Modeling Spin-off Creation in University Technology Transfer with System Dynamics

Mutiara Laksminingrum Sidharta[1,2], Takeshi Arai[1], Utomo Sarjono Putro[2], and Hidetsugu Morimoto[1]

[1]Department of Industrial Administration, Faculty of Science and Technology
Tokyo University of Science, Japan
[2]School of Business and Management, Institut Teknologi Bandung, Indonesia

laksminingrum@sbm-itb.ac.id, tarai@rs.noda.tus.ac.jp, utomo@sbm-itb.ac.id, m0r1m0t0@rs.tus.ac.jp

ABSTRACT

University spin-offs become more and more preferred in recent years as an option to transfer university technology to the market due to its social economic advantage. As a result of Japanese government policy in 2001, number of university spin-offs increased at the beginning yet declined after five years. By focusing on university level, this paper explores activity of technology transfer from research project as initial step of technology transfer to university spin-off as one of technology transfer channel. System dynamics is used to model the system. The proposed model allows intervention to the activity in form of initial capital and support on business model and practice to increase number of new university spin-off. Simulation results show that both factors positively correlates with number of new university spin-off. In addition, TLO support is found to have higher influence than initial capital in longer term.

Keywords: University technology transfer, Spin-off, System dynamics

1. INTRODUCTION

In recent years, more attention has been given to new firms founded by university faculty and staffs to exploit intellectual property (university spin-offs), as it is believed to have importance in regional economic growth through knowledge spillover. University spin-offs also open wider chance of employment, which cannot be met by established firms. Further, with good management university spin-offs may grow into major firms, naming Genentech in biotechnology, Cirrus Logic in semiconductors, and Lycos in Internet search engines in the line (Di Gregorio & Shane, 2003). Therefore, not only as technology transfer channel, university spin-offs also contribute in helping the economy.

Compared to the United States and the United Kingdom, Japan is very lack behind in number of university spin-offs (Figure 1) although it leads in number of patent application per year (The World Bank, 2014). To encourage the creation of university-launched ventures[1], Japanese government assigned '1000 university ventures plan' (Hiranuma Plan) in 2001. This plan reached its goal within three years where the plan successfully doubled the number of new companies (Figure 2) (Miki, 2012) . However, unexpected declining trend followed the peak without any sign of significant rebound until recent years. This phenomenon was also recorded in a survey on university ventures with high sales volume as shown in Figure 3 (Teikoku Data Bank, 2013).

In the latest plan to improve the economy, Japanese government had once again put expectation toward university ventures as one strategy in strengthening science and technological innovation (Teikoku Data Bank, 2013). Reflecting to past experience, appropriate efforts should be considered to support creation of university ventures. Although government provides large budget to be used, e.g. for capital, any significant results would not be apparent if not supported by other aspects, including business model, market research, and excellent management team.

This paper tries to unravel the process leading to university spin-off creation (type 1 in Japanese university venture categories). Focusing on institution (university) level, this paper explores possible introduction to increase number of university spin-offs. The policy would be in the form of initial capital and Technology Licensing Office (TLO) support where

[1] In Japan, the term 'university-launched venture' or 'university venture' includes four categories, i.e. 1) firms that are founded by university faculty, researchers, postdocs, students or graduate students based on patented technology; 2) other than 1), firms that are founded based on non-patented technology; 3) firms that are founded by involving university faculty, researchers, postdocs, students or graduate students; 4) firms that are founded due to TLO investment (Ogura, 2009). The term 'university spin-off' used in this paper refers to university venture type 1.

positive correlation is expected.

Founding university spin-off is a dynamic process happens in a highly complex environment. It involves numerous interactions within university and with external environment, which may be subtle enough to be easily pointed out. Time lag may also occur between action and result, adding complexity to the process, especially regarding consequences of one policy.

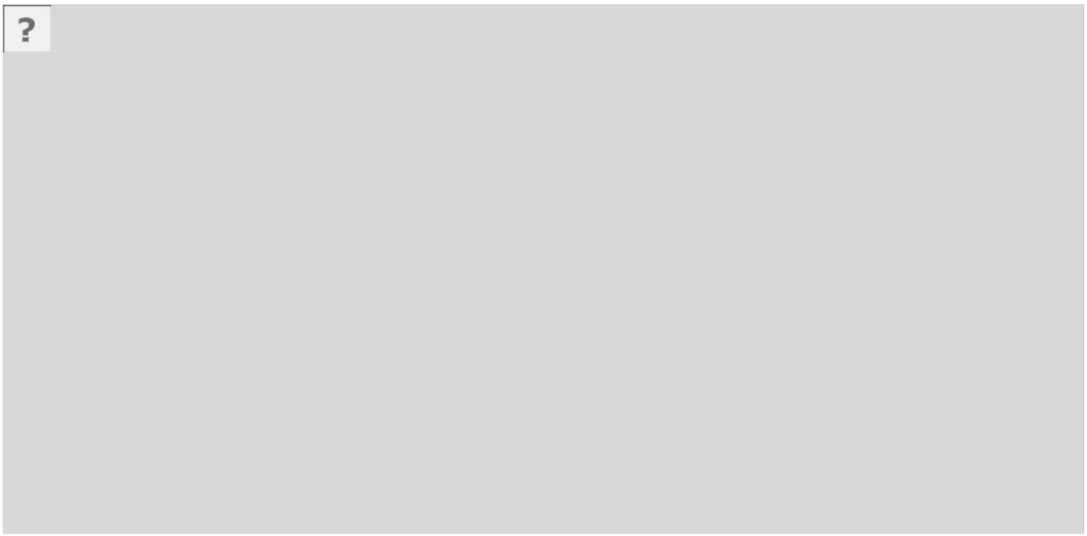

Figure 1. Number of Japanese newly established university spin-off
in comparison with US and UK (Adapted from Ogura, 2009)

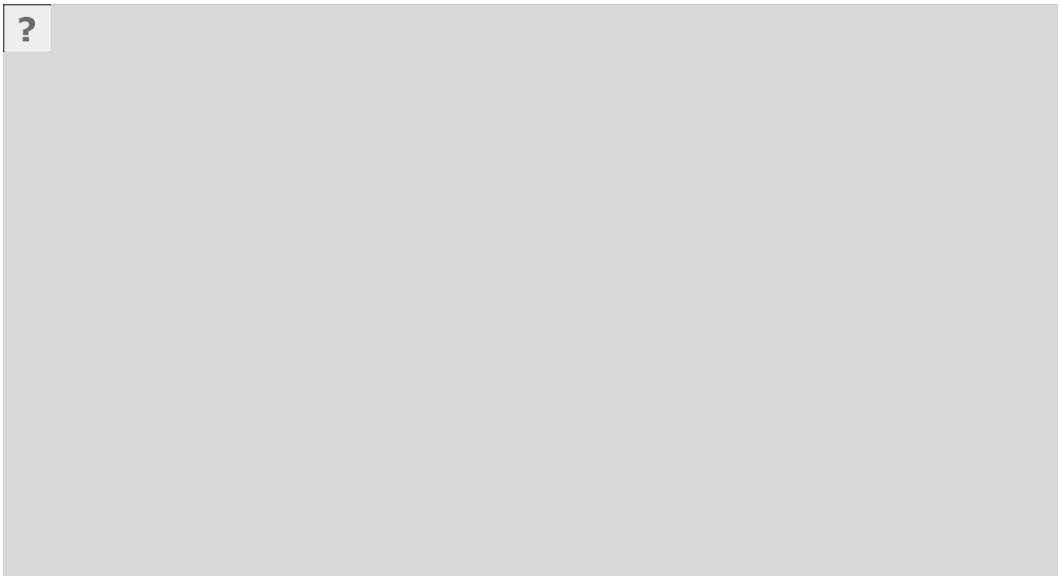

Figure 2. Number of newly established university ventures in Japan (Miki, 2012)

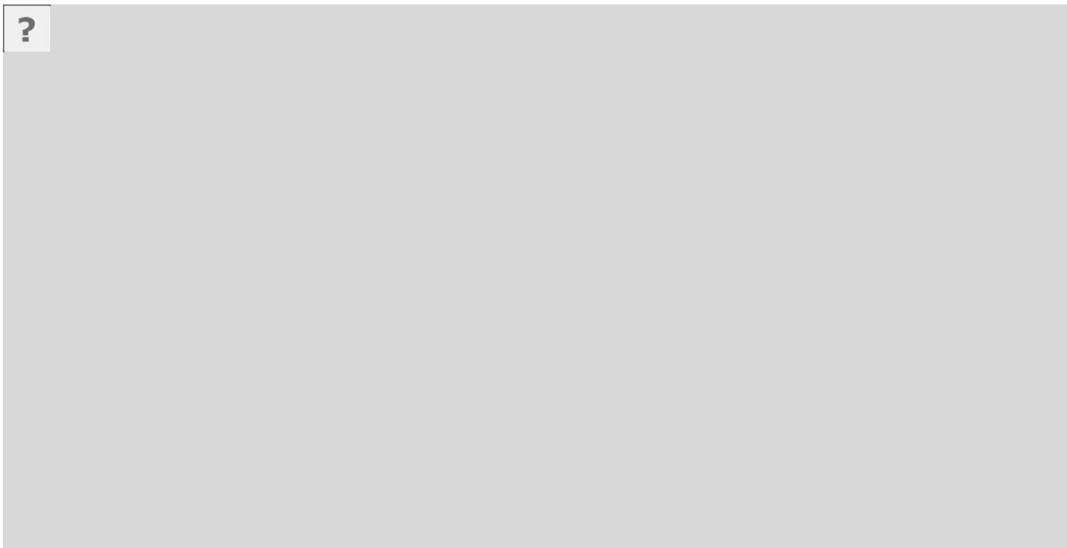

Figure 3. Number of university ventures with high sales volume according to year of establishment
(Teikoku Data Bank, 2013)

System dynamics (SD) model is employed to model the problem. SD model is characterized by feedback loops and stock and flows to model behavior over time of a complex system (Wu et al., 2010). Model structure, time delays, and amplification, which occurs through feedback affect SD model (Thompson & Bank, 2010). There has been no study so far about university spin-off using SD model. Through simulation, SD model can be used to help decision makers in making policy for the problem in question by testing different strategies.

The proposed model is tested by a case study of Tokyo University of Science (TUS). By applying data of university spin-offs, results show that introduction of initial capital and TLO support does influence number of new university spin-off. It may give perspective for future policy regarding both factors.

The rest of the paper is organized as follow. Section 2 consists of literature about university spin-off. Section 3 explains current condition of technology transfer in TUS. Section 4 presents a SD model of technology transfer from university, which illustrate interactions among variables in the system. Section 5 demonstrates the model through simulation using the software Stella 9.1.3. Section 6 is conclusions.

2. TECHNOLOGY TRANSFER CHANNEL: UNIVERSITY SPIN-OFF

The enactment of Japanese Bayh-Dole Act in 1998 became the milestone in the trend of entrepreneurial university in Japan. University is no longer seen solely as an entity where teaching and research takes place; its role expands to what is called as 'third mission', that is economic and social development through commercial activities including patenting, licensing, and creating company (Baycan & Stough, 2013; Etzkowitz, 2003). This highlights the importance of technology transfer in the way to commercialize knowledge produced in university.

University technology transfer process passes on scientific and technical knowledge, in the form of invention or intellectual property, from one party (university) to another (for-profit entity) to gain economic advantage (commercialized) (Friedman & Silberman, 2003; Sheft, 2008). University technology transfer allows scientific and technological developments accessible to wider range of users who can then transform it into products, processes, applications, materials or services (Mitasiunas, 2013). Not just accelerating the process of moving university-produced knowledge to the market place, university technology transfer also contributes largely in realizing knowledge-based economy of one country.

University technology transfer process consists of several steps as explained by Friedman & Silberman (2003) (Figure 4). After disclosure of invention by university faculty, TLO conducts necessary assessment to measure potential marketability of the inventions. The office then submits patent application for technology with good prospect in the market. The right to exploit patent-protected technology may be transferred through licensing agreement to an individual or company who is interested to further develop the early-stage technology. University earns licensing income once the technology is commercially produced and profitable. Particularly for spin-off and start-up, direct impact on job and wealth creation is suggested in the model.

To clearly define university spin-off which become the focus of this paper, we follow Bradley, Hayter, & Link (2013, p.17) who distinct spin-off from start-up. Spin-offs are defined as 'new companies formed by individuals (faculty members) related to the university or university research park to develop a technology that was discovered in, and is transferred from, the parent organization', while start-up companies are "created by licensing an embryonic invention to an independent entrepreneur (who is not necessarily a university faculty member), with the goal of developing the company around the growth and commercialization of the technology'. In summary, university spin-offs involve two main points (Breznitz et al., 2008): 1) transfer of technology from university to new company; 2) inventor academic(s) who may or may not be currently affiliated with university are part of founding member(s).

Spin-offs are exceptionally important in the topic of academic entrepreneurship. Spin-offs are more likely to develop basic research technologies that are not favored by established companies due to its less profitability or which market has not readily available (Swamidass & Vulasa, 2009). Through spin-offs, the gap between university research and industrial commercialization may be reduced. Furthermore as mentioned earlier in this paper, spin-offs also bring social and economic advantages, including employment creation, especially for high-educated graduates and strengthening the local economy (Peng, 2006; Sætre et al., 2009). In terms of early-stage technology development before ready to be launched to market, spin-offs are benefited from the involvement of inventor(s) in creating the company from the beginning due to the tacit knowledge of the invention they possess.

Regarding university spin-offs creation, Di Gregorio & Shane (2003) mentioned about micro- and macro-level factors influencing the decision to create new company intended to exploit university invention. While micro-level factors explain about individual-related determinants, macro-level factors deal with wider scope of determinants, including organizational, institutional, and external determinants (O'Shea et al., 2008). Despite the importance of both factors, this paper only discusses the effect of macro-level factors on university spin-off creation rate corresponding to boundary of the system described in next section.

Intellectual eminence and university policy are two factors, which are suggested to increase creation of new spin-offs (Di Gregorio & Shane, 2003). O'Shea et al. (2008) mentioned tangible and intangible factors related to spin-off creation, such as university funding for R&D activities, nature of research, faculty quality, university policy, and role of Technology Transfer Office (TTO). Entrepreneurship climate is important to support the creation of new companies, thus efforts to foster the climate to grow are necessary, such as constructing reward system for TTO staffs, increasing competencies of TTO staffs, designing flexible university policies, allocating resources to TTO, and eliminating cultural and informational barriers that impede technology transfer process (Siegel et al., 2004).

In a study involving seven European universities, Gómez Gras, Galiana Lapera, Mira Solves, Verdú Jover, & Sancho Azuar (2007) found that the excellence of academic staff and financial support available in universities were two main factors associated with spin-off number and performance. The authors also mentioned about university's support on training and advice before and during first start-up stages, as well as infrastructure support. In addition, the importance of qualified TTO staffs with marketing, technical, and negotiation skills, more than just number of personnel was further underlined. These skills may enable spin-off to be more attractive to external financing.

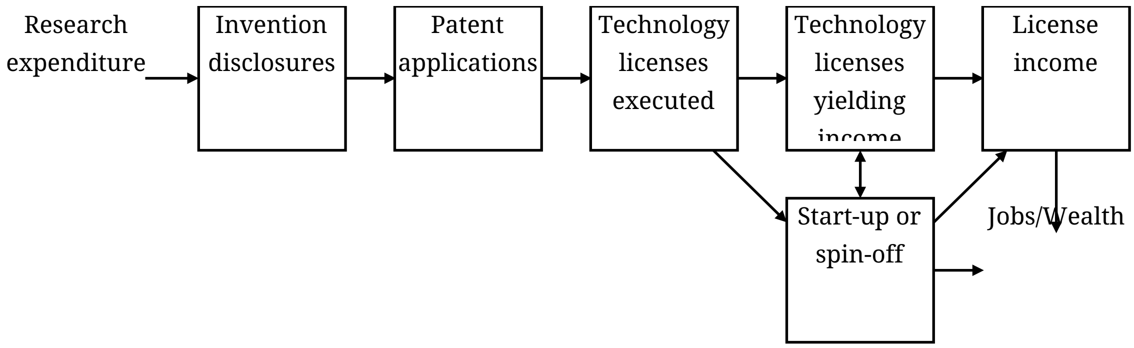

Figure 4. University technology transfer process (Friedman & Silberman, 2003)

3. CASE STUDY: TOKYO UNIVERSITY OF SCIENCE SPIN-OFFS

Tokyo University of Science is one of Japanese private university, which found its history back to 1881 foreran by Tokyo Butsurigaku Koshujo (Tokyo Academic of Physics). Due to the enactment of Japanese TLO Law in 1998 and Bayh-Dole Act in 1999, more attention was paid to transfer university technology to industry. TUS TLO was established to facilitate cooperation between academia and industry by creating, protecting, managing and utilizing university-owned intellectual property rights. The goal is to disseminate university accumulated knowledge to society (TUS TLO, 2010a).

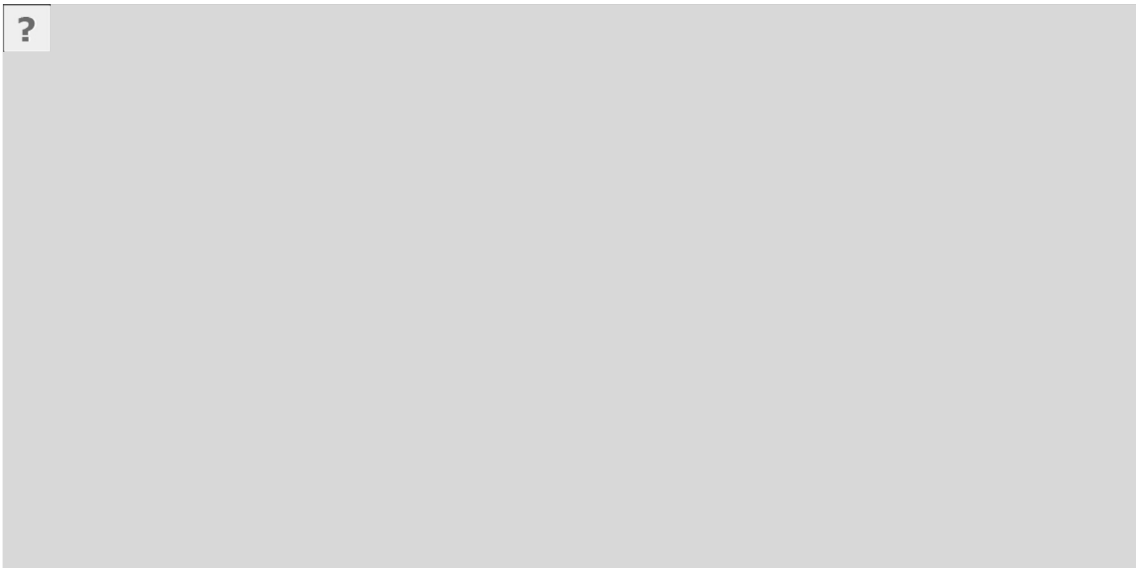

Figure 5. Tokyo University of Science technology transfer statistics

Increasing trend in number of invention disclosure and national patent applications was historically recorded as shown in Figure 5 with highest increase (almost three-fold) happened in 2004 (TUS TLO, 2010b). Slight decrease in 2008 was due to priority shift from quantity to quality. This suggests a preference toward concentrating TLO resources to inventions with high commercial potential rather than submitting many patent applications yet less marketable. Of total national patent applications, TUS sole applications hold about approximately 48% in the last 5-years average. In this paper, we do not incorporate joint applications since its chance to be exploited through industrial licensing is higher than through university spin-offs.

Responding to 2001 Hiranuma Plan, by 2004 fifteen new university spin-offs were created in TUS (Figure 6) (TUS TLO, 2010c). However in the succeeding years, most of the companies were out of business, leaving four companies in 2012. Although one new company was established afterward (will not be incorporated in the model simulation), low establishment and survival rate suggests necessary effort should be taken to improve current condition. At present, TLO support mainly consists of free facilities and equipment for a certain period of time (later use will be offered for a fee) and waived utility use fees for a limited time. Besides that, new spin-off may use the name of university to indicate the institution origin.

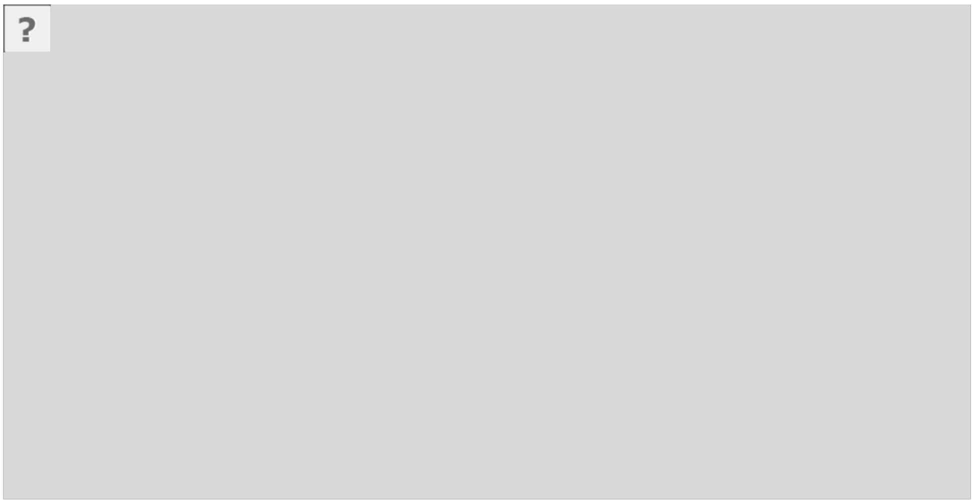

Figure 6. Number of Tokyo University of Science university spin-offs

4. CAUSAL LOOP DIAGRAM

A SD model is usually constructed based on a causal loop diagram (CLD). CLD helps to visualize connections among variables in a system, which is represented by arrows with positive or negative labels. Positive causal link means when the cause (node where the link starts) increases (or decreases), the effect (node where the link ends) also increases (or decreases). The opposite direction is shown by negative causal link, in which increase (or decrease) of cause resulted in decrease (or increase) of effect.

CLD is developed to have comprehensive view of university technology transfer process, particularly that leads to spin-off creation. Variables incorporated in CLD, and in SD model as well, are extracted from direct interview with TUS TLO staff and university faculty who is also a founder of university spin-off and homepage of related institutions, i.e. Japan Patent Office, TUS, and TUS TLO, by referring to previous literatures on university technology transfer. Through these variables, CLD helps to determine the system boundary, which is set to university internal environment.

As suggested by Siegel et al. (2003), the general flow of university technology transfer process consists of variables such as scientific discovery, patent, and license to firm (existing firm or start-up). Consequently university may benefit from royalty or equity stake in a new venture established around licensed technology. Variables related to source of research funds give insight about how university research projects are initiated Ustundag et al. (2011). Research projects might be driven by industrial demand (resulted in industry sponsored research contract) or personal interest of faculty members (funded by university budget or national government fund) (Wayne, 2010). However, in this paper we only include university budget and government fund, assuming that industrial research fund would lead to joint patent application, thus more likely to be licensed by corresponding industry. Other variables include capacity of TLO e.g. size, labor division, PhD holder staffs, experience, policy (Friedman & Silberman 2003; Ustundag et al. 2011), and capacity of university, e.g. type, location, policy, regulations (Friedman & Silberman, 2003; Wayne, 2010). Influence of external factors on university technology transfer is represented by national government policy. This variable will not be included in the SD model as it is out of the system.

Availability of initial capital and TLO support are two variables specific to new business creation focused in this paper. Studies by, e.g. Ismail et al. (2010), Peng (2006), and Sætre et al., (2009) emphasized the importance of securing sufficient funding to develop new technology-based firms. In terms of TLO support, Lockett & Wright (2005) found that TLO staffs with business development capabilities are important determinants of a univer sity's success in creating spin-offs.

CLD of university technology transfer is illustrated in Figure 7. The diagram is composed of core process of university technology transfer (blue arrows), which is inseparably related to university and TLO (red arrows) and external factors, in this case national government policy (black arrow).

University technology transfer traces its process back to research projects, which funds come from the university and government. New technologies resulted from a particular research project add to the stock of invention and may be patented then licensed by established firm. Licensee may gain profit from the licensed technology, which includes percentage of royalty to be given back to researcher. Royalty may further encourage researcher to contribute to increase of stock of invention, thus completes the loop of university technology transfer. Other than established firm, TLO may decide to license new technology to university spin-off. However, higher percentage of royalty from licensing activity to established industry may demotivate researcher to create spin-off.

University and TLO influence the core process of university technology transfer. Amount of yearly budget for research heavily depends on university policy. University capacity, especially the one relates to faculty quality, positively influences number of new spin-offs. University capacity also indirectly influences number of new spin-offs through available initial capital, which is provided through government grants. University policy relates to the capacity of TLO in which it will support or deter university technology transfer process. TLO capacity positively influences number of patent application directly, while indirectly affect number of new university spin-offs through its various support provided to university faculty or staffs.

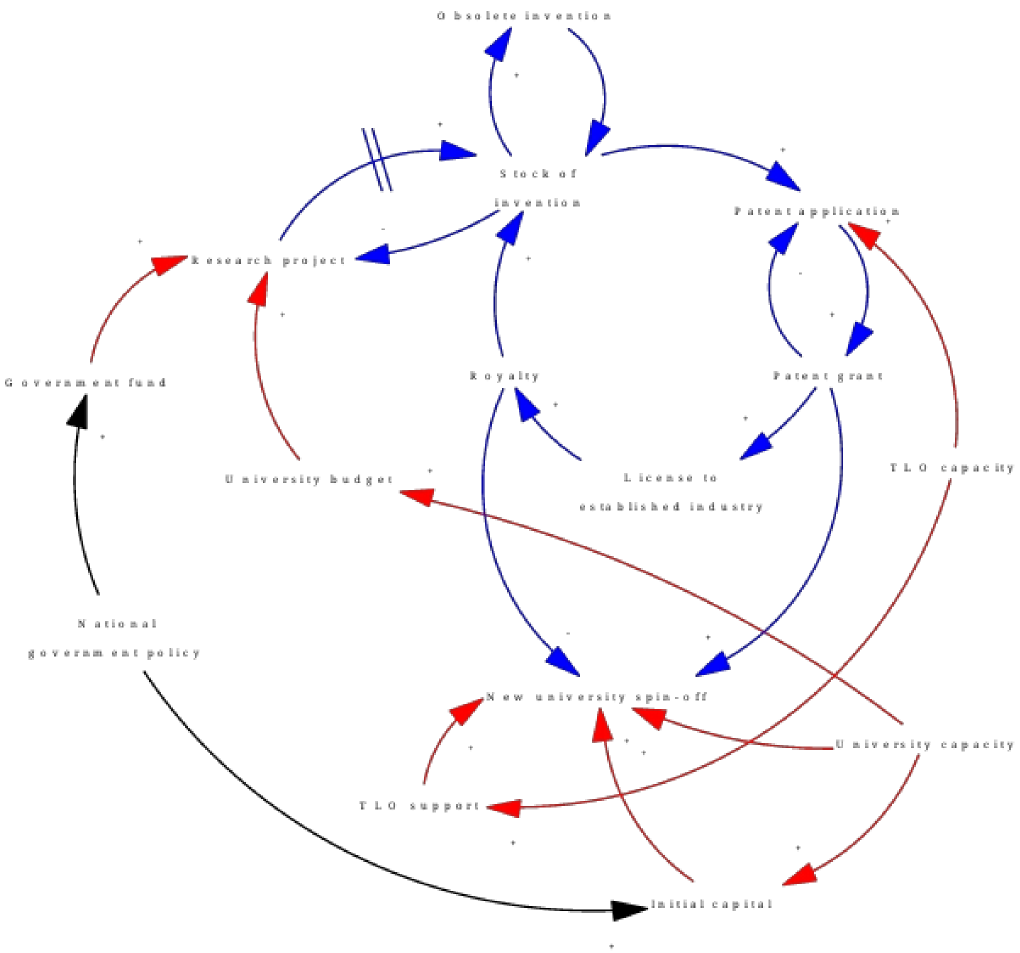

Figure 7. Causal loop diagram of university technology transfer

5. MODEL STRUCTURE

Based on CLD's qualitative descriptions of university technology transfer system, a SD model is then developed to have a quantitative analysis of the system. Three sub-models represent research project model, technology transfer model, and university-spin-off creation model (Figure

8).

5.1. Research project model

Research project is considered as the initial step of technology transfer process as suggested by Friedman & Silberman (2003). Two source of funds are highlighted in this model, i.e. university budget and government fund. University yearly budget is largely determined by number of new and current enrolled students, as it is the first contributor of university yearly income. Researcher capacity (e.g. experience, achievements) may increase the possibility of winning research fund for new project.

5.2. Technology transfer model

Subsequent to the enactment of TLO Law and Japanese Bayh-Dole Act, TLO manages the filing of invention disclosures, which become the entry of proceeding technology transfer stages. Nevertheless, faculty may not disclose their inventions because of various reasons, such as not being able to recognize the commercial potential of the invention or not willing to spend time and effort in licensing or further development of the technology (Jensen et al., 2003). These might be the reasons why only less than half of the inventions with commercial potential are disclosed as reported by the same authors.

On the other hand, not all invention disclosed are actually have commercial value. TLO conducts necessary assessment in terms of patentability and marketability before submitting patent application. Patent application is not certainly examined; Japan Patent Office will carry out an examination on one application only by request. Patent will be granted if no reasons for refusal are found (Japan Patent Office, n.d.). Patents may be licensed to attracted industry, yielding amount of license income for university that is shared with faculty in form of royalty. Royalty may further motivate faculty to disclose their invention and involve in technology transfer activity (Goktepe-Hulten & Mahagaonkar, 2010).

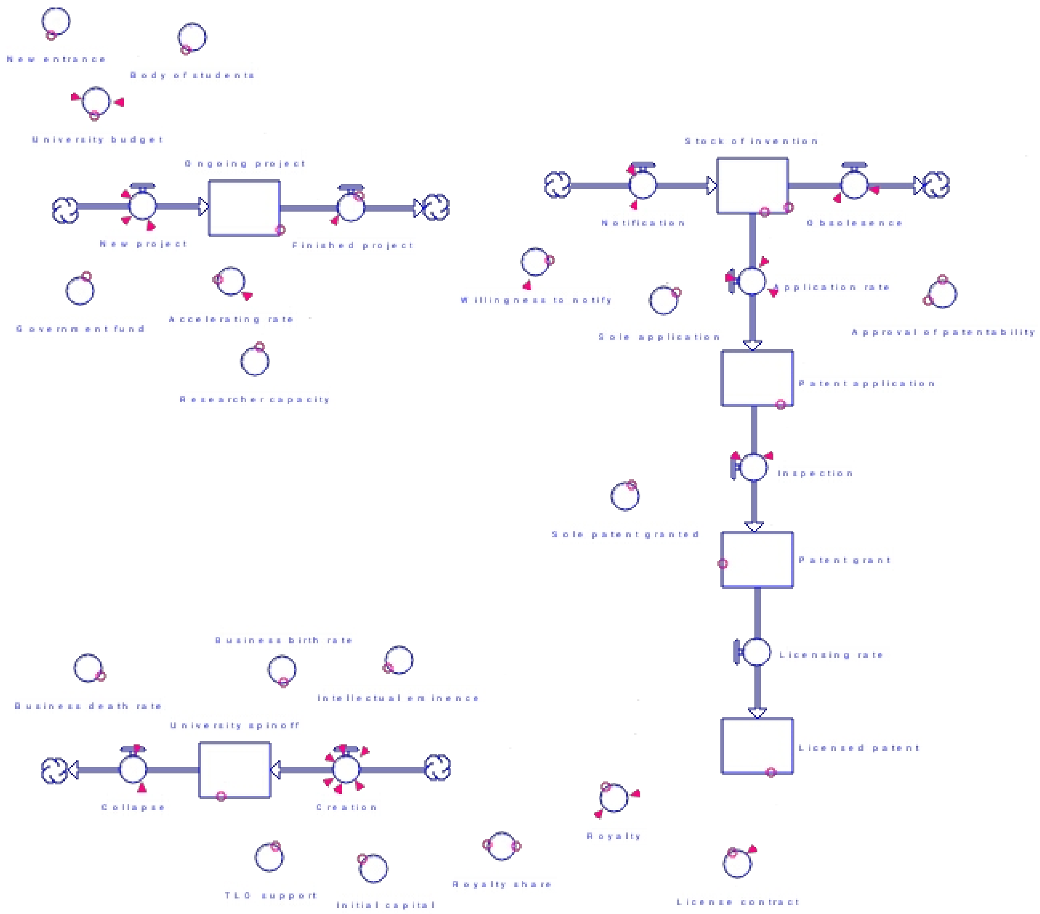

Figure 8. University spin-off creation model

5.3. University spin-off creation model

Although licensing and university spin-off creation seems to not having any close relationship, Di Gregorio & Shane (2003) found that percentage of royalty share inversely related to spin-off creation per year. Higher royalty distribution rate for faculty discourage faculty to choose spin-off to exploit their invention. Other determinants include faculty quality, which is measured by examining overall university ranking of Japanese universities. Business birth rate and death rate are calculated by dividing number of newly established or closed company in certain year by number of active companies exist in the previous year.

Introduction to be observed in this SD model is the introduction of TLO support and initial capital. The first introduction, TLO support, emphasizes TLO roles in providing necessary aids to spin-off creation, particularly because faculty lacks of business expertise and might prefer to concentrate more on research. The importance of TLO in spin-off creation is mentioned in previous literatures, e.g. Siegel et al. (2007), Siegel et al. (2004). Here we define TLO support into constructing business model, conducting market research, connecting to potential business partner, assisting in legal issues. To provide these, TLO must have enough resources, capabilities and knowledge in spin-off creation, which could be met by recruiting qualified and experienced staffs.

Securing capital is an important matter in creating a business, including spin-off. Given many constraints, university cannot afford to provide such fund, thus external funding is crucial (Ismail et al., 2010). Nevertheless, since the technology is still in early-stage, it might be difficult to compete for venture capital. The funding may come in form of government grants allocated to support commercialization of innovative, yet highly risky university technologies (Peng, 2006; Sætre et al., 2009). Different with past program where government only gave certain amount of money at once, this time besides large amount of government grant given in the beginning of policy introduction, fund was also available through a continuous program of which university researchers could access any time.

6. EMPIRICAL ANALYSIS

6.1. Preliminary model testing

Throughout model building process, several model tests were iteratively done. Although it is impossible to validate or verify a model due to the nature of model as limited and simplified representations of the real world (Sterman, 2000), model testing is undoubtedly necessary. Model testing took place after the initial model formulation was completed. Three steps of model testing were suggested by Barlas (1996) of which each has to be fulfilled before proceeding to the next step.

Direct structure tests are the first step, carried out by directly comparing model structure with knowledge about real system structure. Simulation is not yet involved. Besides empirically, direct structure tests can be performed theoretically. Examples of test results are shown in Table 1 (see Barlas (1996) for more tests).

Table 1. Direct structure tests

Test name	Description	Example
a. Empirical test		
Structure-confirmation test	Form of equations of the model is compared with the relationships exist in the real system.	Model: Obsolescence=(1-Approval of patentability)*Stock of invention Real system: Inventions that fail TLO assessments (patentability and marketability) may end up obsolete, thus reduce the stock of invention.
Parameter-confirmation test	Constant parameter is evaluated against the corresponding element exists in the real system, both conceptual and numerical.	Model: Approval of patentability=0.8 Real system: Average percentage of TUS national patent applications is around 80% of number of notification of invention in the last five years (2008-2012) (Figure 5).
b. Theoretical test		
Direct extreme-condition test	The likelihood of the resulting values is assessed against the knowledge of what would happen under similar condition in real system.	Model: Research project model Real system: If no new students enroll in university, then university budget for research must decline. Number of new project, ongoing project, and finished project also must decline.
Dimensional consistency test	The right-hand side of each equation is checked for its dimensional consistency with the left-hand side.	Model: New project (*number/year*)=((University budget (*yen/year/number*)/10000000 (*yen*))+(Government fund (*yen/year/number*)/50000000 (*yen*)))*Accelerating rate (*unitless*)

The second step is structure-oriented behavior tests, which indirectly assess model structure by performing certain behavior tests on model-generated behavior patterns. This time it involves simulation. In extreme-condition test, extreme values are assigned to selected parameters. The model-generated behavior is then compared to the observed or anticipated behavior of the real system under the same extreme condition. The result of extreme condition test toward constructed model is shown in Figure 9. With a 1-year delay in ‘finished project’ variable, behavior of ‘ongoing project’ is oscillatory. As explained in previous direct extreme-condition test, if there is no new entrance, then university budget must decline. New project and ongoing project must decline as well. The same behavior happens when no government fund is available.

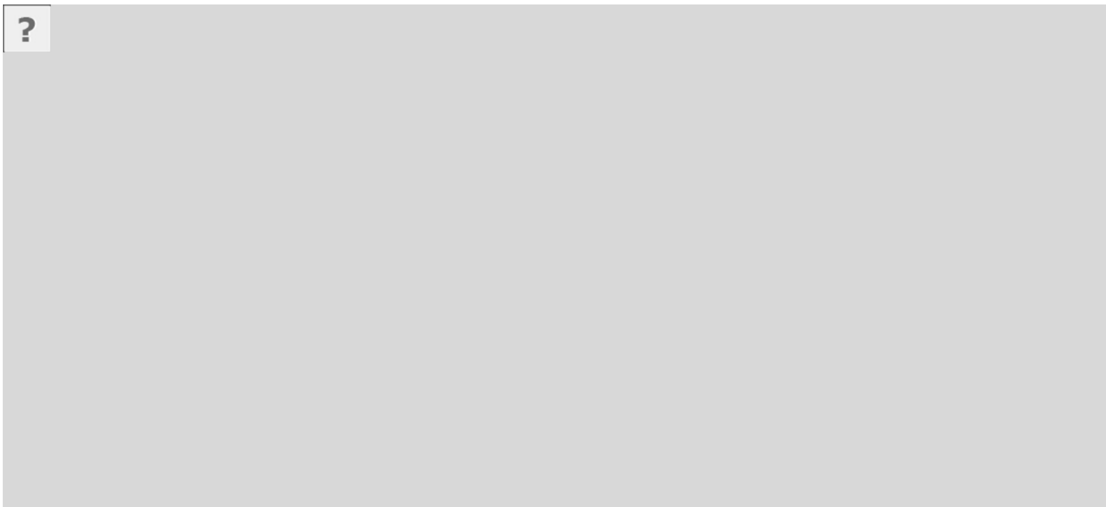

Figure 9. Results of indirect extreme-condition test

The third, also the last test, is behavior pattern test. The model is expected to be able to accurately reproduce major behavior patterns exhibited by the real system. We perform behavior pattern test using current data of university spin-offs in TUS, by also considering actual amount of university income raised from tuition fees and spent as university budget for research, government fund for research acquired by TUS, number of invention notification per year (calculated as notification rate), number of patent application per year (calculated as application rate), total number of patent grant, and number of university spin-offs (unpublished work) (equations are presented in Appendix A). When run with available data, the result shows similar trend with actual data (Table 2).

Table 2. Comparison of actual data and model testing result on number of university

spin-offs

Year	Actual data	Model testing
2002	12*)	12
2003	15*)	14.8
2004	15	14.8
2005	15	14.8
2006	15	14.8
2007	10	10.8
2008	10	9.8
2009	9	8.8
2010	8	7.9
2011	5	4.9
2012	4	3.9

*) Initial number is based on assumption due to unavailable data.

6.2. Simulation

Simulation with the constructed SD model is run for three scenarios. In Scenario 1, new spin-offs receive adequate support from TLO. We set support on business model and practice as logistic curve (value: 1.06-3.76) assuming that TLO would need time to carry out internal transformation, especially in preparing qualified staffs with knowledge, capability, and experience in spin-off creation. Scenario 2 reflected the availability of government grant as initial capital (value: 1.5). Following large amount given in the beginning, government grant is assumed to be available in continuous manner.

To figure out which parameter contributes more in spin-off creation, we run one more scenario. In Scenario 3, both TLO support and initial capital are introduced at the same time. Although it was easy to assume that in this scenario, number of university spin-offs must be higher than previous scenarios, the idea was to see how large the two factors could affect university spin-off creation if applied at the same time.

Because this study aims to, one of them, search for policy that can promote spin-off creation, policy introduction would likely, and logically, increase business birth rate. Corrected birth rate started at 0.67 (same as test model), assumed as a response to Japanese government grant to stimulate university spin-off creation. Yet, it gradually declined over time and was stable at around 0.06. Initial simulation conditions are set as follows: initial time=0, final time=10 (year), time step=1. All other parameters are equal. Figure 10 shows simulation results compared to base simulation.

Figure 10. Number of university spin-offs after introduction by initial capital and TLO support

As expected, introduction of TLO support and initial capital would stimulate creation of university spin-off. Results for Scenario 1 suggest the importance of providing services related to business creation, especially because usually university researchers have insufficient business knowledge and experience to start new company on their own. They might also still prefer to spend their time and effort in research than in commercializing their technology. Quality of services is highly influenced by quality of TLO staffs. Therefore, it is worth the effort to recruit excellent staffs with business experience, knowledge, and skills.

Introduction of initial capital in Scenario 2 would increase number of spin-off in TUS. However, at year nine the number decreases. This indicates that even when initial capital is available continuously, it was not enough to keep number of spin-off in longer term. Other factors might be essential to prevent business collapse.

Interestingly, when introduced separately, effect of initial capital exceeds effect of TLO support for the first six years. It suggests that availability of initial capital would encourage creation of university spin-off in a more instant way, yet it would not last in a longer period. In reverse, since TLO would need some time to improve their support and reach optimum level, following increase in earlier years, number of spin-off would be more stable, with tendency to increase in longer term.

When TLO support and initial capital introduced at the same time, number of spin-off in year ten is 2x compared to effect of initial capital alone and 1.5x compared to effect of TLO support alone. Furthermore, growth trend of spin-off followed the trend for TLO support policy alone. Consequently, when speaking about degree of contribution in the combined policy, TLO support is likely to have higher contribution in increasing university spin-off number than initial capital.

7. CONCLUSIONS

This paper described the use of system dynamics to model university technology transfer, especially spin-off creation. The constructed model simulated relationship between research project funding as the initial step of technology transfer, main process of technology transfer, and spin-off creation as one channel of technology transfer. Case study of TUS was conducted to validate the proposed model.

Simulation results provided general view of how introduction of TLO support and initial capital may enhance number of university spin-offs. TLO support contributed more on the effect, especially for longer term. This suggests that even in the absence of initial capital, it is important for university to improve quality of TLO support, first by recruiting qualified staffs. They may open new doors of opportunity, including finding potential financing and connecting to business partners by using their network. Nevertheless, it is important to be noted that ups and down can still be seen in the later period. Appropriate policy should be made to increase survival rate of university spin-offs, while fostering new companies at the same time.

REFERENCES

Barlas, Y. (1996). Formal aspects of model validity and validation in system dynamics. *System Dynamics Review*, *12*(3), 183–210.

Baycan, T., & Stough, R. R. (2013). Bridging knowledge to commercialization: the good, the bad, and the challenging. *The Annals of Regional Science*, *50*(2), 367–405.

Bradley, S. R., Hayter, C. S., & Link, A. N. (2013). *Models and Methods of University Technology Transfer* (pp. 1–73).

Breznitz, S. M., O'Shea, R. P., & Allen, T. J. (2008). University Commercialization Strategies in the Development of Regional Bioclusters. *Journal of Product Innovation Management*, *25*(2), 129–142.

Di Gregorio, D., & Shane, S. (2003). Why do some universities generate more start-ups than others? *Research Policy*, *32*, 209–227.

Etzkowitz, H. (2003). Research groups as "quasi-firms": the invention of the entrepreneurial university. *Research Policy*, *32*, 109–121.

Friedman, J., & Silberman, J. (2003). University Technology Transfer: Do Incentives, Management, and Location Matter? *Journal of Technology Transfer*, *28*, 17–30.

Goktepe-Hulten, D., & Mahagaonkar, P. (2010). Inventing and patenting activities of scientists : in the expectation of money or reputation ? *J Technol Transf*, *35*, 401–423.

Gómez Gras, J. M., Galiana Lapera, D. R., Mira Solves, I., Verdú Jover, A. J., & Sancho Azuar, J. (2007). An empirical approach to the organisational determinants of spin-off creation in European universities. *International Entrepreneurship and Management Journal*, *4*(2), 187–198.

Ismail, K., Mason, C., Cooper, S., Wan Zaidi, W. O., & Majid, I. A. (2010). University Spin-off Formations: How decision making process has been made? *International Journal of Business and Social Science*, *1*(2), 103–123.

Japan Patent Office. n.d. Procedures for Obtaining a Patent Right. Retrieved March 17, 2014, from https://www.jpo.go.jp/cgi/linke.cgi?url=/tetuzuki_e/t_gaiyo_e/pa_right.htm.

Jensen, R. A., Thursby, J. G., & Thursby, M. C. (2003). *The Disclosure and Licensing of University Inventions* (pp. 1–28).

Lockett, A., & Wright, M. (2005). Resources, capabilities, risk capital and the creation of university spin-out companies. *Research Policy*, *34*(7), 1043–1057.

Miki T. 2012. 我か国における大学発ヘンチャー施策の歩みと今後の方向性

(Progress and future directions of university ventures policy in Japan). 大学発新産業創出拠点プロジェクト(START)シンポジウム, 日本型イノベーション・エコシステムの構築に向けて (Creation of new university-launched industries based project (START) Symposium: Towards the construction of a Japanese innovation ecosystem). National Center for Industrial Property Information and Training, Japan.

Mitasiunas, J. (2013). *Innovation and Technology Transfer* (pp. 1–9).

Ogura M. 2009. Academic Start-ups Survey 2007-08. Survey Material No.173. 3rd Policy-Oriented Research Group, National Institute of Science and Technology Policy (NISTEP), Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

O'Shea, R. P., Chugh, H., & Allen, T. J. (2008). Determinants and consequences of university spinoff activity: a conceptual framework. *The Journal of Technology Transfer*, *33*, 653–666.

Peng, X. (2006). University spin-offs: Opportunity or challenge? *Nature Materials*, *5*(December), 923–926.

Rasmussen, E., & Borch, O. J. (2010). University capabilities in facilitating entrepreneurship: A longitudinal study of spin-off ventures at mid-range universities. *Research Policy*, *39*(5), 602–612.

Sætre, A. S., Wiggins, J., Atkinson, O. T., & Atkinson, B. K. E. (2009). University Spin-Offs as Technology Transfer: A Comparative Study among Norway, the United States, and Sweden. *Comparative Technology Transfer and Society*, *7*(2), 115–145.

Sheft, J. (2008). Technology transfer and idea commercialization. *Nature Biotechnology*, *26*(6), 711–713.

Siegel, D. S., Veugelers, R., & Wright, M. (2007). Technology transfer offices and commercialization of university intellectual property: performance and policy implications. *Oxford Review of Economic Policy*, *23*(4), 640–660.

Siegel, D. S., Waldman, D. a, Atwater, L. E., & Link, A. N. (2003). Commercial knowledge transfers from universities to firms: improving the effectiveness of university–industry collaboration. *The Journal of High Technology Management Research*, *14*(1), 111–133.

Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2004). Toward a Model of the Effective Transfer of Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technologies. *Journal of Engineering and*

Technology Management, *21*(1-2), 115–142.

Sterman, John D. (2000). Business Dynamics: System thinking and Modeling for a Complex World. The McGraw-Hill Companies, Inc. US.

Swamidass, P. M., & Vulasa, V. (2009). Why university inventions rarely produce income? Bottlenecks in university technology transfer. *J Technol Transf*, *34*, 343–363.

Teikoku Databank. 2013. 大学発ベンチャー、過半数が黒字経営 ~自民党政権、「1000 社計画」が寄与~ (University venture, majority profitable: Liberal Democratic Party government, "1000 companies Plan" contribution). 特別企画: 大学発ベンチャー企業の実態調査 (Special Event: Survey of university-launched venture company). Teikoku Databank, Ltd.

The World Bank. 2014. Patent Applications, Residents. Retrieved March 10, 2014 from http://data.worldbank.org/indicator/IP.PAT.RESD?order=wbapi_data_value_2011+wbapi_data_value+wbapi_data_value-last&sort=desc.

Thompson, B. P., & Bank, L. C. (2010). Use of system dynamics as a decision-making tool in building design and operation. *Building and Environment*, *45*, 1006–1015.

TUS TLO. 2010. Greetings from the Director. Retrieved March 15, 2014, from http://www.tus.ac.jp/tlo/english/tlo/ greeting.html.

———————. 2010. Historical Results. Retrieved March 15, 2014, from http://www.tus.ac.jp/tlo/english/service/result.html.

—————. 2010. 大学発ベンチャー(University ventures). Retrieved March 15, 2014, from http://www.tus.ac.jp/tlo/contents/venture.html.

Ustundag, A., Ugurlu, S., & Kilinc, M. S. (2011). Evaluating the performance of technology transfer offices. *Journal of Enterprise Information Management*, *24*(4), 322–337.

Wayne, K. (2010). Determinants of Commercial Innovation for University Technology Transfer. *Journal of Behavioral Studies in Business*, *2*, 1–23.

Wu, D. D., Kefan, X., Hua, L., Shi, Z., & Olson, D. L. (2010). Modeling technological innovation risks of an entrepreneurial team using system dynamics: An agent-based perspective. *Technological Forecasting & Social Change*, *77*, 857–869.

APPENDIX A. Description of parameters

Parameters	Equation	Value	Unit
Research project model			
Ongoing project		300	Number
New project	Z_1=10000000, Z_2=5000000; Y= ((University budget/Z_1)+(Government fund/Z_2))*Accelerating rate		Number/year
Finished project	Y=DELAY(Ongoing project,1)		Number/year
New entrance		5700	Person
Body of students		20000	Person
University budget	Z_1=1500000/person, Z_2 =1200000/person; Z_3=0.15; Y= ((New entrance*Z_1)+(Body of students*Z_2))*Z_3		Yen /year/number
Government fund	Graph		Yen /year/number
Researcher capacity		1	Unitless
Accelerating rate	Graph		Unitless
Technology transfer model			
Stock of invention		30	Number
Patent application	Y=Application rate		Number
Patent grant		5	Number
Licensed patent	Y=Licensing rate		Number
Notification	Y=Finished project*Willingness to notify		Number/year
Obsolescence	Y=(1-Approval of patentability)*Stock of invention		Number/year
Application rate	Graph		Number/year
Inspection	Z=0.4; Y=Patent application*Sole patent granted*Z		Number/year

Licensing rate	Graph		Number/year
Willingness to notify	Graph		Unitless
Approval of patentability		0.8	Unitless
Sole application		0.5	Unitless
Sole patent granted		0.4	Unitless
License contract	Graph		Yen
Royalty	Y=Royalty share*License contract		Yen
Royalty share		0.5	Unitless
University spin-off creation model			
University spinoff		12	Number
Creation	Y=Patent grant*Birth rate of business*Intellectual eminence*Royalty share* Capital*Support on business model and practice		Number/year
Out of business	Y=University spinoff*business death rate		Number/year
Business birth rate	Graph		Unitless
Business death rate	Graph		Unitless
Intellectual eminence		0.97	Unitless
Capital		1.5	Unitless
Support on business model and practice	Graph		Unitless