metropolitan Small and Medium Enterprise Support Center.”

⁴³ Tokyo Metropolitan Small and Medium Enterprise Support Center, “Startup Support facility ‘Aoyama Startup Promotion Center’ opens | Tokyo Metropolitan Government.”

(24) Tokyo Startup Station

A center of Tokyo Metropolitan Government to support entrepreneurs which locate near Tokyo Station. Consultants at the center help entrepreneurs without a fee.⁴⁴ There are event spaces for lectures, networking events, and other events related to innovations, and the center opened in January 2017.

(25) Life Science Venture Startup Support Program

Tokyo Metropolitan Government supports life science related startups that are founded within five years, by subsidizing half of rent fee for office up to 2 million JPY per year, and the support continues for three years in maximum.⁴⁵ This program started in 2015. There was a budget for 10 startups in 2015, and for 20 startups in 2016.

3.2. Players from Private Sectors for Innovation and Entrepreneurship

(1) Venture Capital Investment in Japan

Venture Enterprise Center, an incorporated association of VC firms, carries out surveys for venture business in Japan annually and summarizes VC investment.⁴⁶ In 2015FY, Japanese VC investments were 130.2 billion JPY(1.302 billion USD) in total for 1,162 startups. It increased from 2014 by 11.2% in amount and 19.9% in a number of investments. Still PC, mobile, and telecommunication are the primary field for startups, and 57.9% of the investments went to those areas.

(2) Innovation Leaders Summit

Innovation Leaders Summit(ILS) is the largest open innovation event in Asia held annually, established in 2014.⁴⁷ Dream Gate/Project Nippon is the organizing company, and METI is a strong supporter since the launch of the summit. In the 4th ILS in 2016, 5,516 participants, 100+ large enterprises, and 400+ startups attended to find business partners and opportunity for M&A. One of the main programs, POWER MATCHING, is a one-on-one

⁴⁴ Bureau of Industrial and Labor Affairs, Tokyo Metropolitan Government, “TOKYO Startup Station | Counseling for Starting New Business | Tokyo Startup NET.”

⁴⁵ Tokyo Metropolitan Government, “Call for Life Science Startups Subsidy Applications | Tokyo Metropolitan Government.”

⁴⁶ Venture Enterprise Center, “Venture White Paper 2016.”

⁴⁷ Project Nippon, “Open-Innovation Report 2016.”

business matching event between startups and large enterprises, to promote collaboration/partnership/M&As. There were 2190 one-on-one meetings in 2016. Besides, there were 80 startup pitches, 187 startup show cases, 35 key player lecture sessions, and 2 networking parties.

(3) Samurai Incubate

Samurai Incubate, founded in 2008, is an incubator which invests in startups, and Samurai Incubate also rent office spaces to startups. Recently, it expanded to Israel to invest in Israeli companies.⁴⁸ Also, Samurai Incubate hosts startup-related-events to foster innovation ecosystems. Samurai Incubate has been invested in 100 IT companies and hosted more than 1000 events in Japan by 2017. Startups can use Samurai Startup Island, the shared office for startups, from 15,000 JPY to 30,000 JPY per month rent fee.

(4) Startups support by large companies

Interests of large Japanese companies to startups are gradually increasing. For example, several Corporate VC firms were established in 2015.⁴⁹ Also, large companies are making facilities and programs to help startups and connect with them. For example, KDDI Mugen Lab, startups support program hosted by KDDI group, organizes acceleration program⁵⁰ and DMM.make Akiba, a shared office with maker space for hardware startups⁵¹ have established in this four years.

3.3. Innovation and Entrepreneurship programs at the University of Tokyo

(1) Entrepreneur Dojo

Entrepreneur Dojo is an entrepreneurship education program, mainly focusing on junior to graduate students at the University of Tokyo.⁵² Division of University Corporate Relations of the

⁴⁸ Samurai Incubate.inc, “Samurai Incubate.inc Incubation Program.”

⁴⁹ Venture Enterprise Center, “Venture White Paper 2016.”

⁵⁰ KDDI, “KDDI ∞ Labo | KDDI Ventures Program | KDDI.”

⁵¹ DMM, “DMM.make AKIBA.”

⁵² The University of Tokyo Division of University Corporate Relations, “The University of Tokyo Entrepreneur Dojo | The University of Tokyo Division of University Corporate Relations.”

University of Tokyo has hosted this program since 2005, and now there are three courses, beginner, intermediate, and advanced course. The beginner course focuses on lectures from entrepreneurs, the intermediate course focuses on introductions to basic skills to draft business plan, and the advanced course focuses on mentoring and pitches.

(2) Incubation Offices in the University of Tokyo

Division of University Corporation Relations manages four types of incubation offices.⁵³ Entrepreneurs and startups, who are planning to commercialize technology from the University of Tokyo, can apply for those incubation offices. One of the incubation offices, University of Tokyo Entrepreneur has laboratories for experimental research.

(3) Todai mentors

Division of University Corporation Relations has five part-time mentors who support startups. The mentors are business professionals and most of them (4/5) are from auditing firms.⁵⁴

(4) UTokyo 1000k

Division of University Corporation Relations' product idea contest for students and postdocs of the University of Tokyo, started in 2016.⁵⁵ There are two types of competition, Technology type and Theme type. In Technology type competition, applicants propose new products based on technology from the University of Tokyo. On the other hand, applicants of Theme type competition propose products that fit annual theme of the competition. For example, the topic for 2016 competition was "Time and Energy. The winner for each type awarded 250K JPY(2.5K USD). Competition is by application review and 3 minutes pitches.

⁵³ The University of Tokyo Division of University Corporate Relations, "Incubator/How to Apply | The University of Tokyo Division of University Corporate Relations."

⁵⁴ The University of Tokyo Division of University Corporate Relations, "Startup Mentoring/Business Mentoring| The University of Tokyo Division of University Corporate Relations."

⁵⁵ The University of Tokyo Division of University Corporate Relations, "UTokyo 1000k - ¥1000K in Total Prize, Product Idea Contest for the University of Tokyo Students |."

(5) i.school

i.school is an educational program for students to learn innovative idea creation, focusing on “human-centric innovation.”⁵⁶ i.school was established in 2009 by the University of Tokyo Center for Knowledge Structuring. It hosts 20 workshops and several symposiums annually with students and sponsoring companies. i.school also connects students, corporate sponsors, and institutes around the world to be an innovation hub.

(6) The University of Tokyo Edge Capital

The University of Tokyo Edge Capital(UTEC) is a VC firm which invests in seed/early stage startups focusing on, but not exclusive to technologies from the University of Tokyo.⁵⁷ Since its foundation in 2004, UTEC has raised 30 billion JPY in total for its three venture funds, and UTEC has invested in approximately 70 startups. Within 70, nine companies went public and eight were successfully purchased.

(7) Innovation Platform for The University of Tokyo

Innovation Platform for The University of Tokyo(UTokyo IPC) is a VC firm established in 2016 by the University of Tokyo under Public-Private Innovation Partnership program of the Japanese government.⁵⁸ UTokyo IPC manages a VC fund that provides capital to other venture funds as “fund of funds,” to promote commercialization of technology developed at the University of Tokyo. The 1st IPC fund raises 25 billion JPY from the University of Tokyo(23 billion JPY) and commercial banks.

3.4. Public policies around MIT

(1) NSF Innovation Corps

National Science Foundation (NSF) Innovation Corps (I-Corps) is a program of federal government to broaden the impact of basic-research projects by preparing scientists and

⁵⁶ i.school, “The University of Tokyo I.school – New Educational Program in the University of Tokyo ‘i.school.’”

⁵⁷ The University of Tokyo Edge Capital, “The University of Tokyo Edge Capital-UTEC-.”

⁵⁸ Innovation Platform for The University of Tokyo, “Innovation Platform for The University of Tokyo.”

engineers to focus beyond the laboratory.⁵⁹ Leveraging experience and guidance from established entrepreneurs and a targeted curriculum, I-Corps help researchers to identify promising product opportunities from NSF-supported research. NSF awards 50,000 USD to researchers to try commercialization of their technologies. Also, NSF supports forming of sites for entrepreneurial activity as I-Corp Site.

(2) Small Business Innovation Research and Small Technology Transfer Research

Small Business Innovation Research(SBIR) and Small Technology Transfer Research(STTR) are programs of Small Business Administration(SBA) that help high-growth small business community with access to two things: financial capital and R&D funds to develop commercially viable innovations.⁶⁰ In SBIR scheme, funds for R&Ds is allocated to small enterprises that are obtained by a certain percentage of total R&D budget of 11 federal agencies. STTR is also a research funding program for small enterprises, but it requires the enterprise to have a partnership with a research institute.

(3) Massachusetts Technology Collaborative

Massachusetts Technology Collaborative (Mass Technology) is a public agency to support economy across Massachusetts; (1) fostering the growth of dynamic, innovative businesses and industry clusters in the Commonwealth, accelerating the creation and expansion of firms in technology-growth sectors (2) accelerating technology use and adoption, helping ensure statewide connectivity and promoting competitiveness, and (3) harnessing the value of research by supporting and funding research initiatives, and encouraging greater collaboration with industry to help bring ideas to market.⁶¹ There are research funding, educational programs, and research carried out by Mass Technology.

⁵⁹ National Science Foundation, “News - Special Reports: I-Corps - About I-Corps | NSF - National Science Foundation.”

⁶⁰ the United States Government, “About | SBIR.gov.”

⁶¹ Massachusetts Technology Collaborative, “Meet MassTech.”

3.5. Players from private sectors for innovation and entrepreneurship around MIT

(1) Cambridge Innovation Center

Cambridge Innovation Center(CIC) is an office for startups whose mission is to change the world through building innovation ecosystems.⁶² CIC was founded in 1999 in Kendall Square, and it is now serving 1,400 client companies. Companies originally headquartered at CIC have raised 2.7 billion USD in venture capital and strategic investment since 2001. Also, CIC companies have generated more than 40,000 jobs in the economy.

(2) MassChallenge

MassChallgen is an entrepreneur-friendly acceleration program that provides workspace, mentoring, and non-dilutive awards for startups. The award in MassChallenge Boston was \$1.5M in total in 2016.⁶³ MassChallenge is founded in 2010 and organizes acceleration event annually. Through 6 years presence, 1,211 alumni have graduated the program, and the alumni have raised over 1.8 billion USD, generated over 700 million USD annual revenue, and created over 60,000 jobs. MassChallenge is founded in Boston and has expanded to Israel, Mexico, Switzerland, and UK since 2015.

3.6. Innovation and Entrepreneurship programs in MIT

(1) MIT Innovation Initiative

MIT Innovation Initiative, started in 2015, collaborates with all five schools at MIT to foster entrepreneurship and innovation related activity of the institute.⁶⁴ The initiative serves as a connector across the student groups, program, and campus centers. Also, it supports innovation and entrepreneurship programs of the university to reach more students and to create new programs. For example, the innovation initiative launched Project Manus, that built a system for access to maker spaces spread in MIT.⁶⁵ The initiative also built an online catalog of Innovation and Entrepreneurship resource to navigate students to find the best fit program.

⁶² Cambridge Innovation Center, "Homepage."

⁶³ MassChallenge, "Impact Report 2016."

⁶⁴ MIT Innovation Initiative, "Home."

⁶⁵ Massachusetts Institute of Technology, "Home | MIT Project Manus."

(2) Martin Trust Center for MIT Entrepreneurship

Martin Trust Center accommodates entrepreneurship activity by providing a working place for entrepreneurs, entrepreneurial education programs, events, and other resources.⁶⁶ The center was founded in 1990 and has served all MIT students across all schools. The center runs programs including MIT delta v and MIT fuse that are acceleration program for startups. There are series of entrepreneurial events such as t=0 and other speaker series.

(3) MIT Sandbox Innovation Fund Program

MIT Sandbox Innovation Fund Program provides seed funding of up to 25,000 USD for student-initiated ideas, mentoring from within MIT and from a broad network of committed partners, and tailored educational experiences.⁶⁷ Sandbox started in 2016, and it secured two million USD/year for funding. Sandbox is accessible to all MIT graduate and undergraduate students, that provides not only money but also educational program and mentorship.

(4) MIT The Engine

The Engine is a new initiative announced in October 2016 that aims to build innovation ecosystem by supporting startups around MIT.⁶⁸ There are two programs announced as of April 2017, Engine room and Engine Accelerator Fund. Engine room is an online marketplace that provides easy access to equipment, space, and services at MIT. Companies selected to MIT Engine program can access to those resources. The Engine Accelerator Fund mainly invests in hard-technology sectors such as biotech, medical devices, manufacturing, clean energy, robotics, IoT, and software that takes significant time and resource. The Engine also provide co-working and private offices, expertise, and community activity to the selected startups.

(5) Deshpande Center

The Deshpande Center helps MIT faculty and students commercialize breakthrough technologies and inventions by transforming promising ideas at MIT into innovative products and cutting-edge spinout companies.⁶⁹ There are two types of grants, Ignition Grants and

⁶⁶ Massachusetts Institute of Technology, “The Martin Trust Center for MIT Entrepreneurship.”

⁶⁷ Massachusetts Institute of Technology, “MIT Sandbox.”

⁶⁸ Massachusetts Institute of Technology, “The Engine.”

⁶⁹ Deshpande Center for Technological Innovation, “MIT Deshpande Center | For Technological Innovation.”

Innovation Grants, that both are open to MIT faculty and students. Ignition Grants is a grant up to 50,000 USD, and Innovation Grant is up to 250,000 USD. The center has reviewed more than 600 grant proposal, funded more than 125 projects that are totaling more than 15 million USD, produced 32 spinout companies.

(6) MIT \$100K

MIT \$100K is a series of three entrepreneurship competitions that is organized by MIT students. The competitions support students and researchers from across MIT and Greater Boston Area to launch their business.⁷⁰ MIT \$100K provides mentorship, media exposure, prototyping funds, business plan feedback, and more than 300,000 USD non-dilutive awards in total to help these new ventures. There are three contests, Pitch, Accelerate, and Launch. For winners, Pitch awards 3,000 USD, Accelerate awards 10,000 USD, and Launch awards 100,000 USD.

(7) MIT Legatum Center

Legatum Center supports entrepreneurs, by a fellowship program and a seed grants.⁷¹ The fellowship program awards selected students that can be used for their tuition and stipend. Students in their graduating year can access up to 60,000 USD, and other students can access up to 30,000 USD. The seed grant supports students to explore innovation-driven entrepreneurship opportunities in the developing world. The seed grants fund travel to locations throughout the developing world so students may learn about the local business context, conduct primary market research and pilot prototypes.

(8) Courses related to entrepreneurship

According to Martin Trust Center for MIT Entrepreneurship, in the 2015-2016 academic year, there were more than 60 entrepreneurship courses offered through MIT.⁷² The courses can be searched using web site of Martin Trust Center. MIT also has over 40 student clubs and initiatives involved in entrepreneurship or innovation.

⁷⁰ MIT \$100K, “MIT \$100K.”

⁷¹ The Legatum Center for Entrepreneurship & Development, “The Legatum Center at MIT - Home.”

⁷² Martin Trust Center for MIT Entrepreneurship, “Annual Report 2016.”

4. Literature Review

In this section, a literature review is carried out to figure out current understanding of innovation ecosystem and entrepreneurship, to frame issues in the system. Also, research related to a growth of startups and relations between university and startups are reviewed. Finally, data and research for Japanese culture related innovation and entrepreneurship are reviewed.

4.1. Innovation System and Public Policy

As a model for innovation system, Etzkowits proposes Triple Helix, in which overlap of three spheres, academia sphere, state sphere, and industry sphere, takes vital role to produce innovation.⁷³ In this model, academia, government, and industry can generate knowledge by utilizing the overlapping institutes, and Etzkowits analyzes that conventional policies were based on a model in which government directs industry and academia or a model in which government, academia, and industry collaborate with strong border. This research argues innovation system with a macroscopic view, but it is without discussing granular breakdown of the three spheres. here is another research investigates elements of innovation ecosystems. Elements of the innovation ecosystem in both Silicon Valley and Japan are analyzed to understand how Japan can improve the system.⁷⁴ After the analysis, the research recommends to build institutional foundation to drive economic growth that includes (1) financial system for risk capitals, (2) high quality and diverse human resources with high mobility, (3) interaction between industry, university and government, (4) industrial organization, (5) social system that encourages entrepreneurship, and (6) professionals who assists startups. This research has shown a breakdown of the innovation ecosystem and policy recommendations, however, relationships between elements are not well explained quantitatively. Another perspective of research is a role of universities in the society. For example, economic impacts by universities to a region are investigated and it is shown that number of universities has positive relation with GDP growth in the region.⁷⁵ In this research, mechanism of the economic impact is not well investigated in the research, but it suggests innovation and human capital supply may have influence on GDP growth.

⁷³ Etzkowitz and Leydesdorff, "The Dynamics of Innovation."

⁷⁴ Dasher et al., "Institutional Foundations for Innovation-Based Economic Growth."

⁷⁵ Valero and Reenen, "The Economic Impact of Universities."

Public policies for entrepreneurship is also argued for existing research because new business and economic growth in a country can be stimulated by fostering entrepreneurship. O'Connor provides perspectives to policymakers for entrepreneurship education policies to maximize impact to economy, such as (1) focus on economic utility of entrepreneurs, (2) design entrepreneurship education to introduce knowledge, achieve economic development, or productivity, (3) connect new ideas, technology, and new application of knowledge, (4) achieve sustainable business creation⁷⁶ The propositions are focused on an economic growth of the region and policy, but the discussions are not based on data. Another research argues people's motivation to become entrepreneurs, and the research warns how it is difficult to evaluate effects of entrepreneurship policy of government.⁷⁷ The research also suggests some failure modes for public policy implementation in public health field and other fields, but there is no direct evidence of inefficiency of entrepreneurship policy.

4.2. Capital Market

Risk capital can take a major role in innovation ecosystem which finance startups, because investment of startups can be used for marketing, R&Ds, and covering other costs, especially for startups in early stage. Beside, IPO in capital market and M&A by large companies can be paths for entrepreneurs and investors to get reward from the startups.⁷⁸ It is discussed in a research how venture capital works for capital market, how exit is important for venture capital firms, investors, and entrepreneurs, and how capital is reinvested.⁷⁹ In this research, control structure of startups by capital market is also discussed, and it compares market in the US with other developed countries including Japan. It is argued that most of major Japanese VC firms were affiliated with a bank or insurance company, and those VC firms rarely invested in high-tech companies. There is another investigation for effect of IPOs for various type of venture capitals, and it argues that maturity of IPO market in the country influences especially late stage venture capitals.⁸⁰ This research also argues that government-funded venture capitals are less sensitive to IPOs.

⁷⁶ O'Connor, "A Conceptual Framework for Entrepreneurship Education Policy."

⁷⁷ Acs et al., "Public Policy to Promote Entrepreneurship."

⁷⁸ Roberts, Murray, and Kim, "Entrepreneurship and Innovation at MIT."

⁷⁹ Black and Gilson, "Venture Capital and the Structure of Capital Markets."

⁸⁰ Jeng and Wells, "The Determinants of Venture Capital Funding."

On the other hand, Japanese government points out M&A in the Japanese market is limited compared with the US and it is important to facilitate M&A to establish innovation ecosystem.⁸¹ Figure 1 shows structures of exit of VC-backed companies in both Japan and the US from the report of METI. Clearly, M&A is the major means for exit for startups in the USA, but it's not in Japan.

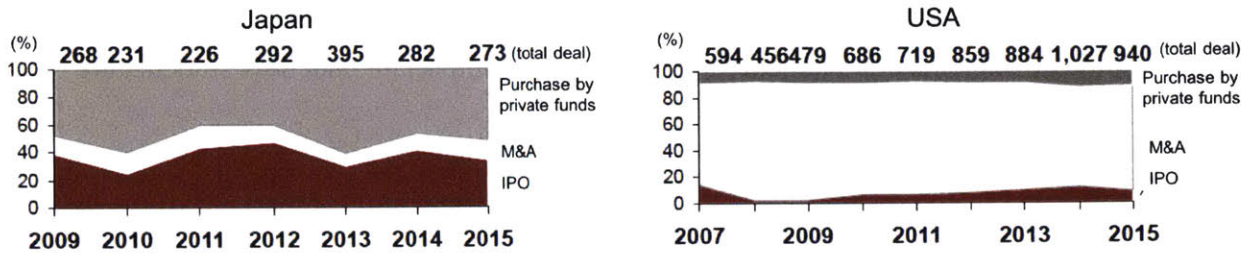


Figure 1 Number of exists of VC backed startups in Japan and the US⁸²

4.3. Growth of Startups

Growth patterns and growth factors of startups are crucial for innovation ecosystem, because risky but impactful business are developed usually by startups. There is a research investigates that how entrepreneurship education affects students' intentions to become entrepreneurs both positively and negatively. The study found entrepreneurship education can be useful for students to figure out how themselves fit entrepreneurial jobs, that will result in better career choice for them. The research also suggests entrepreneurship education doesn't dramatically increase entrepreneurial activities, but may contribute to quality of startups.⁸³ There is another research for an impact of entrepreneurship education on 64 graduate students in the UK that investigated how entrepreneurship education in college after they finish the program. After graduation, annual telephone surveys were carried out, and it found out entrepreneurship education had a positive impact for their business. For example, companies owned by the graduates showed a relatively rapid growth compared to average companies. Even though the samples are limited and contents of entrepreneurship education are not defined, the research quantitatively showed entrepreneurship education may have a positive effect on performance on a student in ten-years time scale.⁸⁴ In a different study, influence of entrepreneurship education

⁸¹ Ministry of Economy, Trade and Industry, "About Innovation and Startup Policies."

⁸² Ibid.

⁸³ von Graevenitz, Harhoff, and Weber, "The Effects of Entrepreneurship Education."

⁸⁴ Matlay, "The Impact of Entrepreneurship Education on Entrepreneurial Outcomes."

program on 275 French students in master's program in management degree was investigated. There was no significant effect for short term, but there were significantly positive impact on their attitudes in medium term (around 6 months). In addition, effect of initial level of entrepreneurial intention and experience changes intensity of the positive impact, that students with limited experience had larger impact from the entrepreneurship education program. This research provides quantitative discussion for impact of entrepreneurship education. Samples are limited to graduate students in management, but it provides important data how students are influenced by entrepreneurship education in long term.⁸⁵

Those research discuss effects of entrepreneurship education on performance of startups, but growth process of entrepreneurs is also important. Brixy divided entrepreneurial process into four stages, latent entrepreneurship, latent nascent entrepreneurship, nascent entrepreneurship, and young entrepreneurship, then investigated what kind of selection or discrimination exists for each stage.⁸⁶ For example, the research points out latent entrepreneurs are particularly young in age compared to entrepreneurs in other stages. As an important part of an entrepreneurial process, many researchers suggest opportunity identification and development. Ardichvili argues Entrepreneurs identify business opportunity to create and deliver value for stake holders for startups, and the research identifies five unites for opportunity identification and development (1) entrepreneurial alertness; (2) information asymmetry and prior knowledge; (3) discovery versus purposeful search; (4) social networks; (5) personality traits, including risk-taking, optimism and self-efficacy, and creativity.⁸⁷ Tang points out that entrepreneurs' alertness to understand nascent activities and to identify opportunities is an important factor to launch startups.⁸⁸ The research proposes that there are three dimensions for alertness; (1) systematically or non-systematically scan the environment and search information; (2) associate or piece together previously unconnected information; and (3) make evaluations and judgments about the possibility for commercialization of the idea. A survey was carried out and it was confirmed that those three dimensions have a positive relationship with innovation.

⁸⁵ Fayolle and Gailly, "The Impact of Entrepreneurship Education on Entrepreneurial Attitudes and Intention."

⁸⁶ Brixy, Sternberg, and Stüber, "The Selectiveness of the Entrepreneurial Process."

⁸⁷ Ardichvili, Cardozo, and Ray, "A Theory of Entrepreneurial Opportunity Identification and Development."

⁸⁸ Tang, Kacmar, and Busenitz, "Entrepreneurial Alertness in the Pursuit of New Opportunities."

Phases of the Entrepreneurial Process (GEM, Global Entrepreneurship Monitor)

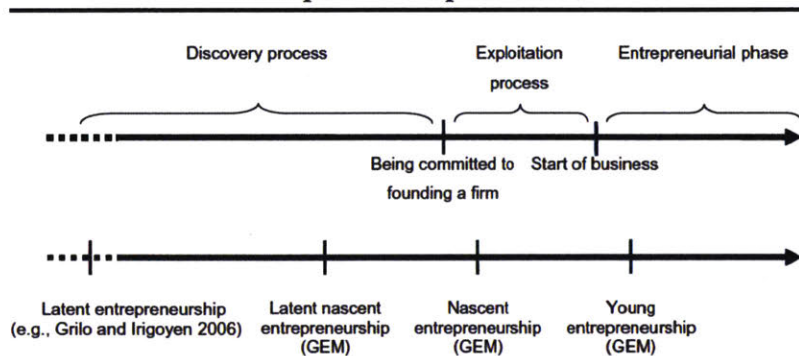


Figure 2 Four entrepreneurial stages and corresponding entrepreneurial processes⁸⁹

4.4. Academia Spinoff Startups

When we model an innovation ecosystem around an university, spinoff startups from universities, includes startups founded by faculty members, researchers, current students, and recent graduates, can be a major stakeholder. For spinoff startups that directly use academic knowledge, several paths to bring academic research to market are identified in a research; (1) Partnership between faculty and experienced entrepreneur(23%), (2) Partnership between Faculty and PhD student/Posdoc(41%), (3) Partnership among Faculty, PhD/Posdoc, and Business school student(13%), and (4) PhD/Posdoc and business school student(23%).⁹⁰ The research concludes that it is important to align objective of stakeholders in university, leverage entrepreneurial resources in university, and encourage graduate students to choose career option to work for technology commercialization. As for influence of academic background and personal traits of entrepreneurs to performance of their startups are investigated in another research, and the result shows that academic degree in technology major and higher social capital are important factors for performance of startups.⁹¹ Higher social capital in this context means the entrepreneurs keep more contact with former colleague, maintain business relations, or jointly own their company with others. Another research reveals that startups founded by recent graduates of universities outnumbers startups founded by faculty, not only in number but also in possibility per person to found startup, hence, capability of university to found startups would be

⁸⁹ Brixy, Sternberg, and Stüber, “The Selectiveness of the Entrepreneurial Process.”

⁹⁰ Böh, De-Haan, and Strom, “University Technology Transfer through Entrepreneurship.”

⁹¹ Nielsen, “Human Capital and New Venture Performance.”

underestimated if a research focuses only on spin-out founded by faculty.⁹² In other words, recent graduates take major role in founding spinoff startups. Those research also suggest startups tend to have higher quality when the startups are founded by science and technology major graduate and when the businesses are related to their major. Entrepreneurship education is not necessary for recent graduate, but the education can affect students interests to be an entrepreneurs.

On the other hand, universities can also support small and medium enterprises by research collaborations. There is a research shows that research collaboration with universities benefits small firms for R&D, that results in increase in number of patent applications.⁹³ In addition, small firms with more local ties receive more knowledge spill overs. The research shows how small firms can benefit from collaborations with universities, but it is not clear in this research whether young companies can also benefit by the collaboration for their growth.

4.5. Entrepreneurship and business cultures related to innovation in Japan

There are several surveys about entrepreneurship and business cultures related to innovation. Global Entrepreneurship Monitor carries out annual surveys for entrepreneurial activity around the world.⁹⁴ In 2014 report, Japan had lowest score(3.83) for Early Stage entrepreneurial activity among 29 innovation driven countries. The average score was 8.54, and United States scored 13.81. The score of Japan for a question "Entrepreneurship as a good career choice" was also quite low(30.98) in average score of 55.07, and United States scored 64.73. This report clearly indicates low entrepreneurial activity in Japan by quantitative data and comparison with other countries. On the other hand, Japanese government carries out surveys to understand obstacles for innovation. METI carried out research for R&D investment in private sector in 2015FY, that is outsources to Institute for Future Engineering.⁹⁵ Figure 3 shows a result from the survey and it is a ratio of styles of R&D activities of Japanese companies. About 70% of R&Ds are carried out only within companies or affiliated group, and R&D collaborations with

⁹² Åstebro, Bazzazian, and Braguinsky, "Startups by Recent University Graduates and Their Faculty."

⁹³ Fukugawa, "University Spillovers into Small Technology-Based Firms."

⁹⁴ Slavica Singer, Jos. Ernesto Amor.s, Daniel Moska Arreola and Global Entrepreneurship Research Association (GERA), "GEM Global Entrepreneurship Monitor."

⁹⁵ Institute for Future Engineering, "Industrial Economy Research Program 2015 (Survey for R&D Investment in Private Sector)."

external organizations, especially with startups are less than 1.5% including both domestic or oversea startups.

Table 1 Ratio of R&D collaborations⁹⁶

Within own company (no collaboration)	62.2 %
With affiliated company	8.3 %
With other Japanese company from same industry	3.4 %
With other Japanese company in same value chain	5.3 %
With other Japanese company from different industry	4.2 %
With Japanese university	7.8%
With Japanese startups	0.8 %
With foreign university	0.9 %
With foreign company	1.5 %
With foreign startups	0.4 %

This closed culture of Japanese companies can result in barriers for startups to grow if startups cannot acquire customers easily. Venture Enterprise Center investigated needs for startups, and the result shows that acquisition of sales channel is the largest problem for startups, as shown in Figure 3 and 4.⁹⁷ It is prominent for expansion stage startups, but it is less important for a later stage, as illustrated in Figure 4. Definition of stages in this survey is shown in Table 2. This survey result suggests that development of sales channel is the largest barrier to be a later stage startup.

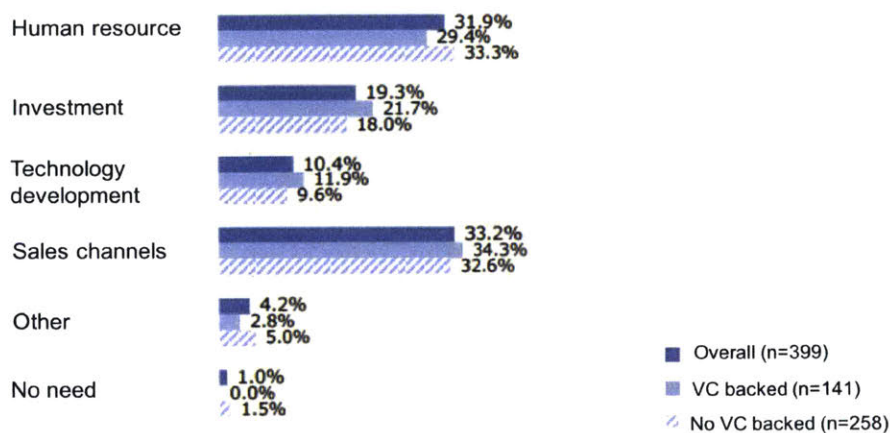


Figure 3 Current or near term needs for startups(for all stages)⁹⁸ Labels are translated from Japanese.

⁹⁶ Ibid.

⁹⁷ Venture Enterprise Center, “Venture White Paper 2016.”

⁹⁸ Ibid.

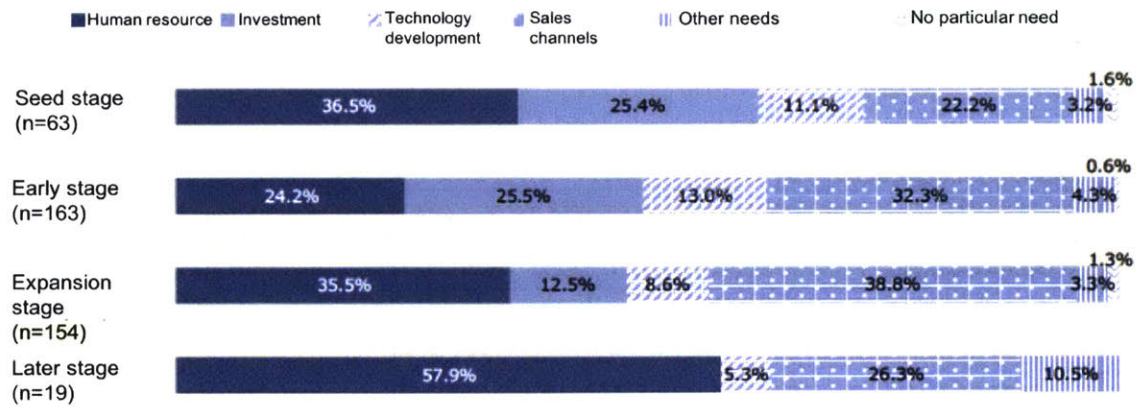


Figure 4 Current or near term needs for startups by stages⁹⁹ Labels are translated from Japanese

⁹⁹ Ibid.

Table 2 Definitions of stages in survey by Venture Enterprise Center

Stage	Definition
Seed	Startups that are not doing business and focusing on technology and product development
Early	Startups that are doing product development, early marketing, early manufacturing, and early sales.
Expansion	Startups started manufacturing and shipping. Inventory and sales are growing.
Later	Startups with sustainable cash flow, and it is close to exit.

Also, trends in the job market can influence notion of students to be an entrepreneur. Japan has a low job mobility and a high long-term unemployment rate, that is shown by Cabinet Office’s Annual report for economy and finance, as shown in Figure 5.¹⁰⁰ The vertical axis shows rate of long term unemployment and horizontal axis shows average years of working for one company, and the figure shows higher long term unemployment rate and longer average year of working in Japan compared to the US, that means it is more riskier and not acceptable to quit work and start new business.

¹⁰⁰ Cabinet Office, “Annual Economy and Financial Report, 2011.”

Mobility and risk for long-term unemployment

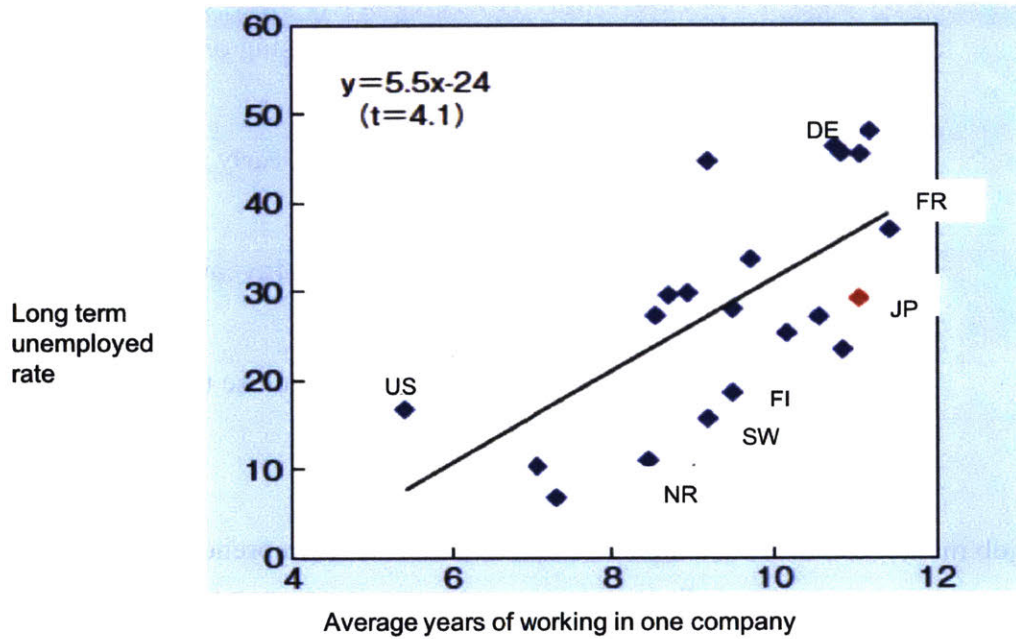


Figure 5 Mobility and risk for long-term unemployment.¹⁰¹ Labels are translated from Japanese

Small Business Administration of Ministry of Economy, Trade and Industry publishes a white paper on small and medium enterprises annually, and the white paper showed that ratio of new company in Japan is lower than that in other developed countries as shown in Figure 6.¹⁰²

¹⁰¹ Ibid.

¹⁰² Small Business Administration, Ministry of Economy, Trade and Industry, “2014 White Paper on Small and Medium Enterprises in Japan.”

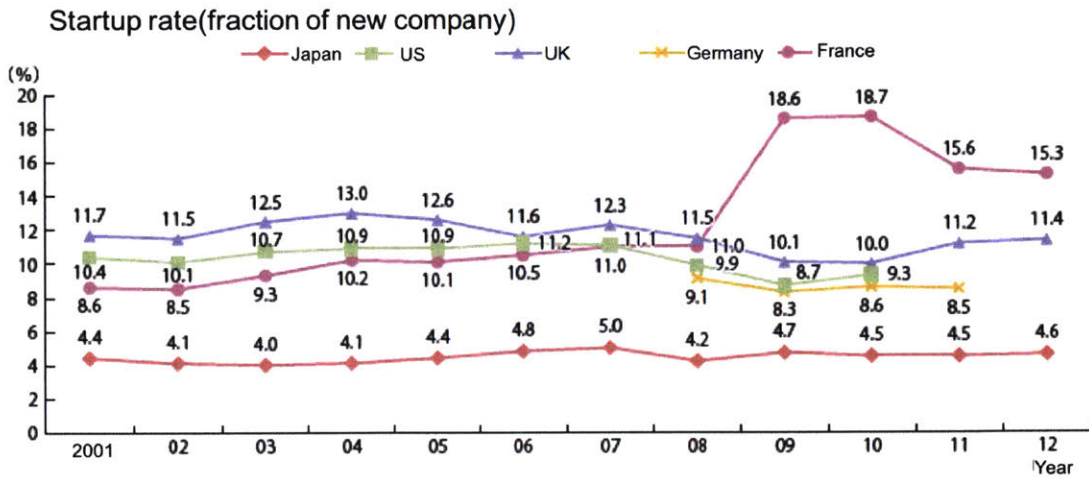


Figure 6 Startup rate of Japan, US, UK, Germany and France.¹⁰³ Labels are translated from Japanese

¹⁰³ Ibid.

5. Framing of the problem

In section 3 and 4, current innovation policies, players, and literature are reviewed to frame the research. Specific problems and hypotheses which this research approaches are discussed in this section, regarding finding from the reviews. At first, hypotheses for innovation ecosystem around the University of Tokyo are proposed. Next, major stakeholders and their relationships in innovation ecosystem are analyzed to illustrate the ecosystem. Third, the system boundary and structure of innovation ecosystem are discussed, to have a holistic view. Finally, causal loops of the system are illustrated to be bases of system dynamics modeling.

5.1. Hypotheses for the policy lever to improve the Innovation Ecosystem around the University of Tokyo

Hypotheses to be verified under a set of assumptions are discussed here, to approach the research questions stated in section 2. At first, the most important hypothesis is related to the foundation of startups in the ecosystem. As shown in section 4, the fraction of new companies that are entrepreneurial activities is low in Japan.¹⁰⁴ That fraction may be related to the social status of entrepreneurs, which is low in Japan as shown in the Global Entrepreneurship Monitor.¹⁰⁵ Countries which have higher startup rates give higher social status to entrepreneurs, hence, there can be a reinforcing feedback that impacts innovation ecosystem. This first hypothesis (H1) is formally stated as:

H1: There is a reinforcing feedback loop in innovation ecosystem that higher social status for entrepreneurs promotes foundations of startups results in more successful entrepreneurs.

Many researchers investigate influences of entrepreneurship education on the success rate of entrepreneurs. However, mechanism of how entrepreneurship education affects successes of startups is not discussed well, and surprisingly we could not find research on how entrepreneurship education influences the innovation ecosystem. One might guess that entrepreneurship education programs can result in more startups generated, faster growth of startups, faster product development, customer acquisition, or other results. It is important to

¹⁰⁴ Ibid.

¹⁰⁵ Acs et al., *Global Entrepreneurship Monitor*.

distinguish those effects of entrepreneurship education, to understand innovation ecosystem around universities and to consider policy levers. Therefore, the second hypothesis (H2) is formally stated as:

H2-1: Entrepreneurship education in universities can be designed to introduce entrepreneurial career, help product development, or increase meaningful interaction between startups and potential customers.

H2-2: However, influences of entrepreneurship education to the innovation ecosystem are different by the design of entrepreneurship education.

Some literature we reviewed suggest behavior of the large companies, such as M&A of startups, hiring pattern, and collaboration of startup are different from other developed countries, and it influences entrepreneurs. Therefore, the next hypothesis (H3) asserts that the behaviors of large companies can be a key of the dynamics of innovation ecosystem, in three specific areas

H3: Behavior of large companies for (1) purchasing startup product, (2) investing & acquiring startups, and (3) hiring pattern affect dynamism of the ecosystem, that changes establishment and growth of startups.

The validities of those hypotheses are discussed, especially under what condition those hypotheses can be true or not.

5.2. Analysis of stakeholders and elements of the system

Table 3 is a list of stakeholders in the innovation ecosystem, as an initial list which includes stakeholders outside the model or not directly related to hypotheses.

Table 3 Initial list of stakeholders in innovation ecosystem around the University of Tokyo

Stakeholder	Role
MEXT	MEXT promotes entrepreneurship education in universities.
METI	METI supports entrepreneurs and startups through educational programs and awards startups to improve the social status of entrepreneurs.
MIC	MIC funds research in ICT fields that have potential to be startups.
JST	JST funds research which has potential to be startups, invests in startups, and awards startups.
NEDO	NEDO helps startups by funding and awards startups.
Tokyo Metropolitan Government	Tokyo Metropolitan Government subsidies startups and incubation centers.
Students	Students participate in entrepreneurship education and found startups.
Researchers	Researchers, including postdocs and faculty, participate in entrepreneurship education and found startups.
Entrepreneurial resources in university	Entrepreneurial resources in university, including entrepreneurship education program, technology transfer office, and mentors, facilitate students and researchers to start a business. Entrepreneurial resources in universities can also help startups to grow.
Startups	Startups, founded by students and researchers, receive investment from risk capitals, collaborate with large companies, and grow by acquiring customers. Also, some of the startups are acquired by large companies or go public, that result in a better capital gain of investors.
Large companies	Large companies purchase products of startups, acquire startups, provides risk capitals, and hire graduates.
Venture capital firms	Venture capital firms raises money to form venture capital funds and manages funds through investment in startups
Angel investors	Angel investors provide money to startups and take equity. They also help startups providing advice and connections.
Accelerators	Accelerators support startups by providing funds and connect them with potential customers.
Employees of startups	Employees join startups after the startups are launched by students or researchers.
Consumers	Consumers purchase products of startups that make cash flow.
Media	Media influences students' and researchers' notion of starting a business.

The table shows stakeholders of the ecosystem, but some of the stakeholders can be divided into sub-categories for our purpose to verify the hypotheses. For example, students can be divided into “entrepreneurial” students who are interested in starting business and “non-entrepreneurial”

students who want to be employed by large and stable companies. Also, non-entrepreneurial students don't want to take a risk starting their own business. In addition, startups can be divided according to their phase of growth. The first category is startups which haven't acquired a customer, that equivalent to seed, early, and middle stage startups in Venture Enterprise Center's definition.¹⁰⁶ The second is for startups which have acquired customers and have stable positive cash flow, that is later stage startups in Venture Enterprise Center's definition. Table 4 shows those sub-categories of stakeholders.

For "systems" view, we need to recognize not only stakeholders but also variables that are important to analyze the system. For example, an amount of risk capital in the market takes an important role to support startups, because sufficient investment in startups can help them grow. Another example of important variables is interactions between startups and large companies which increase a possibility of acquisition of customers for startups and M&A of startups by large companies. Therefore, for analysis of the system, we list those variable as well as stakeholders as elements of the innovation system, as shown in Table 5.

¹⁰⁶ Venture Enterprise Center, "Venture White Paper 2016."

Table 4 Sub-categories of stakeholders

Sub category	Role
Non-entrepreneurial students	Non-entrepreneurial students become entrepreneurial students, influenced by entrepreneurship education.
Entrepreneurial students	Entrepreneurial students start business.
Non-entrepreneurial researchers	Non-entrepreneurial researchers become entrepreneurial researchers, influenced by entrepreneurship education.
Entrepreneurial researchers	Entrepreneurial students start business.
Earlier stage startups	Earlier stage startups, including seed, early, and middle stage startups, are founded by students and researchers. Those startups receive investment from risk capitals, collaborate with large companies, and grow by acquiring customers to be late stage startups.
Later stage startups	Later stage startups receive investment from risk capitals and collaborate with large companies. Also, some of the later stage startups are acquired by large companies or go public, that result in a capital gain of investors.

Table 5 Important variables in the system

Variables	Role
Social status of entrepreneurs	Influence students' and researchers' notion of starting a business. Higher social status of entrepreneurs more students and researchers to be entrepreneurial.
Risk capital in the market	Risk capital in the market

5.3. System boundary of the innovation system and relationships between elements

Based on stakeholder analysis, we illustrate innovation ecosystem this research focus on, as shown in Figure 7. The stakeholders outside the system boundary are not directly related to the hypotheses proposed prior in this section, and further analyses focus on dynamics inside the system boundary. Also, relations among MEXT, METI, JST, NEDO, and Tokyo Metropolitan Government are not related to the validations of the hypotheses. Therefore, they can be regarded as one entity as National and regional governments.

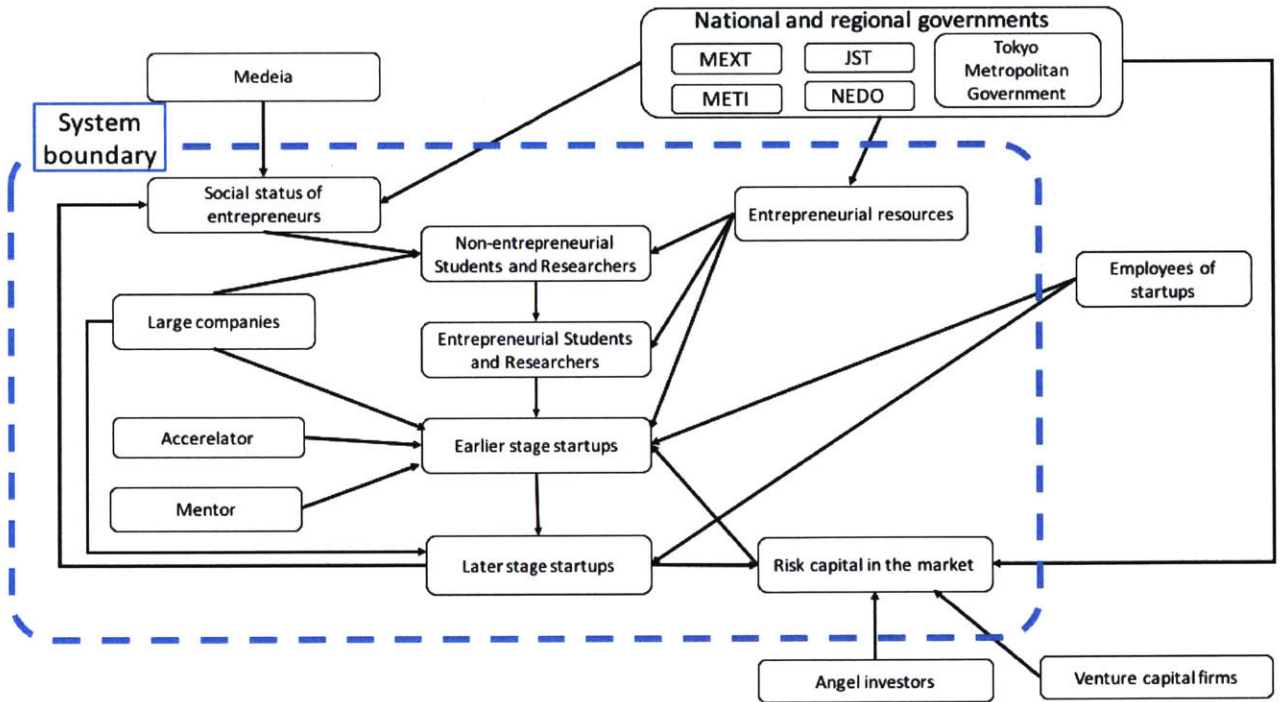


Figure 7 Boundary of System on focus

Relationships between stakeholders are summarized in Table 5. In the right column, related hypotheses to the relationship are stated. From this analysis, some of the stakeholders and relationships are less important to discuss in this research. The first is relationships among national and regional government entities, as discussed above. Second, employees of startups are not directly related to the hypotheses. Therefore, they are placed outside the system boundary. Third, media and governments impact the ecosystem through the social status of entrepreneurs, and those influences can be represented by the valuable Social status of entrepreneurs, for a simplification. Fourth, investment from national and regional government, angel investors, and venture capital firms can be simplified to Risk capital in the market when we only take financial support from venture capital firms and angel investors into account.

Table 6 Relationships between stakeholders

From	To	Relationship	Related hypotheses
Media	Social status of entrepreneurs	Media can improve the social status of entrepreneurs by covering success story of entrepreneurs.	
National and regional government	Social status of entrepreneurs	National governments can improve the social status of entrepreneurs by honoring and giving prizes startups.	
National and regional government	Entrepreneurial resources	National and regional government can support entrepreneurship educations and subsidize students to start a business.	H2
National and regional government	Risk capital in the market	National and regional government both directly and indirectly provide risk capitals. For example, MEXT's and JST's funds invest in startups.	
Social status of entrepreneurs	Non-entrepreneurial Students and researchers	Higher social status of entrepreneurs facilitates non-entrepreneurial students and researchers to become entrepreneurial.	H1
Large companies	Non-entrepreneurial Students and researchers	Hiring behavior of large companies influences students' notion to become entrepreneurial. Longer-term employment, fewer students become entrepreneurs.	H3
Large companies	Earlier stage startups	Large companies can be customers and collaborators of earlier stage startups that can contribute to the growth of the startups. Large companies also purchase later stage startups.	H3
Large companies	Later stage startups	Large companies purchase later stage startups.	H3
Accelerator	Earlier stage startups	Accelerators provide connections with potential customers to earlier stage startups and help them acquire customers.	H3
Mentor	Earlier stage startups	Mentors provide connections with potential customers to earlier stage startups.	H3
Mentor	Later stage startups	Mentors support later stage startups.	H3
Non-entrepreneurial students and researchers	Entrepreneurial students and researchers	Non-entrepreneurial students and researchers become entrepreneurial students and researchers.	H1, H2, H3
Entrepreneurial students and researchers	Earlier stage startups	Entrepreneurial students and researchers found earlier stage startups	H1, H2, H3
Earlier stage startups	Later stage startups	Earlier stage startups grow into later stage startups.	H1, H2, H3

Later stage startups	Risk capital in the market	Later stage startups indirectly increase risk capitals in the market through successful IPO and M&As, which give positive capital gain to investors.	H1, H2, H3
Later stage startups	Social status of entrepreneurs	Later stage startups improve the social status of entrepreneurs by showing entrepreneurs can create value to customers.	H1, H3
Entrepreneurial resources	Non-entrepreneurial students and researchers	Entrepreneurial resources provide entrepreneurial perspectives to non-entrepreneurial students, that make hem entrepreneurial students and researchers.	H1, H2
Entrepreneurial resources	Entrepreneurial students and researchers	Entrepreneurial resources help entrepreneurial students and researchers to establish earlier stage startups.	H2
Entrepreneurial resources	Earlier stage startups	Entrepreneurial resources help earlier stage startups to grow.	H2
Employees of startups	Earlier stage startups	Employees of startups are fired by earlier stage startups	
Employees of startups	Later stage startups	Employees of startups are fired by later stage startups	
Risk capital in the market	Earlier stage startups	Risk capitals in the market are invested in earlier stage startups and help their growth.	H1, H2, H3
Angel investors	Risk capital in the market	Angel investors provide risk capitals.	
Venture capital firms	Risk capital in the market	Venture capital firms provide risk capitals.	

5.4. Basic Causal Loops of the System

Here we discuss causal loop structures of innovation ecosystem around a university that can be interpreted from Figure 7 and Table 6. Those causal loops can be structural elements of system dynamics model built in next chapter.

(1) Entrepreneur boom

The social status of entrepreneurs influences students' and researchers' motivation to start a business. Successes of startups can improve the social status in a university when startups from the university grow, and students and researchers can see it. Therefore, improvement of the social status increases entrepreneurial students and researchers, that result in more startups founded. And more startups establishments lead to more success of startups, which consists reinforcing loop, as shown in Figure 8. Increasing number of successful startups increases social

status that leads to more startups established again. In this reinforcing loop, there are exogenous variables controls this reinforcing loop, such as expectation for a stable job, opportunity to start a business, and growth rate of startups. In Japan, a concept of lifetime employment prevails that result in higher expectation for a stable job compared to in the United States. Those exogenous variables decide how this reinforcing loop drives. For example, if expectation for a stable job is strong, it inhibits the loop to increase entrepreneurial students and researchers.

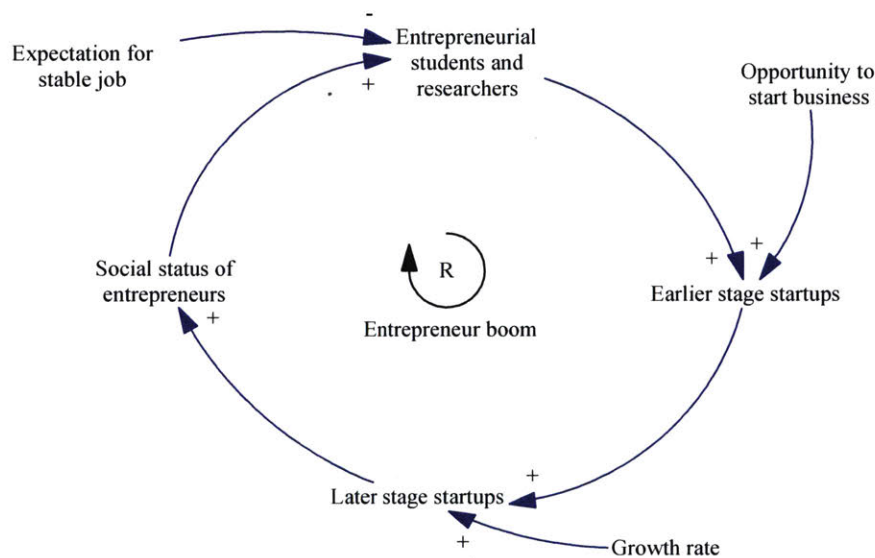


Figure 8 Entrepreneur boom loop

(2) Reinvestment

Another structure is a reinvestment of capitals. A product development needs capital for many startups, and investment from risk capital can promote the development for growth. Growths of startups result in successful exits of capital that give better capital gain to investors. If investors satisfied with the return of the venture investment, most of them reinvest their money into risk capital market or other investors also invest in the venture business. This process composes reinforcing feedback loop as in Figure 9, as shown in *Reinvestment* loop. On the other hand, there is a balancing feedback loop for over investment, which prevents investors from invest in startups unlimitedly. It is shown as *Excess investment* loop in Figure 9. If the

investment is more than necessary for startups to develop a product, it just hurts capital gain of investors, that will prevent investors from reinvesting larger amount of capital.

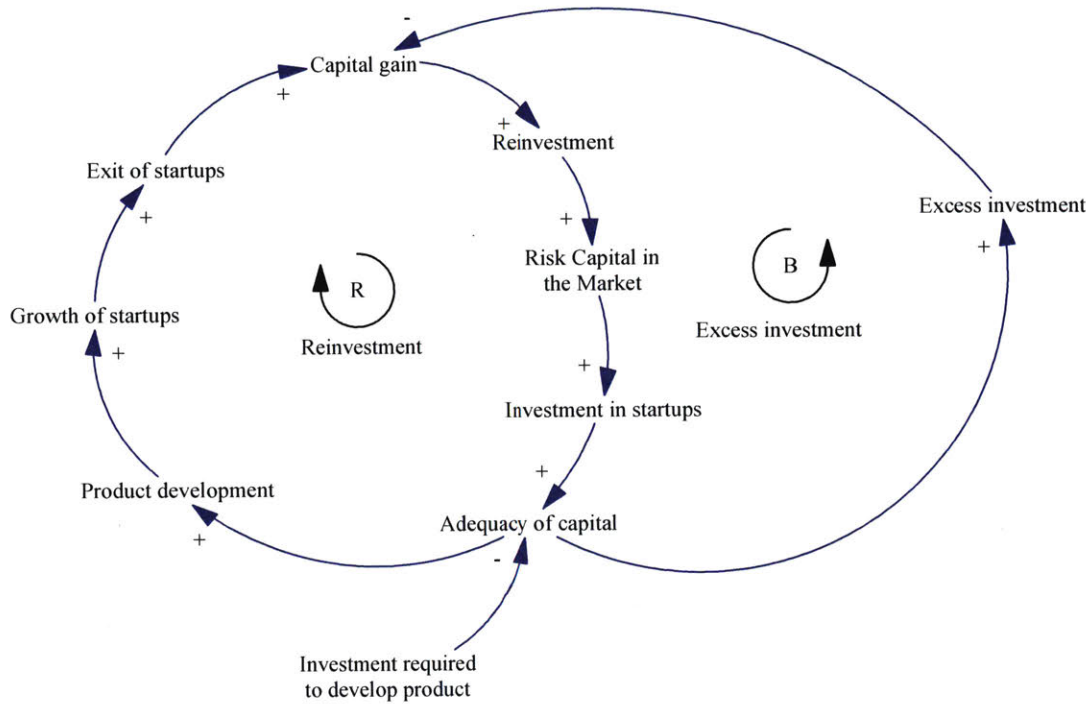


Figure 9 Reinvestment loop and excess investment loop

(3) Accessibility to startups

How students and researchers are exposed to startups and entrepreneurs also influences attitude toward starting their own business. For example, if students have a lot of opportunities to work for startups as an internship, they feel familiar to start a business by themselves in future, and the students know how to start one by themselves. This structure consists a reinforcing loop that promotes students and researchers to become entrepreneurs, that is shown in Figure 10.

More startups around a university increase opportunities to interact with startups for students and researchers. Those interactions make students and researchers more entrepreneurial and increase chances to start a business, then more startups formed from the university.

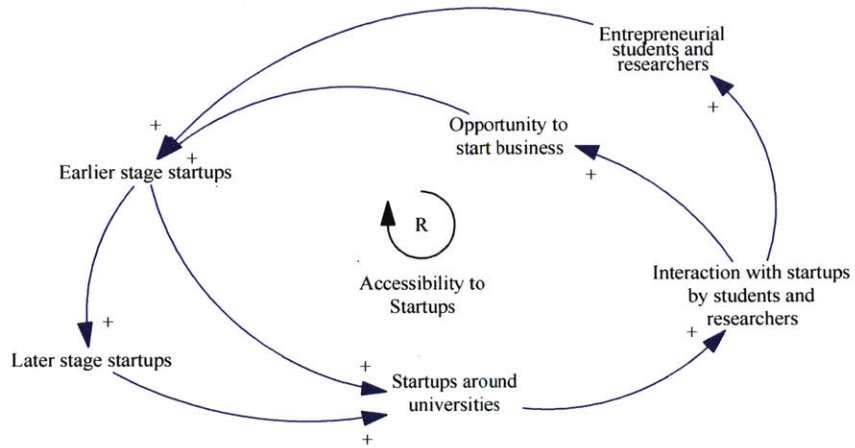


Figure 10 Accessibility to startups loop

6. System Dynamics Modeling

Regarding analyses in the previous sections, we build system dynamics models in this section, to discuss the hypotheses we proposed in section 5. At first, assumptions for modeling are listed, then basic mathematical relations are discussed. Next, inputs and outputs are listed. The modeling is carried out using Vensim PLE for Macintosh version 6.4b.

6.1. Assumptions for Modeling

Assumptions for the model are listed as below.

- 1) The model takes an ecosystem around a single university into account. There is no interaction between universities.
- 2) Students and researchers, who enter a university, are either non-entrepreneurial or entrepreneurial. Non-entrepreneurial students and researchers are not interested in starting a business, therefore, no startup is founded if there are only non-entrepreneurial students and researchers. Entrepreneurial students and researchers look for opportunity and they found startups.
- 3) Non-entrepreneurial students and researchers can become entrepreneurial students and researchers. Probability to become entrepreneurial is decided by expectations for a stable job, the social status of entrepreneurs, and entrepreneurship education.
- 4) There are inflow and outflow of both types of students and researchers, and total students and researchers are constant.
- 5) The ratio of entrepreneurial students and researchers enroll in the university annually changes based on an expectation for a stable job and social status of entrepreneurs. If expectation for a stable job is higher, there are less entrepreneurial students and researchers enter to the university. If the social status is higher, there are more entrepreneurial students and researchers.

- 6) Startups founded by entrepreneurial students and researchers are initially earlier stage startups, then grow into later stage startups, under variable “growth rate.”
- 7) Both earlier stage startups and later stage startups liquidate at fixed rate.
- 8) Risk capital in the market represents the amount of money that can be invested in startups from the university. The risk capital in the market decrease when investment takes place and increase by reinvestment.
- 9) Annual risk capital invested in startups is proportional to the number of startups from the university and amount of risk capital in the market.
- 10) Risk capital invested in startups exits through IPO or M&A. Annual deals of M&As is influenced by large companies. Risk capital exits through IPO and M&A is reinvested to the capital market, and capital gain decides how much of capital is reinvested.
- 11) The growth rate of startups relies on sales capability of startups. Startups with sales capability acquire customers and become later stage after several months to few years.
- 12) Startups acquire sales capability by having a promising product and meaningful interactions with potential customers. Investments of risk capitals facilitate the product development. However, if the investment is more than a certain level, additional investment doesn't accelerate product development.
- 13) Meaningful interactions between startups and potential customers can be increased by accelerators, meet up events, mentors, and other factors. Also, a higher interest of large companies to startups increases meaningful interactions between startups and potential customers.
- 14) Entrepreneurship support resources, represented by entrepreneurship education in the model, can increase the meaningful interactions between startups and potential

customers, promote students and researchers to become entrepreneurial and reduce the time for product development.

6.2. Basic relations

(1) Students and researchers

Students and researchers can be represented as two stocks, Non-entrepreneurial students and researchers (A) and Entrepreneurial students and researchers (B), as shown in Figure 11. Non-entrepreneurial students and researchers are converted to entrepreneurial students and researchers with a rate of Entrepreneurship activation (C). The activation is determined by amount of Non-entrepreneurial students and researchers. Also, there are inflow and outflow of students and researchers annually, Non-entrepreneurial students and researchers entering (E), Non-entrepreneurial students and researchers graduating (F), Entrepreneurial students and researchers entering (G), and Entrepreneurial students and researchers graduating (H). A at time t , $A(t)$ can be represented as follows, using A at time zero $A(0)$.

$$A(t) = \int_0^t F - E - C dt + A(0)$$

Entrepreneurial students and researchers can be calculated in the same way

$$B(t) = \int_0^t G - H + C dt + B(0)$$

Non-entrepreneurial students and researcher entering (E) and Entrepreneurial students and researchers entering can be express as below, using Annual enrollment (J) that and Ratio of entrepreneurial students and researchers entering.

$$E = J \times (1 - I)$$

$$G = J \times I$$

Non-entrepreneurial students and researchers graduating (F) and Entrepreneurial students and researchers graduating (H) can be calculated from Non-entrepreneurial students and researchers (A), Entrepreneurial students and researchers (B), and average years of staying at university (K).

$$F = A/K$$

$$H = B/K$$

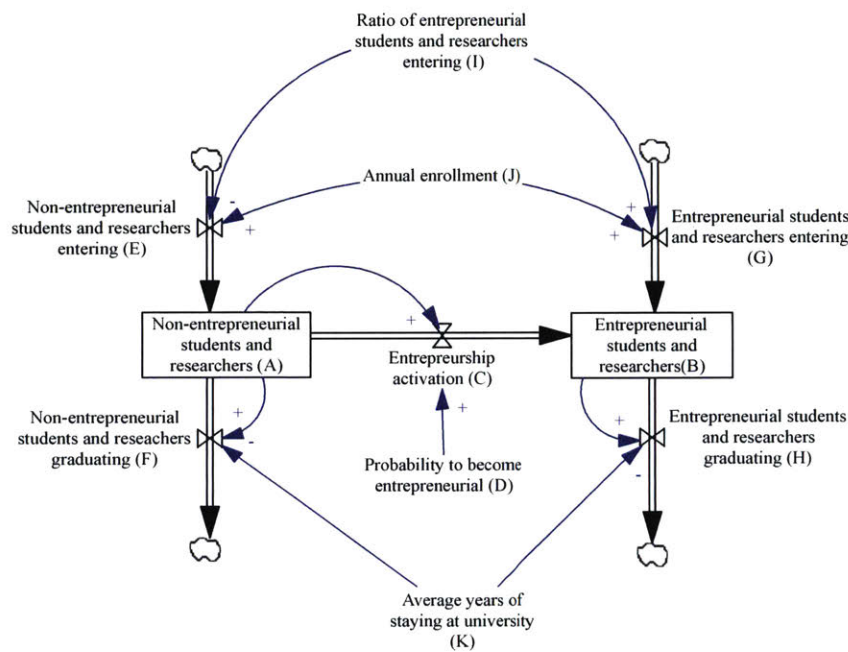


Figure 11 Students and researchers

(2) Foundation and growth of startups

Earlier stage startups (L) and Later stage startups (M) are also represented by stocks, and Earlier stage startups change into Later stage startups with Growth (N), as shown in Figure 12. Earlier stage startups increase with Registration (O), and decrease with Liquidation of earlier stage startups (Q). Later stage startups increase with Growth and decrease with Liquidation of later stage startups (Q).

$$L(t) = \int_0^t R - N - Q dt + L(0)$$

$$M(t) = \int_0^t N - R dt + M(0)$$

Registration can be calculated by Entrepreneurial students and researchers (B) and Opportunity to start a company (P).

$$O = B \times P$$

Rates of liquidation are products of startups and Annual liquidation rate (S).

$$Q = L \times S$$

$$R = M \times S$$

Growth rate (N) is a product of Earlier stage startups and Growth rate (T), that is a variable calculated by other factors.

$$N = L \times S$$

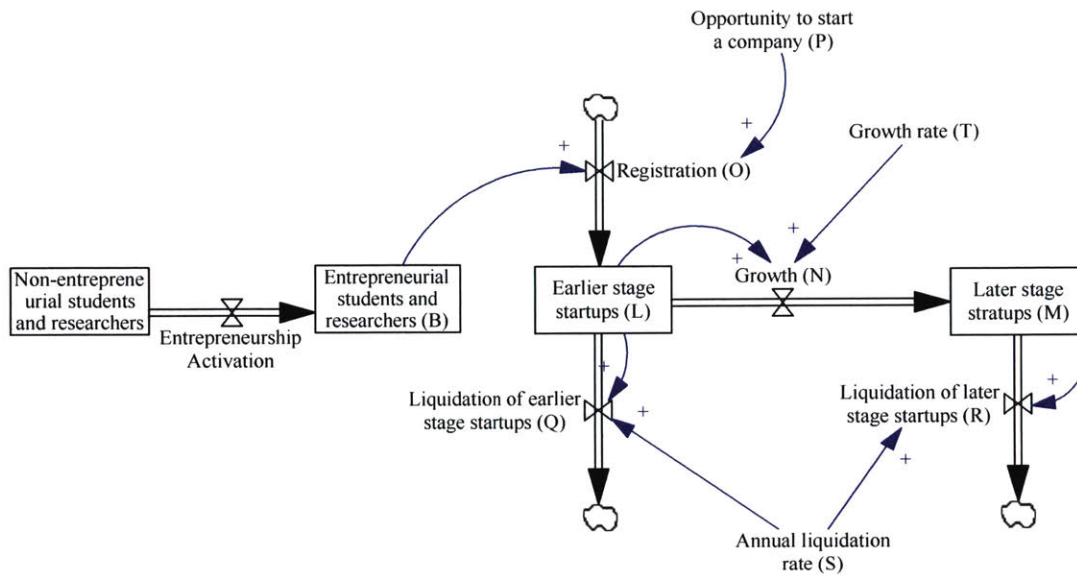


Figure 12 Growth of startups

(3) Capital market

Risk capital in the market (U) can be represented as a stock, and it flows into another stock Risk capital invested in startups (V) by Investment (W), as shown in Figure 13. Risk capital invested in startups decrease by Exit of Risk Capital (X). Also, Risk capital in the market changes with Change in risk capital (Y).

$$U(t) = \int_0^t W - Y dt + U(0)$$

$$V(t) = \int_0^t W - X dt + V(0)$$

Investment (W) is a product of Annual investment rate (a) and Total university spinoff startups (b).

$$W = a \times b$$

Exit of risk capital (X) is total of Risk capital exit through M&A (c) and Risk capital exit through IPO (d).

$$X = c + d$$

Risk capital exit through M&A (c) is a product of M&A deals (e) and Risk capital invested in startups (V) divided by Total university spinoff startups (b). V/b is equivalent to average investment to university spinoff startups.

$$c = e \times V/b$$

This is same for IPO. Risk capital exit through IPO (d) is calculated as following from Annual IPO of startups and Total university spinoff startups (b), and Annual IPO of startups (f).

$$d = f \times V/b$$

Annual IPO of university spinoff startups (g) is a product of Total university spinoff startups and Average IPO rate of startups (h), if the probability for a university spinoff startup to become public is same with other startups.

$$g = b \times h$$

Annual M&A deals of university spinoff startups (e) is product of Total university spinoff startups (b) and Average M&A rate of startups by large companies (h)

$$e = b \times h$$

If Average M&A rate of startups by large company (h) is influenced by interest of large companies to startups, it can be written using Standard M&A rate of startups by large companies.

$$h = i \times j$$

Finally, Change in risk capital is equivalent to Reinvestment as risk capital (Z) as we assumed prior, and Reinvestment as risk capital is a product of Exit of risk capital (X) and Capital gain(k)

$$Y = Z = X \times k$$

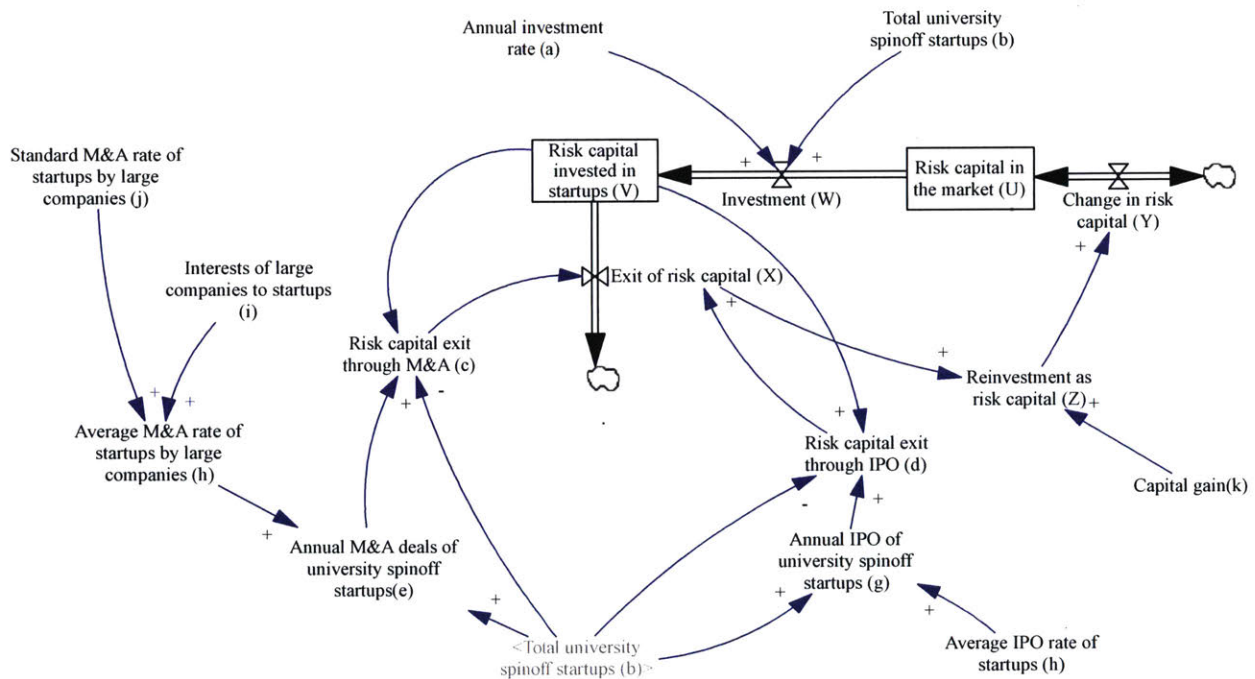


Figure 13 Capital market

(4) Growth rate of startups

As shown in Figure 12, earlier stage startups grow into later stage startups with Growth rate (T). Here growth rate is decomposed as shown in Figure 14. We assume that startups which have acquired sales capability turn into later stage startups after several months to few years, and the time period is represented as Time required to acquire customers to become later stage(l) in the figure. Therefore, Growth rate (T), the probability of earlier stage startups to become later

stage, is equal to Ratio of startups with sales capability (m) divided by Time required to acquired customers to become later stage (l).

$$T = m/l$$

Ratio of startups with sales capability (m) is decided by what ratio of startups with promising product took enough meaningful interactions with potential customers. Therefore, Ratio of startups with sales capability (m) can be formulated using Average interactions with customers to acquire sales capability (n), Meaningful interaction between startups and potential customers (o), and Ratio of startups with promising product (p).

$$m = p \times o/n$$

Meaningful interaction between startups and potential customers (o) can base on Average opportunity to meet potential customer, and how many of opportunities are “meaningful” can be decided by interests of large companies to startups (i), Entrepreneurship education(t), and Effect of entrepreneurship education on increasing meaningful interaction (s).

$$o = q \times i \times s \times t$$

Ratio of startups with promising product (p) is impacted by Capital adequacy (v), that represents whether sufficient funding is provided to finish product development in Average time for product development (u).

$$p = u \times v$$

Capital adequacy is decided by Investment per startups (z) and Investment required to complete product development in average time. However, it does not exceed 1, that means excess investments to startups more than adequate does not speed up product development.

$$v = z/y \quad \text{if } z/y \leq 1$$

$$v = 1 \quad \text{if } z/y > 1$$

Here investment per startups (z) is Risk capital investment in startups (V) divided by Total university spinoff startups (b).

$$z = V \times b$$

Average time for product development (u) bases on Standard time for product development (x) and reduced by Entrepreneurship education (t) and Effect of entrepreneurship education to reduce product development (w).

$$u = x / (t \times w)$$

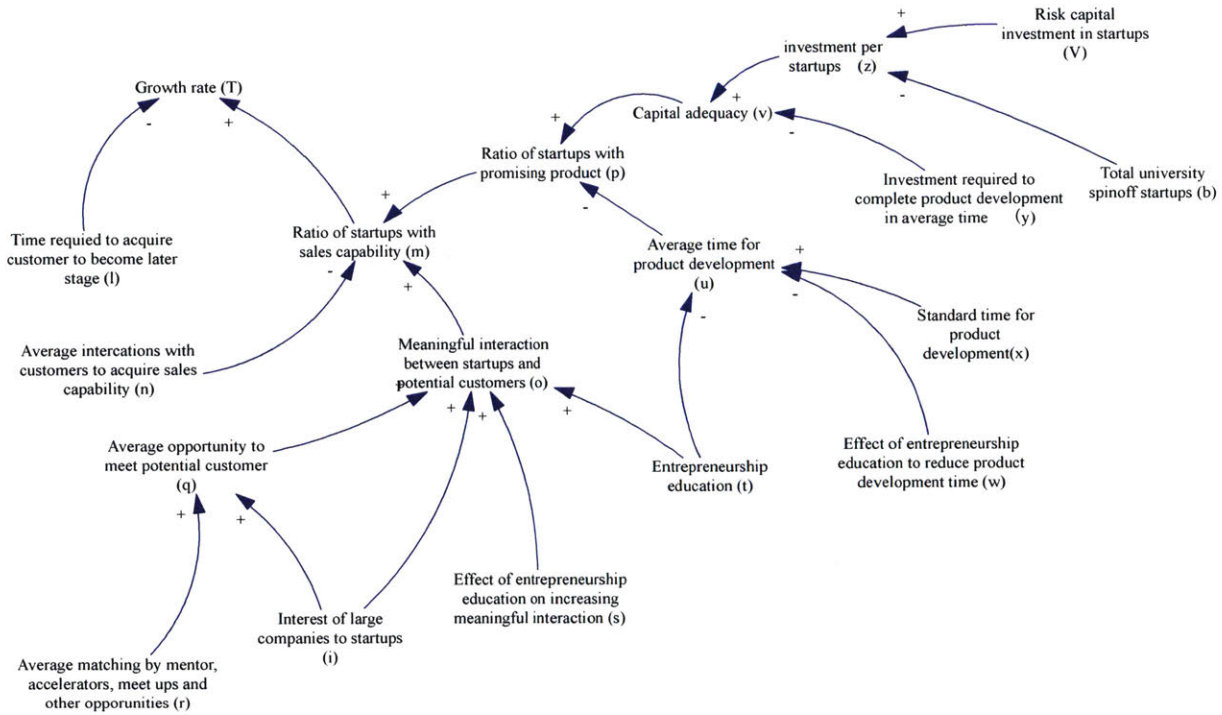


Figure 14 Growth rate

Based on those relations, a system dynamics model of innovation ecosystem around a university is built as shown in Figure 15 and Figure 16.

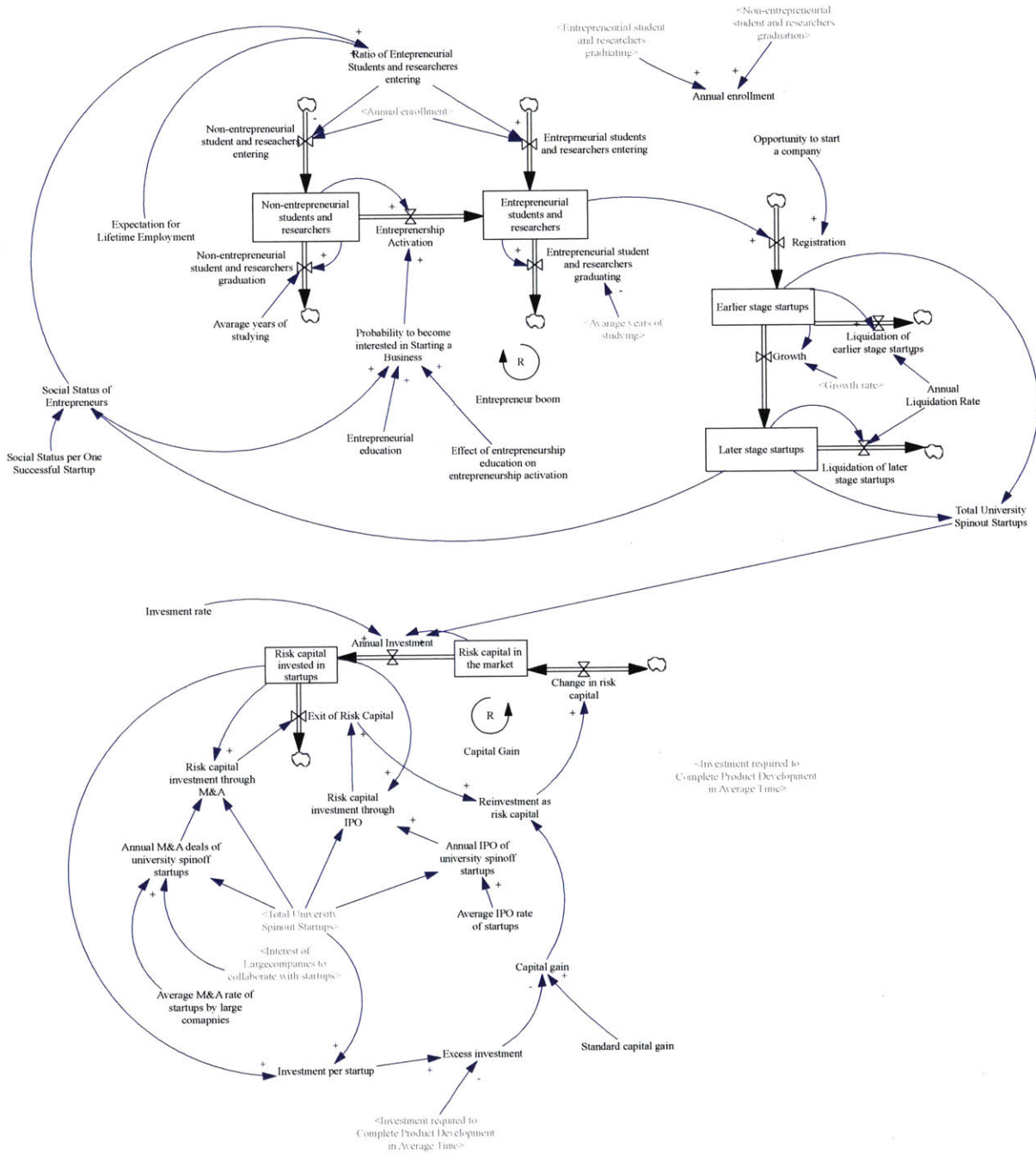


Figure 15 Initial modeling of the innovation ecosystem

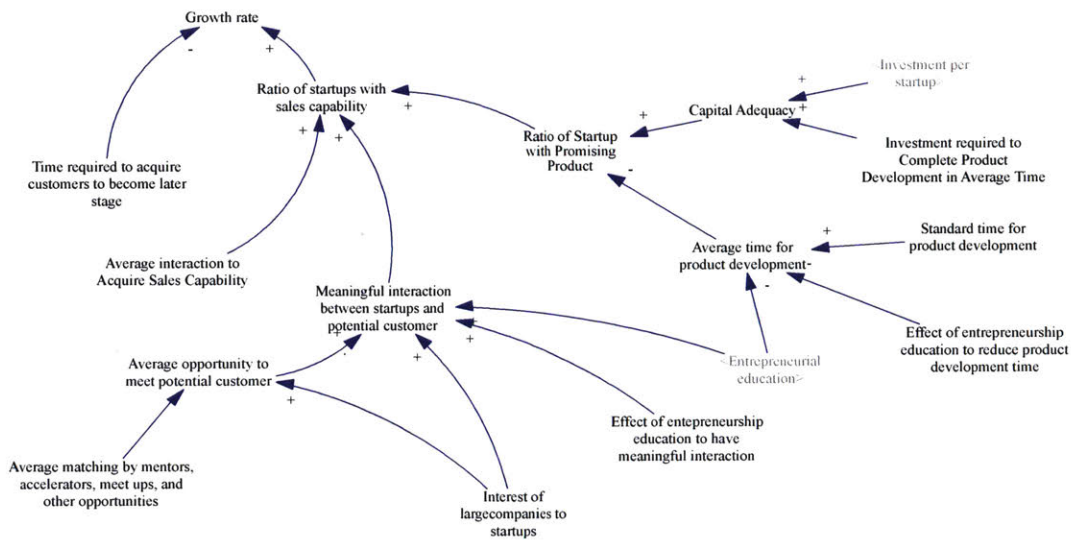


Figure 16 Another part of initial modeling of the innovation ecosystem

6.3. Inputs

Table 7 and Table 8 shows values of exogenous variables and the initial values of stocks for the initial run of the simulation. The simulation runs from year 0 to year 20, with 0.015625 time steps.

Table 7 Values of variables for initial run

Variable	Initial value	Unit
Average years of studying	5	Years
Effect of entrepreneurship education on entrepreneurship activation	0.7	Dimensionless
Entrepreneurial education	0.1	Dimensionless
Opportunity to start a company	0.05	Companies/People/Year
Expectation for lifetime employment	0.7	Dimensionless
Social status per successful Startup	0.001	Dimensionless
Annual liquidation rate	0.01	1/Year
Investment rate	0.0001	1/Year/Companies
Average M&A rate of startups by large companies	0.01	1/Year
Average IPO rate of startups	0.01	1/Year
Standard capital gain	1.2	Dimensionless
Time required to acquire customers to become later stage	1	Years
Average interaction to acquire sales capability	40	Meetings
Average matching by mentors, accelerators, meet ups, and other opportunities	100	Meetings
Interest of large companies to startups	0.5	Dimensionless
Effect of entrepreneurship education to have meaningful interaction	5	Dimensionless
Effect of entrepreneurship education to reduce product development time	5	Dimensionless
Standard time for product development	3	Years
Investment required to Complete Product Development in Average Time	4,000,000	Dollars/companies

Table 8 Initial values of stocks for initial run

Stocks	Initial value	Unit	Description
Entrepreneurial students and researchers	327	People	1% of faculty, researchers, and students affiliated with the University of Tokyo in May 2010
Non-entrepreneurial students and researchers	32327	People	99% of faculty, researchers, and students affiliated with the University of Tokyo in May 2010
Earlier stage startups	97	Companies	80% of total spinoff startups from the University of Tokyo in 2010
Later stage startups	24	Companies	20% of total spinoff startups from the University of Tokyo in 2010
Risk capital in the market	6,202,200,000	Dollars	37.8% of venture capital funds in Japan
Risk capital invested in startups	121,000,000	Dollars	Average \$1million investment per company

6.4. Outputs

Outputs from the initial run are shown in Figure 17 through 20.

(1) Students

Over the time period of the initial run, non-entrepreneurial students and researchers decrease, and entrepreneurial students and researchers increase. The accelerated increase of entrepreneurial students and researchers comes from reinforcing loop that is shown in Figure 8. However, non-entrepreneurial students and researchers keep dominating that keeps entrepreneurial students and researchers less than 12% of entire population of students and

researchers after 20 years. Even the reinforcing loop works to increase entrepreneurial students, increase of entrepreneurial students and researchers in 20 years is limited.

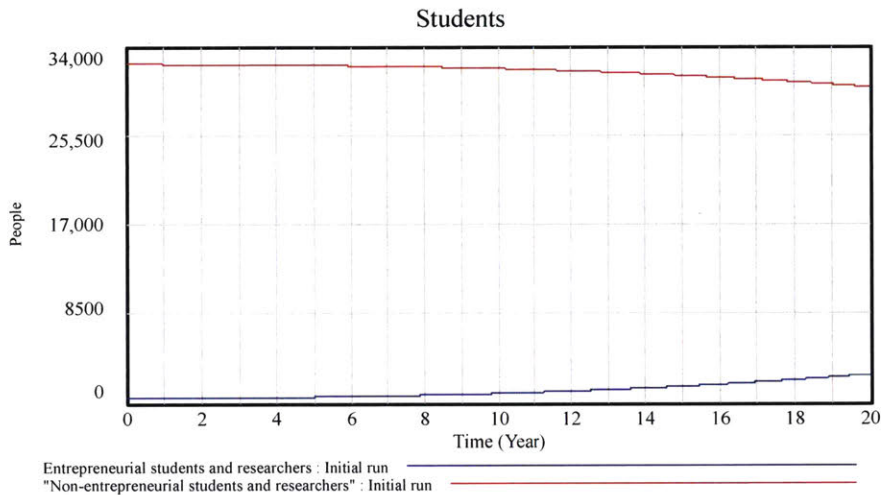


Figure 17 Entrepreneurial and non-entrepreneurial students in the initial run

(2) Startups

Both types of startups increase over time, and the earlier stage startups show steeper increase than later stage startups. The slope of the increases gets steeper over time. This is due to increase in entrepreneurial students and researchers.

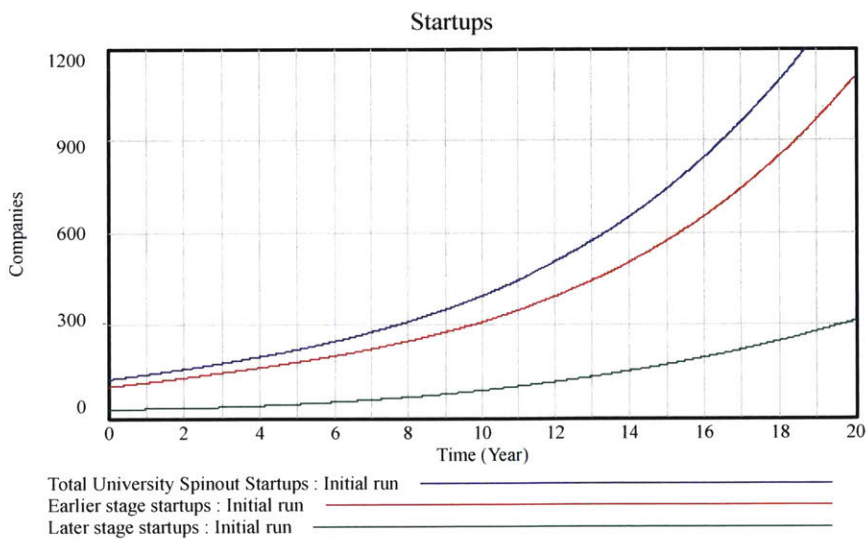


Figure 18 Earlier and later stage startups in the initial run

(3) Investments

Risk capital in the market decreases over time period of the run due to investment in startups, that gradient becomes steeper in later. The risk capital invested in startups increases according to the total number of startups shown in Figure 18. Investment per startups increase over time because of continuous investment, but it starts decreasing after year 13, caused by increasing number of startups.

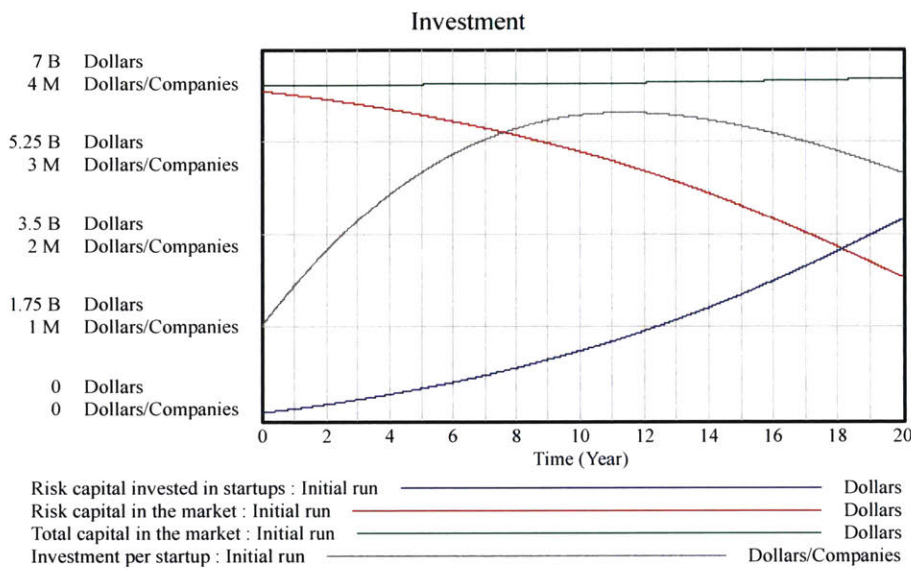


Figure 19 Investments in the initial run

(4) Social status of entrepreneurs and Growth rate

The social status grows over time, that is directly influenced by the increase in later stage startups, that results in a increase in entrepreneurial students and researchers. On the other hand, growth rate keeps low value, even a decreases after year 13. This is from decrease of the investment per startup that is shown in Figure 19. Lower investment per startups speeds down product developments of the startups.

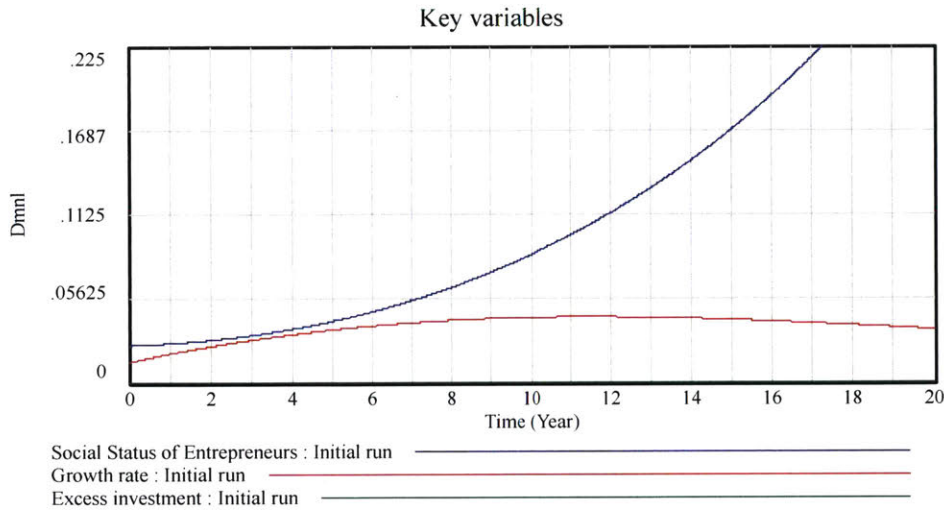


Figure 20 Behavior of the key variables in the initial run

6.5. Validation and improvement of the model

Results of the initial run can be compared to existing data. At first, total spinoff startups from the university can be compared with data from the University of Tokyo,¹⁰⁷ as shown in Table 9 and Figure 21. The value of total startups at year 0 is from the data so that we can observe the difference in growth between actual growth and simulation. Until year 3, the model shows good correspondence with the data. Although there is some difference in year 4, about 10% difference of startups, it can come from the setting of other variables, and the model seems to capture a general trend in generation of startups for the first few years.

Table 9 Total startups from data and the initial run

	Data from the University of Tokyo	Model initial run
2010 (year 0)	121	121
2011 (year 1)	141	140
2012 (year 2)	153	154
2013 (year 3)	177	174
2014 (year 4)	218	195

¹⁰⁷ The University of Tokyo Division of University Corporate Relations, "Introduction to The University of Tokyo Division of Univeristy Corporate Relations 2014."

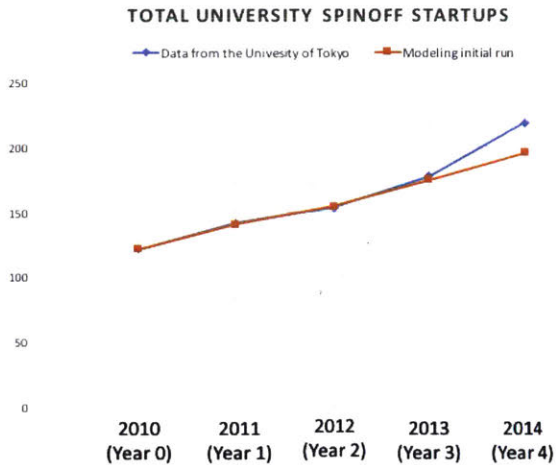


Figure 21 Total startups from data and the initial run

Another data is IPO of companies. Figure 22 shows total IPO deals of VC backed companies in the Japanese market, which includes both university spinoff and not spinoff startups. Figure 23 shows an output from the initial run of the model. The deals in the initial run are less than five for the first ten years because the model only takes spinoff startups from the University of Tokyo into account. Although available data is limited and long term trend cannot be compared, the increase in IPO deals in the initial run looks consistent with the data.

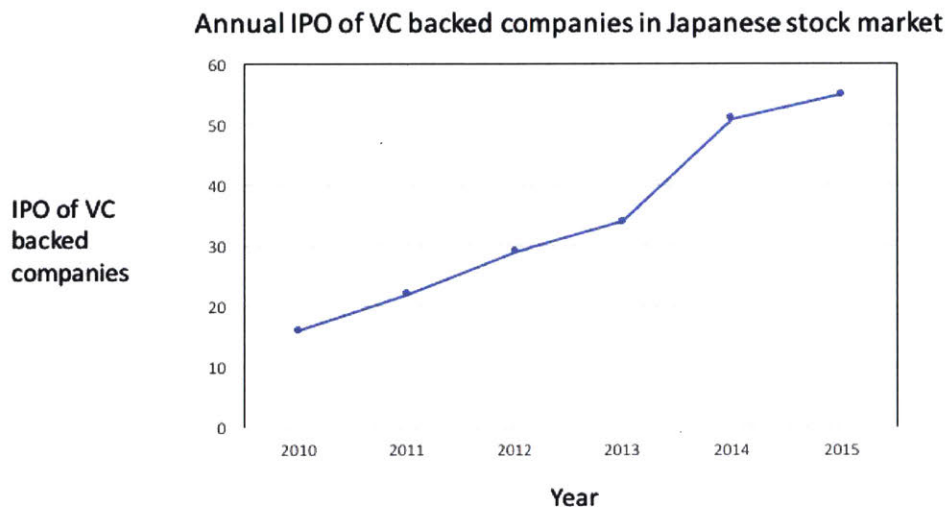


Figure 22 Annual IPO of VC backed companies in Japanese stock market

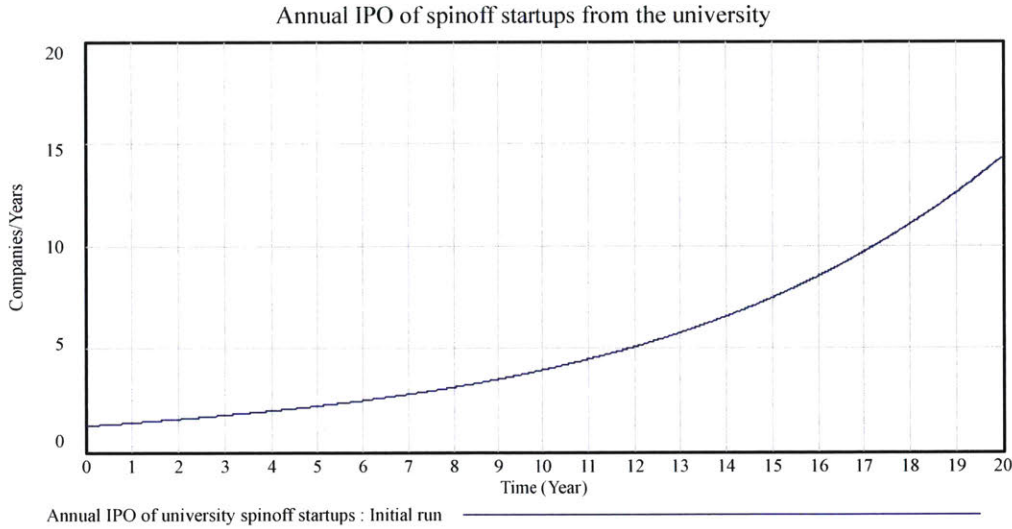


Figure 23 Annual IPO of university spinoff startups in the initial run

In addition, a trend of investments can be compared with available data. Figure 24 shows annual investments from Japanese VC and other investors to Japanese companies, including both university spinoffs and non-university spinoffs, that shows an increasing trend for this five years. The investment to spinoff startups from the University of Tokyo in the initial run is shown in Figure 25, that also shows a trend of increase. Values in Figure 24 and Figure 25 cannot be directly compared because Figure 24 shows investment in all types of startups in Japan, and Figure 25 is only for startups from the University of Tokyo, however, we can see there is no conflict in general trends for the first several years.

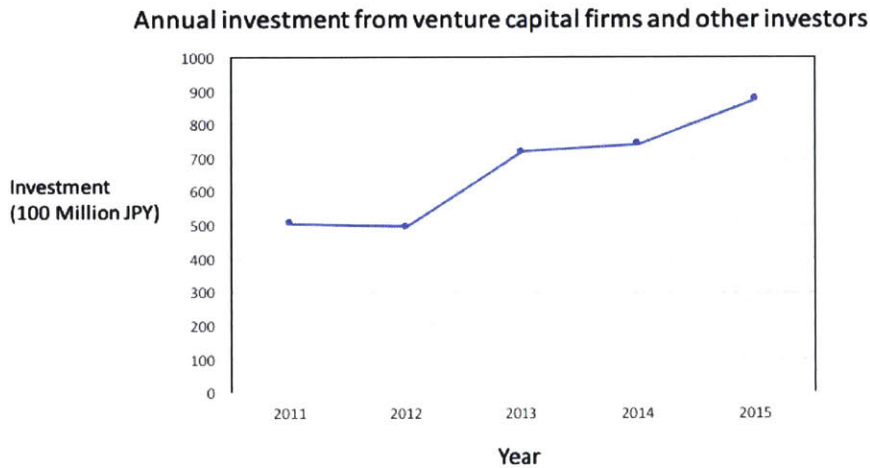


Figure 24 annual investment from venture capital firms and other investors to Japanese companies

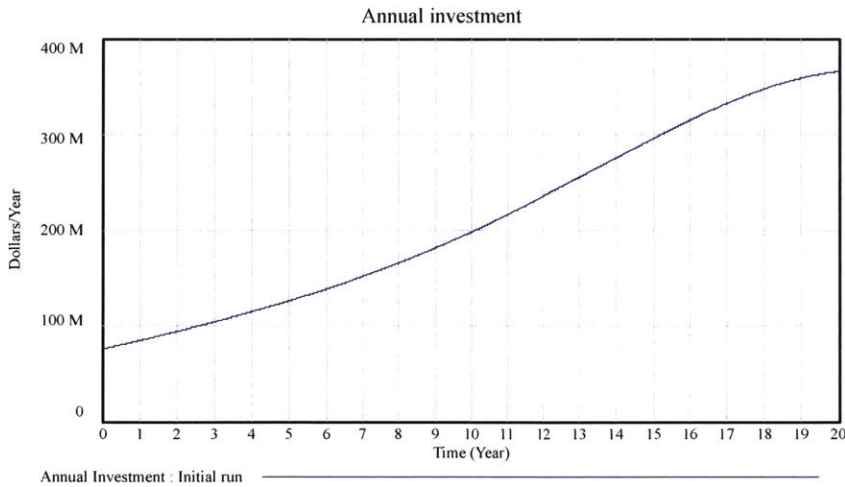


Figure 25 Annual investment from the initial run

From those comparisons in the numbers of spinoff startups, IPO, and amount of investments, no serious conflicts between available data and outputs from the initial run is observed, although we can compare only for the first several years. Therefore, we can use the model for the discussion for policy implementations. For further calibration of the model, we need to have at least five more years of data, with IPO of and investment in startups from the University of Tokyo.

The current model can only run simulations with constant inputs. The model assumes valuables, which are shown in Table 7, don't change over time, but it is better have changing valuables. For discussions for policy implementation, it is necessary to simulate model under changing valuables. Therefore, we added an "input generator" to the model as shown in Figure 26. This input generator can add step, ramp, and noise to variables. The equation of the input is written as follows

$$\text{Input} = 1 + \text{STEP}(\text{Step Height}, \text{Step Time}) + \text{RAMP}(\text{Ramp Slope}, \text{Ramp Start Time}, \text{Ramp End Time}) + \text{STEP}(1, \text{Noise Start Time}) * \text{RANDOM NORMAL}(-4, 4, 0, \text{Noise Standard Deviation}, \text{Noise Seed})$$

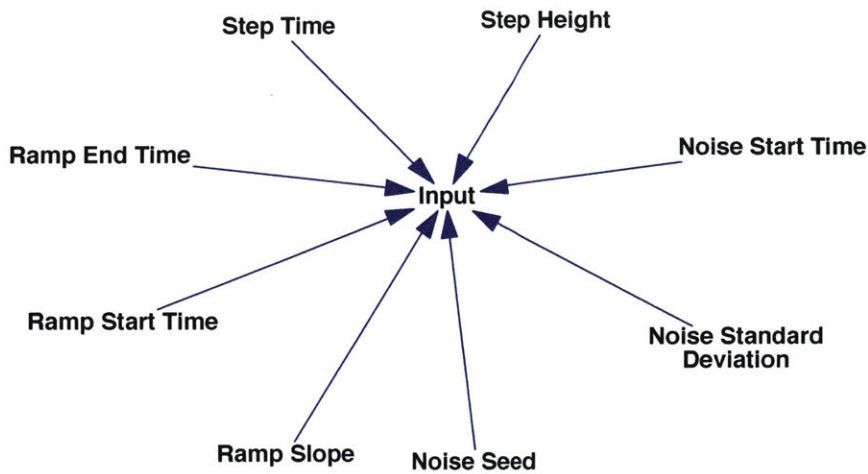


Figure 26 Input generator

We can change exogenous variables in Figure 26 to generate patterns. For example, three types of patterns are generated as shown in Figure 27.

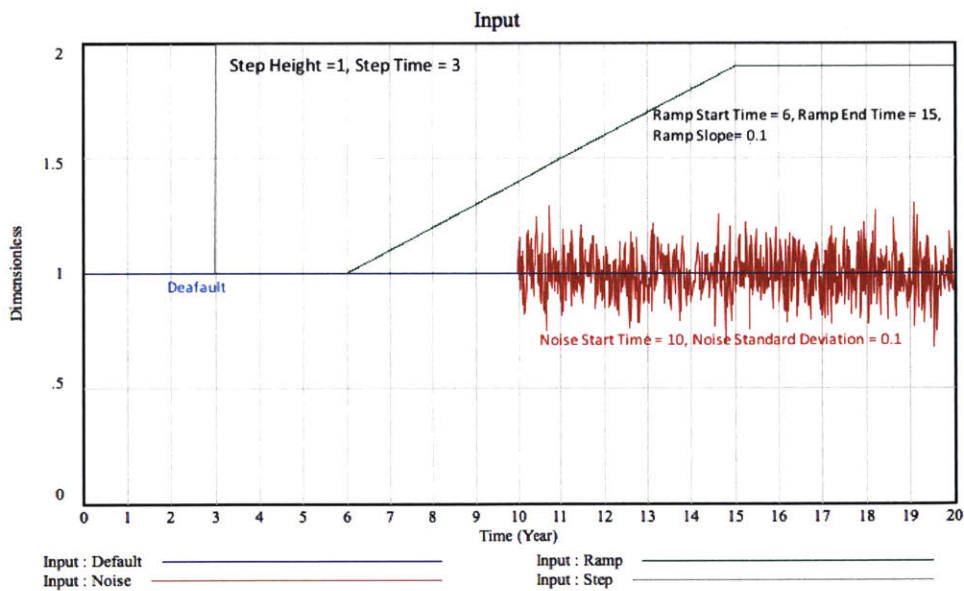


Figure 27 Three patterns of input

Using this input generator, we can simulate policy implementation. For example, if the University of Tokyo promotes entrepreneurial education from year 3 to year 6, the variable entrepreneurship education can change to a red line in Figure 28. This policy implementation can change dynamics completely, as shown in Figure 29 – 31.

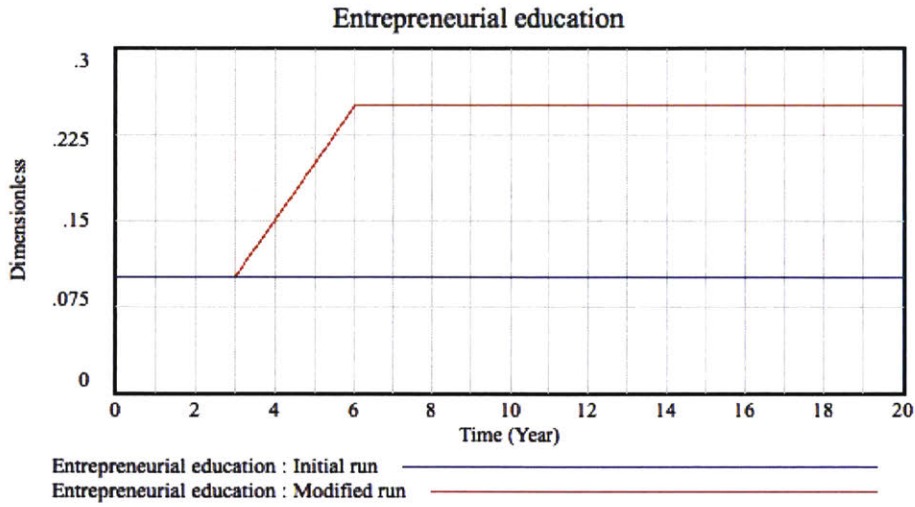


Figure 28 Modified input of entrepreneurship education

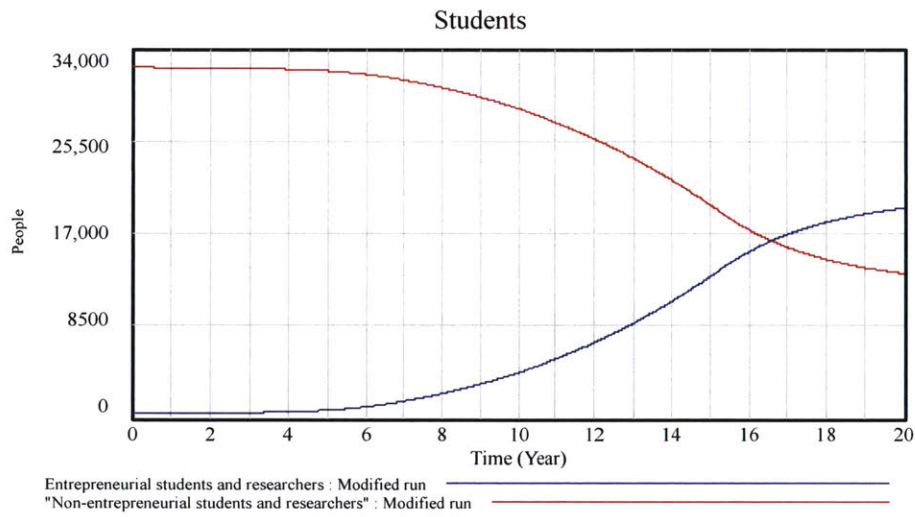


Figure 29 Entrepreneurial and non-entrepreneurial students and researchers with modified entrepreneurship education setting

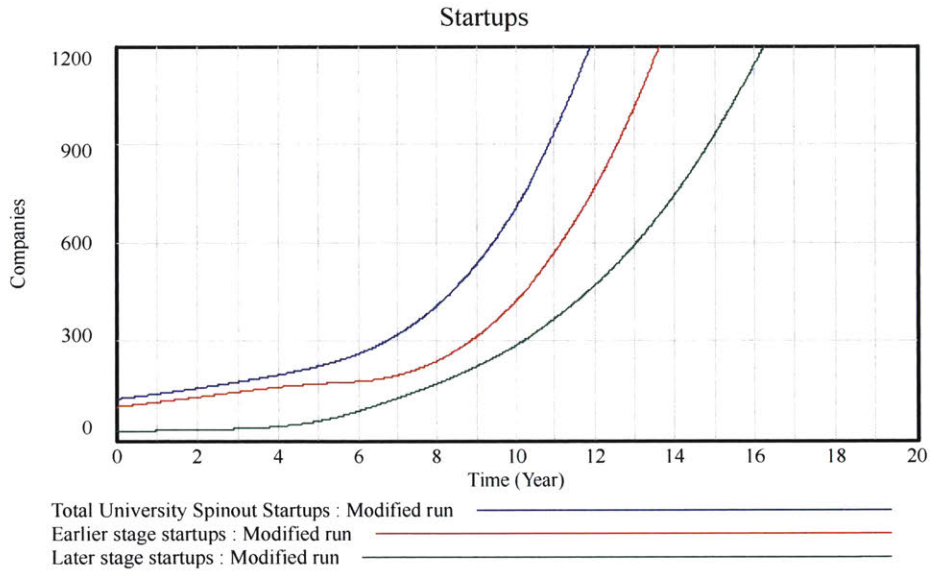


Figure 30 Startups with modified entrepreneurship education setting

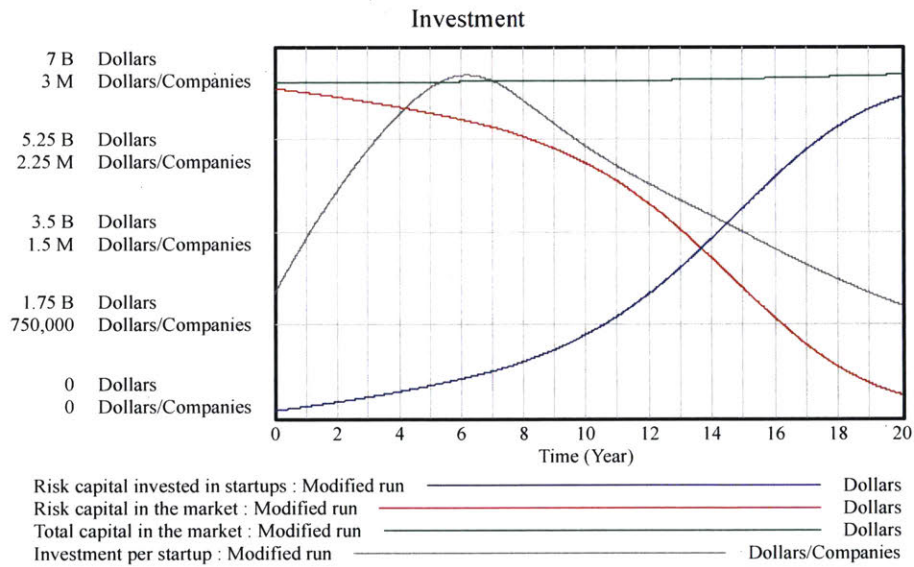


Figure 31 Investments with modified entrepreneurship education setting

7. Results

A system dynamics model for the innovation ecosystem around a university was built in the previous section. In this section, dynamics of the model with different inputs are analyzed. At first, basic behavior of the model is analyzed to identify variables that can be important to as policy levers. Second, simulations for the ecosystem around MIT are carried out to understand the influence of the variables.

7.1. Behavior of the System

(1) Entrepreneur Boom

At first, a behavior described as an *entrepreneur boom* reinforcing structure, which we describe in Figure 8, is investigated by changing exogenous variables directly related to the structure. Values for a “base case” are summarized in Table 10, and we run simulations for 10 cases under different conditions to investigate the influence of the exogenous variables. For each simulation run, only one variable is changed from the base case, and conditions are summarized in Table 11. For example, in High Entrepreneurship Education (EE) case we only changed EE value from 0.1 to 0.15, and keep other variables as the same value as the base case. High EE shows higher growth in entrepreneurial students and researchers, that means higher EE has a positive effect on the feedback loop of *Entrepreneur boom*. The third column in Table 11 shows how those changes in variables affect the loop. Only Expectation for stable job (ESJ) has a negative relationship with *Entrepreneur boom* reinforcing loop, in which increase in ESJ results in decrease in Entrepreneurial students and researchers, but other variables have positive relations with the loop.

Table 10 Values for base case

Variable	Value
Entrepreneurship Education (EE)	0.1
Expectation for Stable Job(ESJ)	0.7
Opportunity to Start a Company(OSC)	0.05
Social Status per Successful Startup(SSSS)	0.001
Initial Entrepreneurial Students and Researchers(ESR)	327

Table 11 Simulation cases

Case	Value	Impact
High EE	EE = 0.12	Positive
Low EE	EE = 0.05	Negative
High ESJ	ESJ = 0.8	Negative
Low ESJ	ESJ = 0.6	Positive
High OSC	OSC = 0.1	Positive
Low OSC	OSC = 0.03	Negative
High SSSS	SSSS = 0.002	Positive
Low SSSS	SSSS = 0.0005	Negative
High Initial ESR	Initial ESR = 627	Positive
Low Initial ESR	Initial ESR = 27	Negative

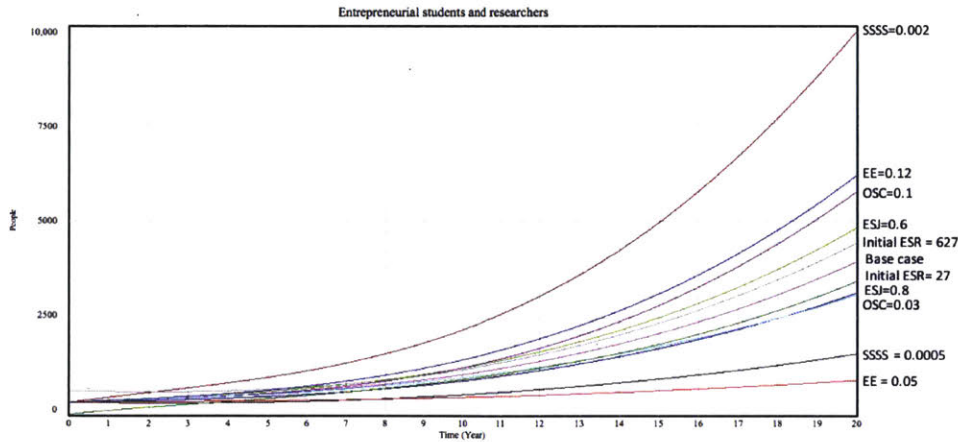


Figure 32 Influence of exogenous variables on Entrepreneurial students and researchers

(2) Overinvestment

Capital investment into startups also takes an important role in the model. If a reinforcing loop of *Reinvestment* shown in Figure 9 works in the model, increase in risk capital promotes startups, then reinvestments will increase again later. However, there should be a drawback from the *Excess investment* balancing loop in which too many investments to startups decrease capital gain and reinvestment. Simulation runs with various initial values of Risk Capital in the Market(RCM) are carried out to investigate the response of the system to a change in the supply of the capital. The values were 1 billion, 3 billion, 6.2 billion (the base case), and 10 billion dollars. Results are shown in Figure 33 - 36. From Figure 33 and 34, increase in RCM clearly shows a positive relationship between Risk capital invested and Entrepreneurial students and researchers. On the other hand, as shown in Figure 35 and 36, too much risk capital not necessary benefit investors and startups in the system. Figure 35 shows saturation of the risk capitals for the growth of companies, which caused by excess investments to startups. There is a limitation of growth rate increase by larger RCM. The excess investments also hurt capital gain, when startups only need a limited amount of capitals. In those simulation runs with exogenous variable “Investment required to Complete Product Development in Average Time” of 5 million dollars, Growth rate stops increasing and Capital gain start decreasing once “Investment per startup” exceeds 5 million dollars. As long as Investment per startup is less than 5 million dollars, Growth rate increases with initial RCM. At the same time, Capital gain keeps 1.2 because startups in the system needs more investment for product developments. This is

represented in *Excess investment* feedback loop in Figure 9. Capital gain recovers after year 11 for Initial RCM 10 billion, as shown in Figure 36, because the number of startups increases continuously that eventually dilute investment per startup which result in a better capital gain.

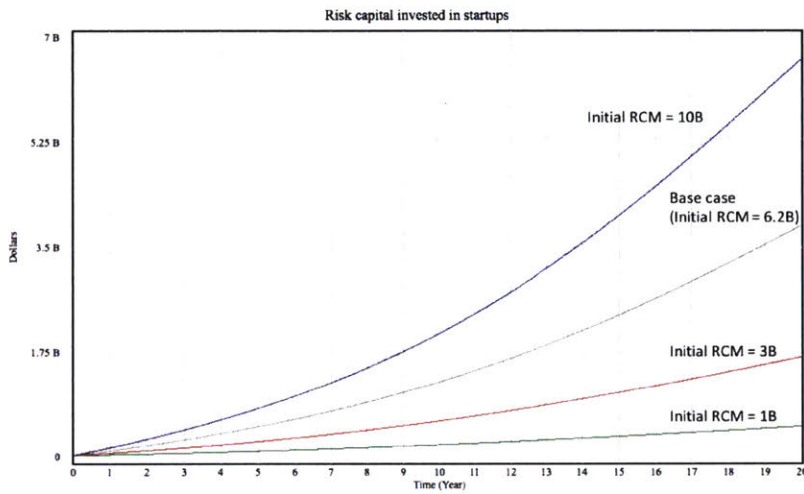


Figure 33 Influence of change in initial value of Risk Capital in the Market on Risk capital invested in startups

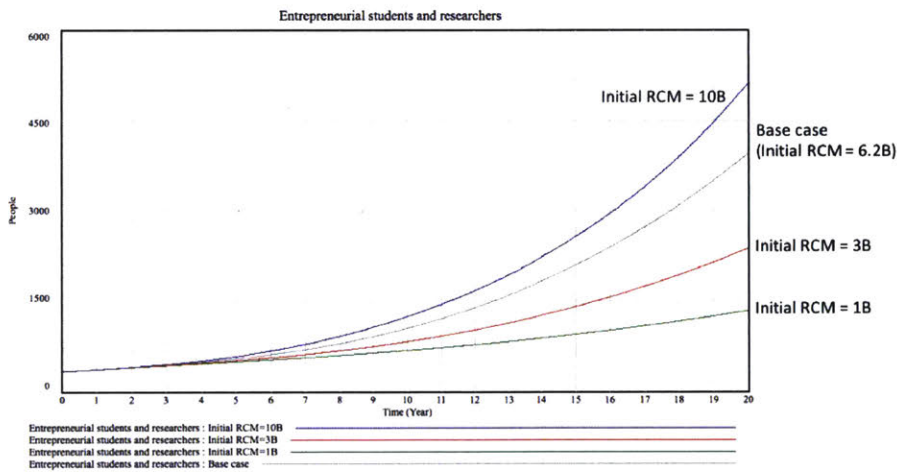


Figure 34 Influence of change in initial value of Risk Capital in the Market on Entrepreneurial students and researchers

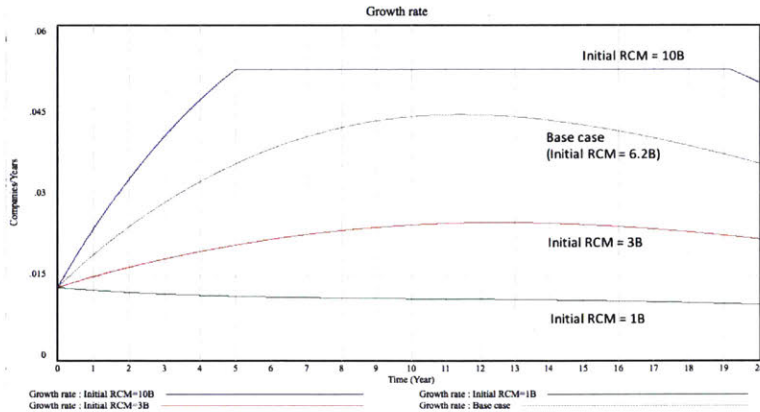


Figure 35 Influence of change in initial value of Risk Capital in the Market on Growth rate

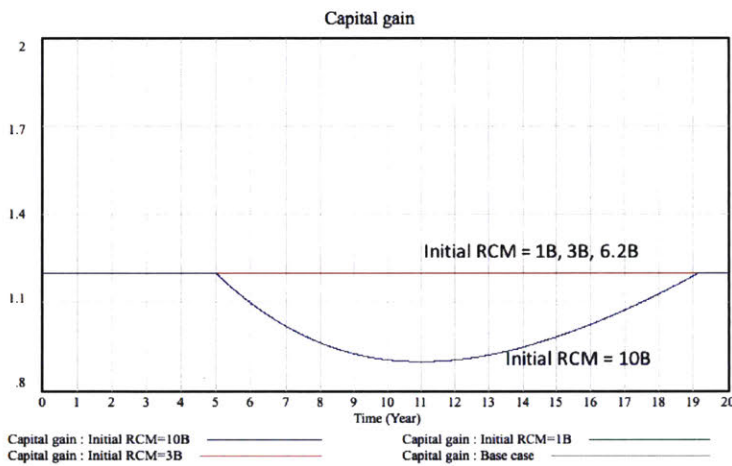


Figure 36 Influence of change in initial value of Risk Capital in the Market on Capital gain

(3) Influence of large companies

In this model, a variable “interest of large companies to startups(ILCS)” influences two parts, M&A of the startups and interaction with customers. Figure 37 through 40 show simulation results with three different values of ILCS, 0.2, 0.5(the base case), and 0.8. Figure 37 shows that increase in ILCS increases Entrepreneurial students and researchers through supporting growths of startups. Also, M&A deals of startups also increase with ILCS as shown in Figure 38. Figure 39 shows Ratio of startups with sales capability, and it increases with ILCS. However, there are decreases in the ratio of startups with sales capability from around year 9 in Figure 39, and the decrease is steeper for higher ILCS. This decrease is from increasing number of startups, as shown in Figure 40. Figure 37 - 40 show that supports of large companies for startups are important to increase the number of startups and improve growth rate, but investments of startups need to follow increasing number of startups to sustain the growth rate.

In this model, investment to startups increases through M&A and reinvestment, but the reinvestment has a delay that causes the shortage of investment.

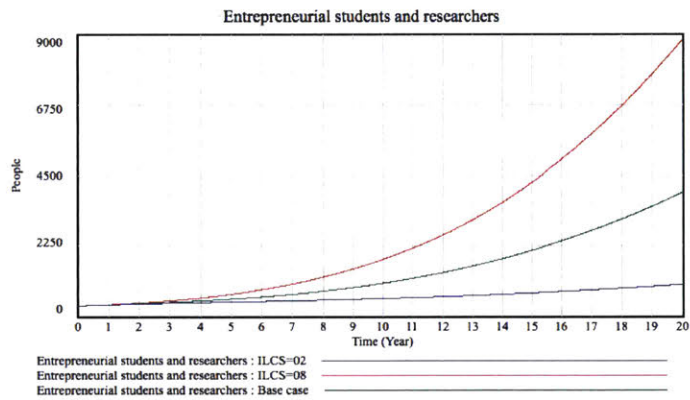


Figure 37 Influence of Interest of large companies to startups on Entrepreneurial students and researchers

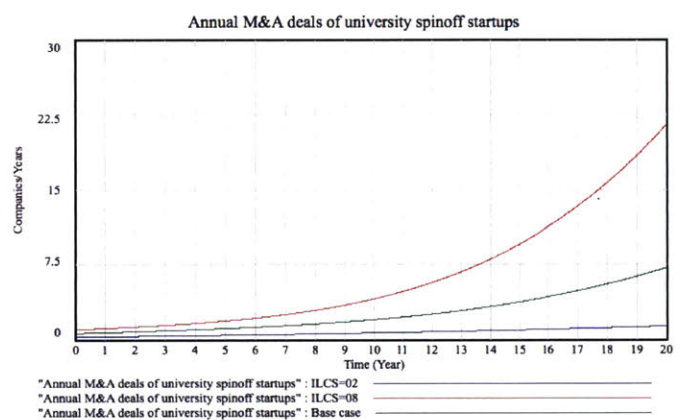


Figure 38 Influence of Interest of large companies to startups on Annual M&A deals of university spinoff startups

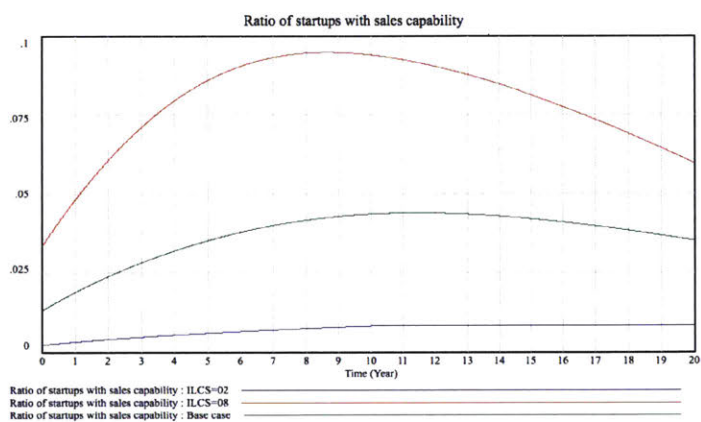


Figure 39 Influence of Interest of large companies to startups on Ratio of startups with sales capability

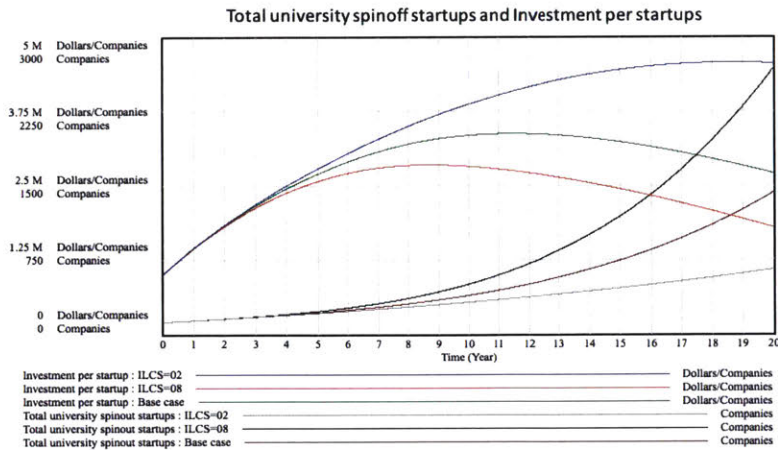


Figure 40 Influence of Interest of large companies to startups on Total university spinoff startups and Investment per startups

The reactions of the system to increasing ILCS found here can be represented in Figure 41. This interrelated structure of ILCS can positively influence *Entrepreneur boom* loop to increase entrepreneurs and startups. However, a larger number of startups causes a side effect that decreases Investment per startups that leads to lower growth rate. This side effect is shown as *Risk capital depletion* loop in Figure 41. *Reinvestment* reinforcing loop can potentially mitigate this side effect by increasing Risk capital invested in startups. However, there is a delay between Reinvestment to capital market and Risk capital investment in startups, that is shown in double line in Figure 41.

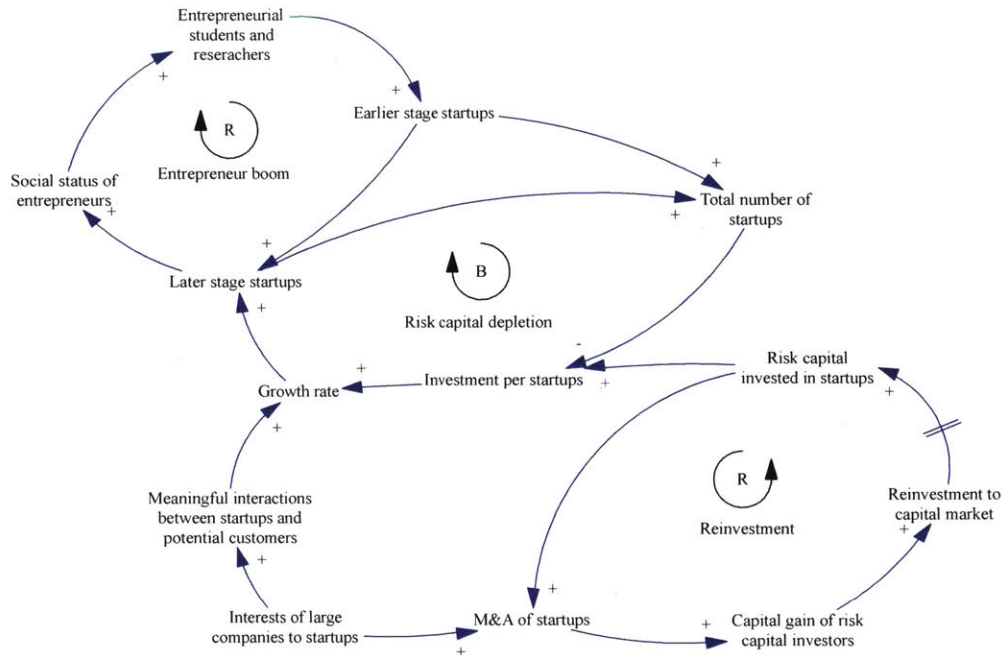


Figure 41 Causal loop structure related to interests of large companies to startups

(4) Impacts of entrepreneurship education

Entrepreneurship education also influences the system through multiple paths, activation of non-entrepreneurial students and researchers, increase meaningful interactions between startups and potential customers, and reducing a time for product development. Those influences are controlled by three variables (1) Effect of entrepreneurship education on entrepreneurial activation (EEEEE), (2) Effect of entrepreneurship education to have meaningful interactions (EEEMI), and (3) Effect of entrepreneurship education to reduce product development time (EEERPD), as shown in Figure 15. Those variables represent focus on entrepreneurship education in the university. For example, if a university improves its entrepreneurship education program to promote students who are not interested in starting a business to be an entrepreneur, the first variable (EEEEE) increases. More focuses on customer hearing and sales increases the second (EEEMI). Enhancement of classes in product development increases the third variable (EEEMI). Simulation runs were carried out to figure out how those variables influences entire system. Values of EEEEA, EEEMI, EEERPD are summarized in Table 12, and other conditions are same as Table 7 and 8.

Table 12 Values of simulation runs to figure out influence of entrepreneurship education

	EEEEA	EEEMI	EEERPD
Base case	0.7	5	5
EEEEA = 0.9	0.9	5	5
EEEEA = 0.5	0.5	5	5
EEEMI = 7	0.7	7	5
EEEMI = 3	0.7	3	5
EEERPD = 7	0.7	5	7
EEERPD = 3	0.7	5	3

Results are shown in Figure 42 and 43, and they show Growth rate and Entrepreneurial students and researchers have positive relations with EEEMI and EEERPD. Increases of EEEMI or EEERPD result in higher Growth rate through Ratio of startups with sales capability. The positive relations with Entrepreneurial students and researchers are through Social status of entrepreneurs because the increase in Growth rate increases Later stage startups that results in larger number of Entrepreneurial students and researchers, as we described as *Entrepreneur boom* structure. On the other hand, EEEEEA has a negative relation with Growth rate, in which higher EEEEEA results in lower Growth rate, as shown in Figure 42. This negative relation is from *Risk capital depletion* structure shown in Figure 41. Just increasing the number of entrepreneurs not necessary results in a growth rate of startups, because startups compete over a limited amount of capital necessary for their product development.

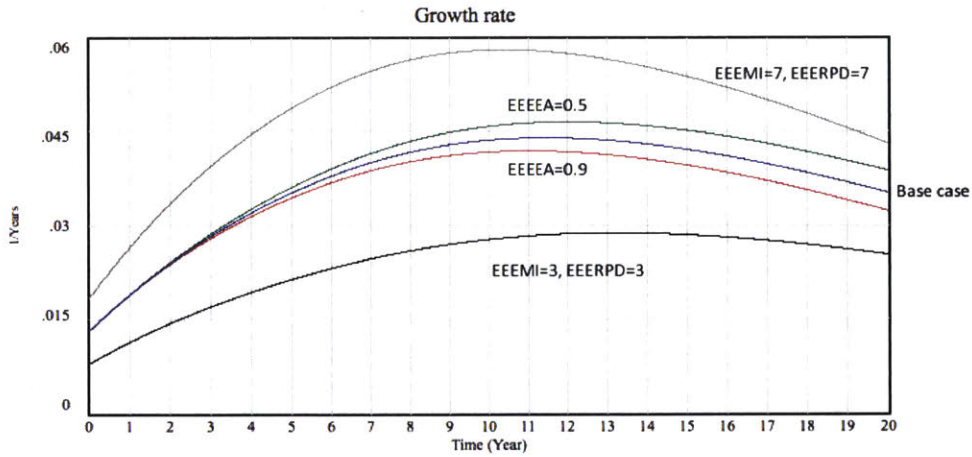


Figure 42 Influence of Entrepreneurship education on Growth rate

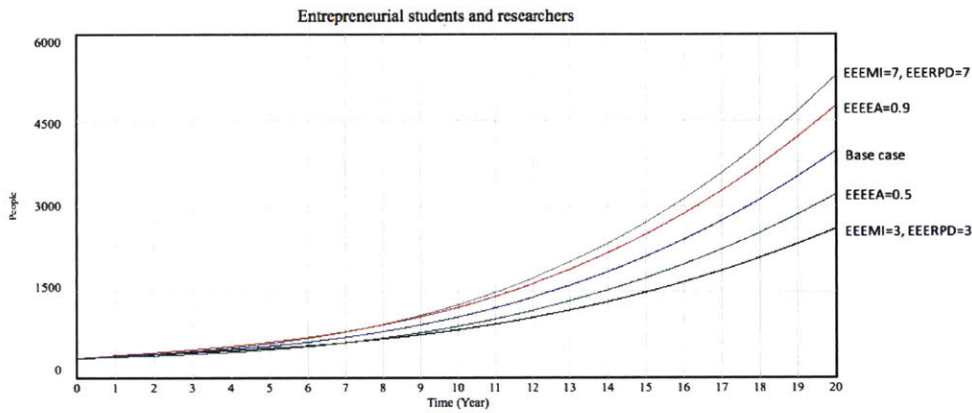


Figure 43 Influence of Entrepreneurship education on Entrepreneurial students and researchers

Figure 44 shows relationships related to entrepreneurship education, that controlled the simulation runs here. The figure shows *Risk capital depletion* balancing feedback loop that causes a decrease in Growth rate after year 10 to 13 in all cases, that is shown in Figure 42. This balancing feedback structure is same with one shown in Figure 41, and it impacts the behavior of the system.

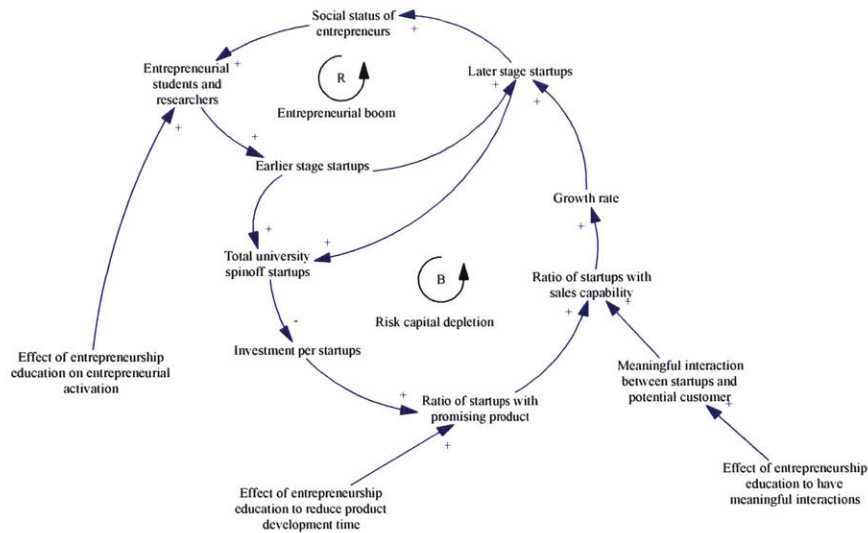


Figure 44 Causal loop structure related to effects of entrepreneurship educations

7.2. Simulation run for ecosystem around MIT

Using this model, we changed several variables using data of ecosystem around MIT for further understanding of the model. Table 13 and 14 shows values for this cases.

Table 13 Values of variables for initial run

Variable	MIT	U Tokyo	Unit
Average years of studying	5	5	Years
Effect of entrepreneurship education on entrepreneurship activation	0.7	0.7	Dimensionless
Entrepreneurial education	0.3	0.1	Dimensionless
Opportunity to start a company	0.1	0.05	Companies/People/Year
Expectation for stable job	0.5	0.7	Dimensionless
Social status per successful Startup	0.00002	0.001	Dimensionless
Annual liquidation rate	0.02	0.01	1/Year
Investment rate	0.00001	0.0001	1/Year/Companies
Average M&A rate of startups by large companies	0.05	0.01	1/Year
Average IPO rate of startups	0.01	0.01	1/Year
Standard capital gain	1.2	1.2	Dimensionless

Time required to acquire customers to become later stage	1	1	Years
Average interaction to acquire sales capability	40	40	Meetings
Average matching by mentors, accelerators, meet ups, and other opportunities	100	100	Meetings
Interest of large companies to startups	0.8	0.5	Dimensionless
Effect of entrepreneurship education to have meaningful interaction	5	5	Dimensionless
Effect of entrepreneurship education to reduce product development time	5	5	Dimensionless
Standard time for product development	3	3	Years
Investment required to Complete Product Development in Average Time	4,000,000	4,000,000	Dollars/companies

Table 14 Initial values of stocks for initial run

Stocks	MIT	U Tokyo	Unit	Description
Entrepreneurial students and researchers	1,844	327	People	10% of faculty, researchers, and students affiliated with MIT in 2016
Non-entrepreneurial students and researchers	16,597	32327	People	90% of faculty, researchers, and students affiliated with MIT in 2016
Earlier stage startups	27,810	97	Companies	90% of total spinoff startups from MIT in 2015
Later stage startups	3,020	24	Companies	10% of total spinoff startups from MIT in 2015
Risk capital in the market	50,243,780,000	6,343,218,000	Dollars	10% of Asset Under Management(AUM) of VC in Massachusetts
Risk capital invested in startups	30,200,000,000	121,000,000	Dollars	Average 1 million dollars investment per company

We made assumptions as below to decide those variables, and those assumptions need to be investigated for a calibration of the model.

- Probability to take any entrepreneurship educational program in MIT is three times higher than in the University of Tokyo.
- 10% of entrepreneurial students and researchers have an opportunity to start a business annually.(5% for the University of Tokyo)

- Expectation for stable job is lower in MIT than in the University of Tokyo.
- Social status of entrepreneurs is less sensitive to the number of later stage startups compared to the University of Tokyo.
- Startups have more opportunity for M&A compared to startups from the University of Tokyo.
- Interests of large company to startups is higher in the US than in Japan.
- 10% of faculty, researchers, and students affiliated with MIT are entrepreneurial.
- 10% of spinoff startups are later stage
- 10% of Asset Under Management(AUM) of VC firms in Massachusetts have a potential to be invested in MIT spinoff startups.
- MIT spinoff startups have 1 million dollars investment in year.

Using the condition listed in Table 13 and 14, we carried out a simulation run, and major results are as follows.

(1) Entrepreneurial students and researchers and Startups

Figure 45 shows Entrepreneurial and non-entrepreneurial students and researchers. The figure shows a rapid increase in Entrepreneurial students and researchers in the first 6 years, then became relatively stable. This is from a high Social status of entrepreneurs and a large number of non-entrepreneurial students and researchers from the beginning. The high social status comes from a large number of later stage startups, which also increased influenced by high Growth rate and a large number of Earlier stage startups.

Those results show it is necessary to have verifications to discuss how the variables are reasonable. For example, the result shows more than 13,000 of students and researchers, which is more than 70 % of total students and researchers, will be entrepreneurial in few years. Also, more than 60 % of earlier stage startups now becomes later stage in 5 years. Those results can largely different from real values, that can be verified by further research.

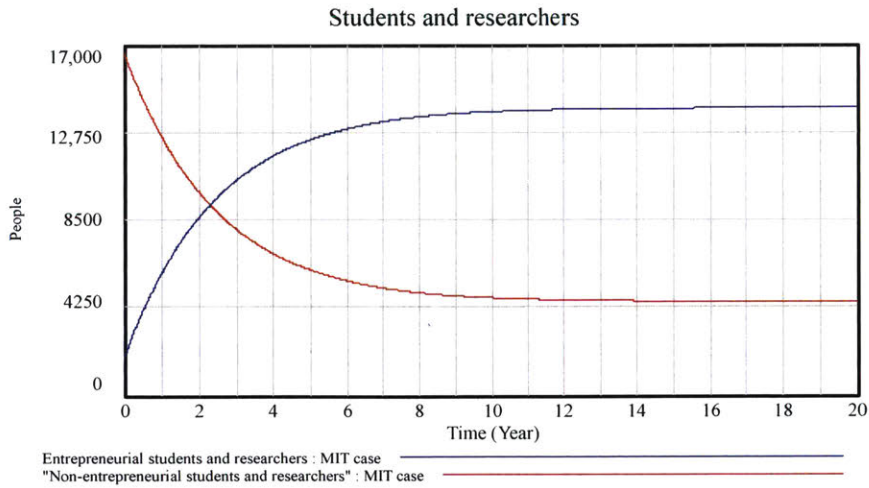


Figure 45 Students and researchers in a simulation for MIT case

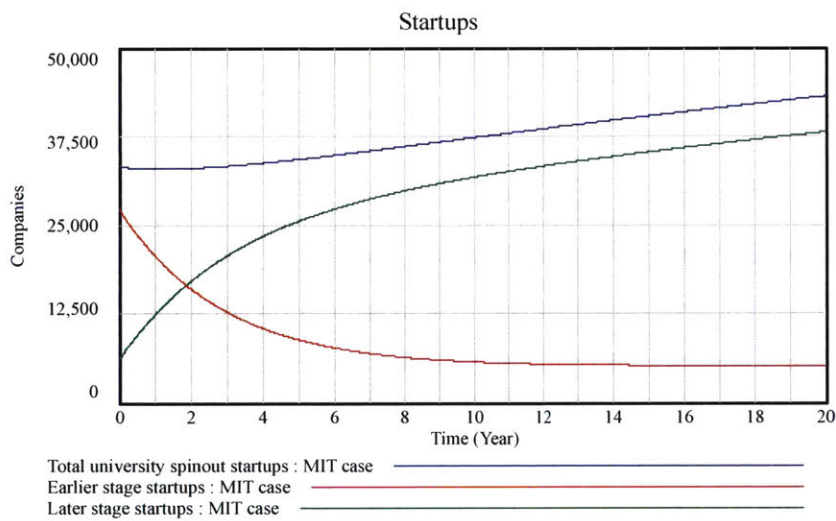


Figure 46 Number of startups in a simulation for MIT case

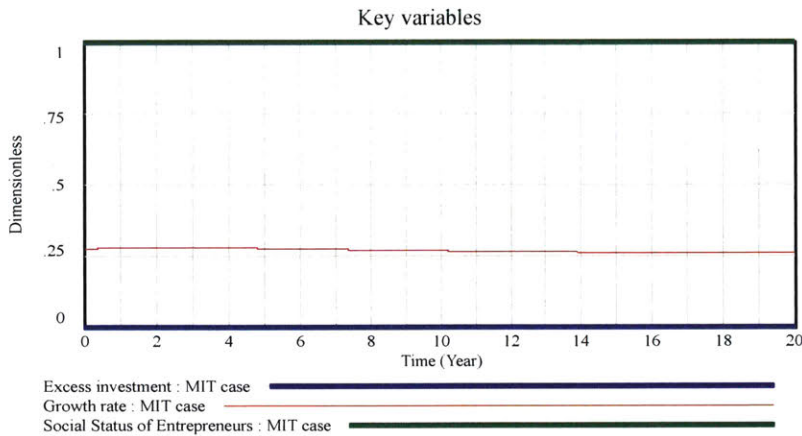


Figure 47 Key variables in a simulation for MIT case

(2) Growth rate and investment

As shown in Figure 47, Growth rate keeps around 0.25 for MIT case, and it is more than five times larger than the base case of the University of Tokyo, which is shown in Figure 20. This higher Growth rate is from higher Interests of large companies to startups and higher Entrepreneurial education. Although this higher Growth rate results in growing number of Later stage startups, the Growth rate could be higher if there are more capital invested in the startups. Growth rate could not become higher because of limited investment per startups for the MIT case. Figure 48 shows investments in startups for the MIT case, and Investment per startups does not go above 1 million dollars per startups. In this system dynamics model, growth rate increases with investment per startups as long as it is under 4 million dollars per company. This low investment per startup means more investment to university spinoff startups speeds up product development and higher growth rate.

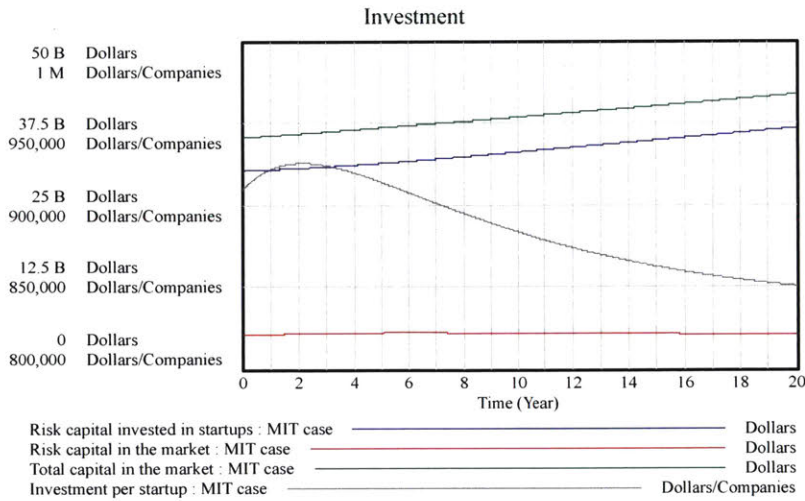


Figure 48 Investments in a simulation for MIT case

This simulation run for the MIT case shows the dynamics are completely different from the case of the University of Tokyo. The difference mainly comes from a number of spinoff startups at time zero. The number of MIT spinoff startups is two magnitudes higher than that of the University of Tokyo, and that completely changes social status of entrepreneurs and risk capital market. Although adequacy of capital for startups is the issue for innovation ecosystem in the simulation run for MIT case, the number of existing startups and interests of large companies are the issue to promote the growth of the ecosystem.

8. Discussions for Policy Implication

In this section, findings from previous parts are summarized at first. Second, research hypotheses are discussed, to argue how those hypotheses can be true under what condition. Third, we discuss limitations of the model that includes further research subject. Fourth, policy implication regarding the modeling study is discussed, with simulation runs that show expected the behavior of the ecosystem. Finally, we discuss research questions.

8.1. Finding from the modeling study

Major findings from the previous sections about the model is summarized as below.

(1) Interrelations of reinforcing and balancing feedback loops

We found interrelations of reinforcing and feedback loops dominates the behavior of the system, especially for long term more than ten years of simulation runs. As we stated in the first research hypothesis, we included in the ecosystem model a reinforcing feedback loop that includes entrepreneurial students and researchers, startups, and social status of entrepreneurs, that is shown in Figure 8 as *Entrepreneur boom* loop. We also included *Reinvestment* reinforcing loop and *Excess investment* balancing loop from dynamics of capital market as shown in Figure 9. On the other hand, through the series of simulations, we found another balancing feedback loop, *Capital depletion* loop, that interferes with the generation and growth of the startups.

(2) Balance between investment and startups

We found a balance between an amount of capital investment in the market and the number of startups can be a key for the growth of startups. Figure 35 shows an amount of the risk capital in the market impacts growth rates of the startups. A larger amount of risk capital in the market promotes startups to develop their product that is required for growth. However, excess investment hurts capital gain of the investors that eventually causes a decrease in risk capital in the market. On the other hand, the simulation run with the MIT case suggests significantly increased successful startups and entrepreneurial students potentially causes a shortage of risk capital. The reinforcing feedback loop of *Entrepreneur boom* produces plenty of startups, but the growth of risk capital can be slower than the pace of startups. In such a case, the risk capital can be a limiting factor of growth of the startups.

(3) Influence of entrepreneurship education

In the current model, entrepreneurship education influences the innovation ecosystem through three parts: entrepreneurial activation, meaningful interactions with potential customers, and product development. Those paths of influences are different, however, increasing meaningful interaction with potential customers and promoting product development indirectly promote students and researchers through growth rate, that is shown in Figure 43. On the other hand, entrepreneurial activation potentially has a negative influence on growth rate as shown in Figure 42, because increasing startups can cause depletion of available capital per startup.

(4) Role of large companies

Interests of large companies to startups influences the ecosystem through M&A and meaningful interaction with potential customers. As shown in Figure 37 and 39, higher interests of large companies contribute to more entrepreneurial students and researchers and help startups to obtain sales capability. In addition, large companies can increase entrepreneurs through changing hiring patterns that indirectly controls expectation for a stable job. Influence of expectation for a stable job to entrepreneurial students and researchers is shown in Figure 32.

8.2. Discussions for research hypotheses

Here we discuss three hypotheses proposed in section 5, and under which condition those hypotheses can be true.

H1: There is a reinforcing feedback loop in innovation ecosystem that higher social status for entrepreneurs promotes foundations of startups results in more successful entrepreneurs.

This hypothesis H1 is true under the assumptions made in section 6 to build a system dynamics model, and this social status dynamics significantly affects performance across various simulation runs. However, we also found balancing loops that potentially hinder generation and growth of startups. An increase in startups decreases investment per startups that causes lower growth rate, which forms *Risk capital depletion* loop. Another balancing feedback loop, *Excess investment* loop can decrease capital gain, and it leads to lower reinvestment of risk capitals. A simulation run with the MIT case shows an increase of entrepreneurial students and researchers

and later stage startups slows down by depletion of non-entrepreneurial students and researchers and earlier stage startup. Those feedback loops are shown in Figure 49, that provides a holistic view of those causal loop structures.

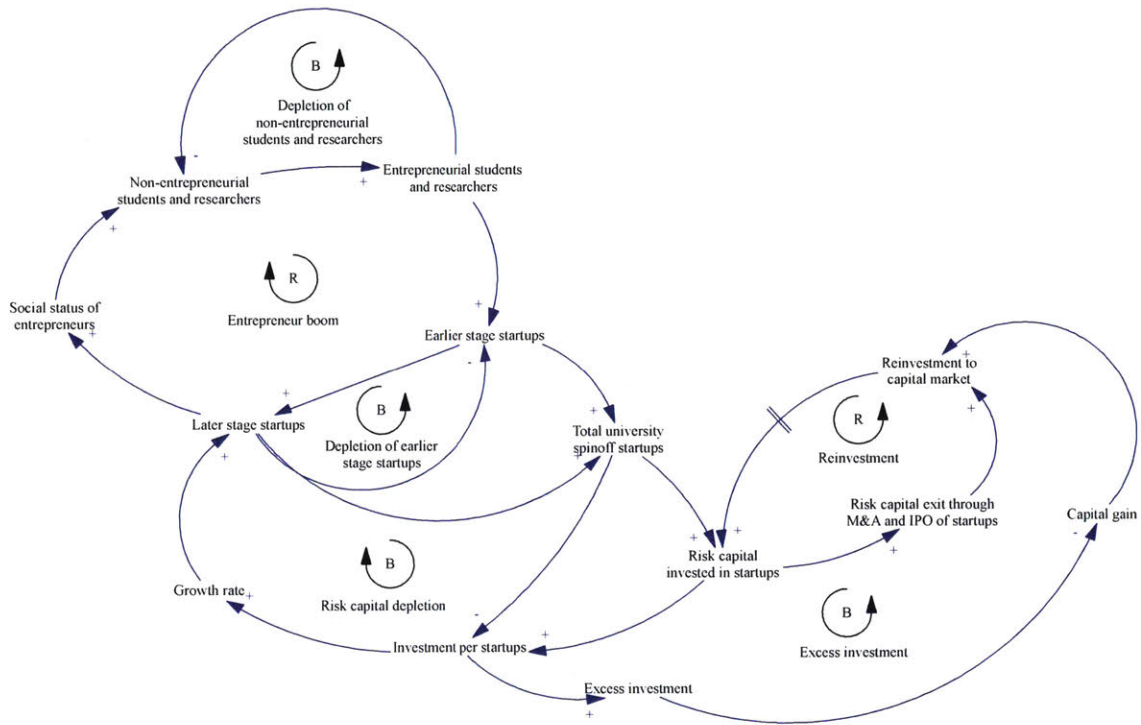


Figure 49 Causal loop structures

H2-1: Entrepreneurship education in universities can be designed to introduce entrepreneurial career, help product development, or increase meaningful interaction between startups and potential customers.

H2-2: However, influences of entrepreneurship education to the innovation ecosystem are different by the design of entrepreneurship education.

In the model, there are three effects of entrepreneurship education controlled by three different variables, (1) Effect of entrepreneurship education on entrepreneurial activation (EEEEA), (2) Effect of entrepreneurship education to have plenty of meaningful interactions

(EEEMI), and (3) Effect of entrepreneurship education to reduce product development time (EEERPD). Results from simulation runs show both EEEMI and EEERPD influences growth rate and eventually, they improve entrepreneurial activation. This means even entrepreneurial education programs in a university focuses on product development and interaction with customers, the programs can eventually increase entrepreneurial students and researchers. In this case, entrepreneurship education programs don't need to encourage students to be entrepreneurs, but students want to be entrepreneurial due to the presence of successful startups from the university. Therefore, this hypothesis is false when improvement of product development and interaction with potential customers contributes to a growth rate of the startups and the growth of startups leads to more entrepreneurial students and researchers.

H3: Behavior of large companies for (1) purchasing startup product, (2) investing & acquiring startups, and (3) hiring pattern affect dynamism of the ecosystem, that changes establishment and growth of startups.

This hypothesis H3 is true if there are causal loop structures shown in Figure 49 in the innovation ecosystem, and hiring pattern influences students' and researchers' expectation for a stable job. If more purchases of products of startups lead to higher growth rate, it increases Later stage startups, that drives *Entrepreneur boom* loop. Active M&A of startups promotes reinvestment to startups, and lower expectation for stable job increases entrepreneurial students and researchers entering the school.

8.3. Limitation of the model

In this study, we build a model of innovation ecosystem around a university, however, there are limitations of the model. For example, we made a series of assumptions to build the model, and those assumptions may cause gaps between the model and real world. Therefore, it is necessary to discuss those limitations before we consider policy implications.

(1) Roles of large companies in the innovation ecosystem

We assumed that roles of large companies were limited to three, (i) interact with startups as potential customers, (ii) purchase ownership of startups through M&A, and (iii) change students' expectation for a stable job through companies' hiring patterns. All of those roles were simplified in the model in this study. For example, companies' interests directly increase meaning interactions between startups and customers in the model, but actual sales process can be more complicated because it involves business cultures, reputations, and other factors.

(2) Detailed discussion of students' and researchers' notion to become entrepreneurs

In the modeling in this study, we simplified how students and researchers become interested to start a business and launch a company. We assumed only expectation for a stable job, the social status of entrepreneurs, and entrepreneurship education decide probability to become entrepreneurial, and entrepreneurial students start a company with fixed probability. In addition, we assumed that social status of entrepreneurs was decided by the number of later stage startups, that could be a topic for further study. If we can implement a mechanism how students and researchers become entrepreneurial and how it is influenced by ecosystem, that implantation will be a large improvement of the model.

(3) Data points to forecast and manage ecosystem

Available data points to calibrate the model are not enough. For example, the University of Tokyo. The number of spinoff startups has been monitored from 2010, but continuous and detailed monitoring is required to understand status quo of the innovation ecosystem. Also, more data is necessary to understand which feedback loop is dominating the system. As shown in simulation runs, there are several years of delays involved in the system that needs patient monitoring to see policy effect. Besides, we could not find data about investment into spinoff startups from the University of Tokyo, that limits our discussion related to the capital market. Those data points are necessary for calibration and further improvement of the modeling study.

(4) System boundaries

To approach research questions, we build a model of an ecosystem around only one university, and we assumed there is no interaction between universities. In addition, the model

does not include startups from graduates from the university, even though graduates potentially be a large source of the university spinoff startups.

8.4. Policy implications

The intentions of many of the innovation policies around the University of Tokyo can be explained using this model. For example, the Nippon Venture Award is aimed to improve the social status of entrepreneurs, funds of SME support increase Risk capital in the market, and the EDGE program promotes students to be entrepreneurial. Many of potential policy levers are already approached by governments and the university. However, there are three policy implementations we can discuss to improve policy making, that we could find using a systems approach.

(1) Holistic view of the system and combination of policy levers

As we discussed above, an innovation ecosystem around a university includes multiple feedback loops. The existence of multiple loops and delays make unexpected reactions of the system to a policy. Therefore, policymakers need to have a holistic view of the system and need to consider a combination of policies to implement. For example, the government can supply risk capitals into the market to support investment in startups, but the policy can cause overinvestment that hurts capital gain of private investors. This overinvestment is due to shortage of startups to invest, compared to plentiful risk capital in the market.

Therefore, this can be solved by combining with a policy that promotes entrepreneurs. Improving the social status of entrepreneurs leads to more startups to invest, and it prevents overinvestment. This policy combination can be simulated using the model we build in the study. To show policy combinations, we run simulations for three cases, the base case, More risk capital case, and Policy combination case. The condition of the base case is same as a condition summarized in Table 7 and 8. Then, we increased initial value of Risk capital in the market(RCM) from 6.2 billion dollars to 10 billion dollars, which represent massive risk capital supply by the government, as More risk capital case. Thirdly, we also increased Social status per successful startups(SSSS) from 0.001 to 0.002 which represent government's effort to give prizes and promote successful entrepreneurs. Those conditions are summarized in Table 15.

Table 15 Simulation conditions to investigate policy combinations.

Simulation run	Initial RCM	SSSS
Base case	6.2 B dollars	0.001
More risk capital	10 B dollars	0.001
Policy combination	10 B dollars	0.002

Capital gains from three simulation runs are shown in Figure 50. In More risk capital case, Capital gain decreases by excess investment, because startups to invest are limited. However, there is no decrease in Capital gain for Policy combination case, because the higher social status of entrepreneurs results in more startups, and it prevents over investment to each startup. This shows there is a waste of money for More risk capital case unless the government makes an effort to increase entrepreneurs.

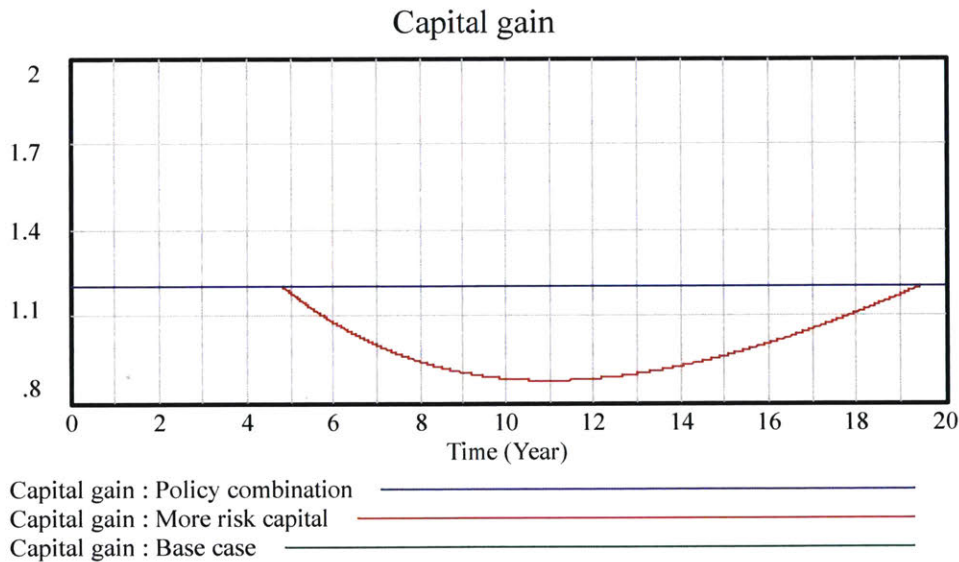


Figure 50 Capital gain for three simulation runs to investigate policy combination

(2) Monitoring and forecast to control balancing structure

Figure 49 shows our understanding of feedback structures of an innovation ecosystem around a university. Successful startups can be increased through driving reinforcing feedback loops and controlling balancing feedback loops because the balancing loops inhibit reinforcing loops to increase entrepreneurs, startups, and risk capitals in the market. Two major balancing

loops, *Risk capital depletion* loop and *Excess investment* loop can be controlled by the government through a supply of risk capitals into the market. However, delays are involved in those loops that make policy interventions difficult. For example, Figure 35 and 36 shows risk capital supply in initial state (year 0) cases excess investment, but it becomes obvious in year 5. Therefore, it is not easy to judge whether risk capital supply is enough or not and control supply only from a snapshot of the system. Therefore, to improve governmental policies, monitoring and forecasts of the adequacy of capital are required. Through the monitoring and forecasts, *Risk capital depletion* loop and *Excess investment* loop can be better controlled.

We need an organization which take a proactive role to carry out continuous monitoring and forecast to for better policy implementation. Ministries should not take this role directly for several reasons. First, the forecasting requires considerable background knowledge to carry out, and ministry officials who have 1-2 years job rotations hardly carry out the forecast in long-term. Second, it is better to separate the role of monitoring and forecasting from policy making because monitoring and forecasting closely related to an evaluation of the performance of policies. The forecasting role can be distorted if someone who has a wish for a state of the system and intervenes. On the other hand, governmental monitoring agency such as Board of Audit of Japan, should not take this role, because reports of such agencies are usually used for criticism. The purpose of the monitoring and forecast is for better steering of policy and not for evaluation. Therefore, academic institutes or independent agency which has a deep understanding of systems methods and ecosystem can be the organization for monitoring and forecasting.

(3) Patient policy support

When we consider growth rate and excess investment, it is better to have risk capital supply to support the acquisition of sales capability but not excess required amount to keep capital gain high. In reality, unnecessarily investment or subsidy inhibits learning process of startups, leading to survival of startups which don't have sales capabilities. However, recent Japanese government's policies, such as Public-Private Innovation Program supply risk capital in the market once, that possibly oversupply capitals. If the government can supply risk capital in long term rather than one time, it can limit the probability of over investment, because there will be more startups in few years. This policy implementation can be tested using the model. We

added Government risk capital supply to Annual investment as shown in Figure 51, and Annual investment can be written as follows.

$$\text{Annual Investment} = \text{Risk capital in the market} * \text{Investment rate} + \text{Government risk capital supply}$$

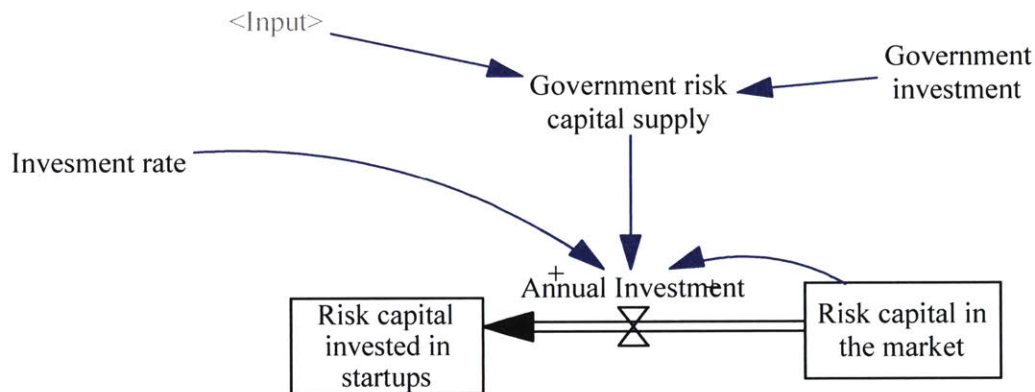


Figure 51 Modification to Risk capital invested in startups

With this modified model, we run simulations with conditions summarized in Table 16, and Government risk capital supply is described in Figure 52. Two simulation runs, 400M_4 years and 400M_8 years supply 400 million dollars from the government in total, but patterns of the investment are different. In 400M_4 years, the capital is invested in four years, but takes eight years for 400M_8 years case.

Table 16 Simulation run for government investment of risk capital

Simulation run	Policy
Base case	No investment from government.
400M_4 years	Government invests 100 million dollars from year 0 to 4.
400M_8 years	Government invests 100 million dollars in year 0, and reduce investment by 12.5 million dollars annually, which means 87.5 million dollars in year 1, 75 million dollars in year 2, then 0 dollar in year 8.

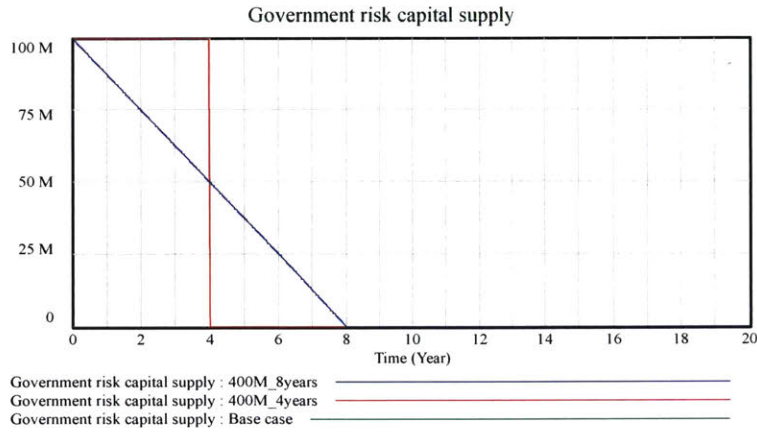


Figure 52 Government risk capital supply for three cases to investigate longer policy intervention

Growth rate and excess investment are shown in Figure 53 and 54. There is no large difference between 400M_4 years and 400M_8 years cases in Growth rate, but there is a difference in Excess investment. There is a larger peak for 400M_4 year case, but the excess investment is mitigated for 400M_8 years case. This result suggests that policy implementation in the short term may cause strong side effect because of delays of generation of startups is included in the system. Therefore, long term policies implementation has potential to mitigate side effects of policies.

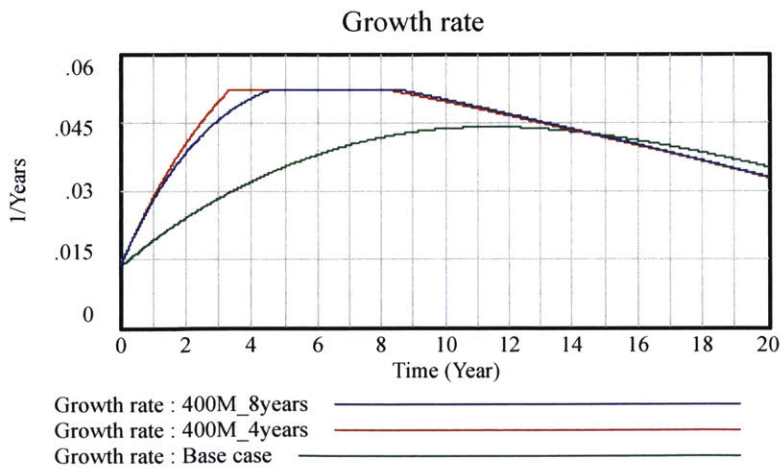


Figure 53 Growth rate of three cases to investigate longer policy intervention

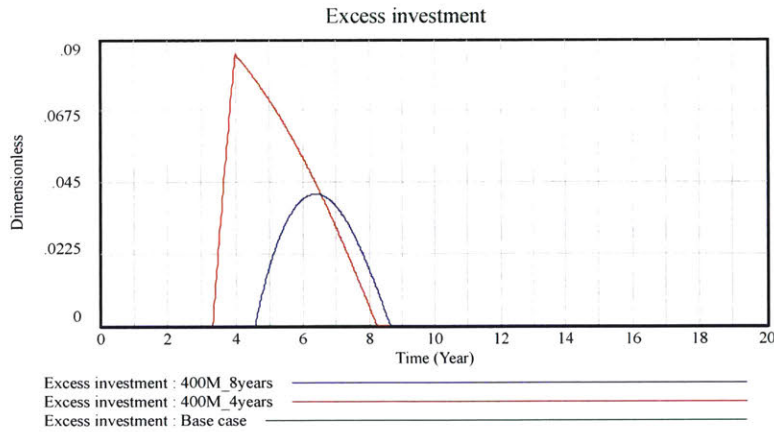


Figure 54 Excess investment for three cases to investigate longer policy intervention

8.5. Insights for research questions

We described research questions to be approached in this study in section 2. Regarding the findings and arguments through the study, we approach to the research questions as follows.

Q1: What are potential policy levers for public policymakers to efficiently promote innovation from a university?

Through the modeling and simulation runs, we found many potential policy levers that can foster innovation. For example, a higher social status of entrepreneurs increases more startup generation, more risk capitals in the market can positively influence the growth rate of startups, and higher interests of large companies to startups can help the growth of startups. All of those policy levers have potential to improve innovation ecosystem. However, as we discuss in this section, it is important for policymakers to implement policies with a holistic and long-term view of the system and combine potential policies. Many of possible policies are already exist in Japan, and now it is important to consider “how” those policies should be managed, rather than “what.” An example performed in this section is that risk capital supply from government can cause excess investment if the supply is done in the short term, but supply in the long term can mitigate those drawbacks.

Q2-1: What are major elements and structure (including feedback loops) that consists the innovation ecosystem?

We built a model for innovation ecosystem around a university, and we found that multiple loop structures are tightly connected that causes delays and side effects of public policies. In our model, major structures are *Entrepreneurial boom* loop, *Risk capital depletion* loop, *Capital gain* loop, and *Excess investment* loop. Other than stakeholders of the ecosystem, several variables such as growth rate, excess investment, and social status of entrepreneurs can be major elements of the system.

Q2-2: How can the model of the innovation ecosystem be validated and what data sets are necessary for the validation?

For a validation of the model, a long term monitoring of the number of startups, investment to university spinoff startups, M&A of startups by large companies, and growth of startups are necessary. More data points with long-term monitoring are required for calibration. In addition, there can be more variables to be monitored, which are not included in the model in this research, and finding important variables can be a subject of further research.

Q2-3: How will the model be used to discuss the policy levers and by whom?

The model can be used to discuss what is necessary for the ecosystem at first. Then the policymakers can find what combination of policies is effective to foster innovations, regarding the status quo. Also, other stakeholders, such as risk capital investors, in the ecosystem can also use the model for their decision making. The risk capital investors can have a better understanding of structure and pattern of risk capital market, and make decisions for their investments. The model is not for a forecast of the capital gain or number of startups, but for their quality of decision making that can result from a better understanding of the long-term behavior of the ecosystem.

8.6. Future works

In this study, we frame a research hypothesis and build a model to discuss innovation ecosystem around a university using system dynamics. There are future works to develop the discussion and improve the model, as we found limitations of the model in this section.

(1) Mechanism of students to become entrepreneurial and startups to grow

As discussed above, there are simplifications in the model, especially for the mechanism of the students and researchers to become entrepreneurial. Besides, we assumed the startups grow by attaining sales capability through interaction with potential customers. Those simplified mechanisms are expected to be improved for better system dynamics simulation of the ecosystem around a university.

(2) Calibration with additional data

When additional data is available, the model can be better calibrated. In particular, there are various exogenous variables that we set with assumptions, and calibration of those variables will lead to better results. There are types of data relatively easy to collect. For instance, investments in spinoff startups can be gathered from a survey to startups, and the number of the University of Tokyo spinoff is limited. The number of later stage spinoff startups can also be counted relatively easily. Besides, the number of students who took any entrepreneurial course can be estimated by the university.

(3) Research for other models

We investigated the University of Tokyo and MIT as examples of universities. However, arguments and modeling may be different for other types of university. Both the University of Tokyo and MIT are located in urban areas that provide easier accesses to large companies for students, and both universities have programs for innovation and entrepreneurship. There are many universities which don't have either of those conditions, and model can be different for those universities. Therefore, researching other universities may bring different insights for innovation ecosystems around universities.

(4) Expanding the system boundary

We defined a system boundary to approach hypotheses in this research. And the boundary can be expanded for other hypotheses, that are for further understanding, to validate.

One of the major possible change in the boundary is that include university graduates in the model because graduates can be founders of startups. In addition, future research can be considering ecosystem that includes multiple universities and research institutes. In the boundary, we defined only includes one university, and it is a closed system for entrepreneurs. Dynamics will change if a system includes entrepreneurs and collaborators from outside the university.

9. Conclusions

In this work, we studied innovation ecosystems around a university, and addressed two research questions to improve innovation policies in Japan. The first question concerns potential policy levers for public policymakers to promote innovation from a university efficiently. The second concerns how an innovation ecosystem around a university should be modeled so that policymakers to select potential and effective policy levers. To approach those questions, we analyzed ecosystems around the University of Tokyo and MIT as examples, and we also built a model of an innovation ecosystem around a university. After policy reviews and literature reviews, we framed the study through analyses of stakeholders, a system boundary, and causal relationships. Based on the analyses, a system dynamics model is built and simulations were carried out to investigate the dynamics of the system.

Policy implications we found through the study are summarized below:

- (1) Policymakers need to have a holistic view of the system to understand delays and side effects of the policies, for better implementation of the policy. In addition, combinations of policies with the holistic view potentially mitigates side effects of single policy implementation.
- (2) Continuous monitoring of the system and forecast of the system behavior is necessary for policy implementation. This is because multiple feedback loops exist in an innovation ecosystem policymakers need to understand which loops are dominating the system before selecting policies to implement.
- (3) Our simulation results show policy implementation in short time can cause serious side effect, but an implementation with longer time can mitigate such side effects.

We also discussed further work for research for innovation ecosystem around universities. At first, discussions of mechanisms of innovation ecosystem we simplified are necessary to build a more robust model. Second, a continuous and detailed monitoring is required for a calibration of the model for a better understanding of the system. Third, research for other universities

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