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The Status of Knowledge Capital in National Innovation Systems

- System Dynamics Model for Policy Implications –

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Abstract

The purpose of this research is to study how we should understand the knowledge capital, how we should locate it in the framework of the national innovation system, and how we should develop our system dynamics model toward policy suggestions for the existing knowledge capitalism. Through this research, I will extended our system dynamics model on the national innovation system which was presented at the 29th annual EAEPE conference 2017 at Budapest. At the previous conference, I proposed our system dynamics model with STELLA which expressed a national innovation system in the recent knowledge capitalism. I have been formulating our system dynamics model on the basis of Marx's general formula of the capital circulation, the Marxian two-sector model and the so-called Schumpeter's hypotheses on the innovation system. But it was not enough, on one hand, to express a difference between the technological knowledge embedded in a real capital and the experienced knowledge accumulated in a human capital. I think now, moreover, I should distinguish between the case of an manufacturing industry and the case of an ICT industry. On the other hand, it was ambiguous on the relation between the fluctuation of the knowledge capital and the other economic variables. Therefore, I will extend and revise our research through this presentation.

The main backgrounds of this research are three previous contributions. The first is the discussions on knowledge itself. I especially focus on the distinction by M. Polanyi between explicit knowledge and tacit knowledge. This has been referred at a really large number of contributions and developed in the area of economics by Foray (2000), Dolfsma (2008), Mazzucato and Dosi (2006), Dolfsma and Soete (2006), and so on. To make clear the characteristics of knowledge in the innovation system will be useful to decide the status of knowledge capital and to express the relations between knowledge flow and knowledge stock in our system dynamics model. In connection with the first point, the second is an evolutionary model of the firm's behaviour by Nelson and Winter (1982) which has been familiar for us. One of the specific methods of their model is the "draw" model which express a stochastic character on success and failure of an innovative investment behaviour. I think this idea can be applied to the knowledge capital as well. I will revise our system dynamics model by adding this implication from the so-called

Nelson-Winter model. The third is an analytical tool of system dynamics. I have been using STELLA to construct our model on the national innovation system because it is useful not only to understand explicitly and intuitively the relations between flow variables and stock variables, but also to express institutional factors which reflect specific innovation policies. Therefore, I will propose policy implications for recent knowledge capitalism through our revised model. Of course, because innovation policies are different among each country, I focus on the case of Japan in this research.

The expected contributions of this research are following points;

1. I can revise our previous system dynamics model to make clear specific roles and characteristics of knowledge in an innovation system and to apply an idea of the "draw" model of Nelson-Winter model to knowledge capital evolution.
2. I will propose some implications toward innovation policies in knowledge capitalism through explicit introduction of actual institutional factors for knowledge creation and knowledge accumulation and examination of the result of our system dynamics model.

Keywords

National innovation system; System dynamics; Knowledge; Institution

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1. Introduction

The purpose of this research is to study how we should understand the knowledge capital, how we should locate it in the framework of the national innovation system, and how we should develop our system dynamics model towards policy suggestions for the existing knowledge capitalism.

According to previous contributions on the historical division of Schumpeter's or Kondratieff's long wave theory, we can consider a present long wave as the 5th long wave whose core technology is ICTs. In Neo-Schumpeterian evolutionary economics, researchers have been developing Schumpeter's grand vision on the long capitalist process and have been understanding it in relation to a concept of national innovation systems (referred to as 'NIS'). This concept has been developed since a latter half of 1980s and there are some variations about its definition and its naming. Carlota Perez who is one of the contributors in this research area gave a name to each long wave the 'techno-economic paradigm' and called a present long wave the 'ICT paradigm' (see Table 1). The distinctive core factors in her theoretical framework are a specific institutional structure of each paradigm and its change through maturing process of each core technology (see Figure 1).

Table 1: Five long waves and three or two phases of each long wave

Long Waves	Core Technologies	Installation*	Turning Point*	Development*
		Upswing**		Downswing**
1st	Water-powered mechanization	1771-90s	1793-97	1798-1829
		1780s-1815		1815-1848
2nd	Steam-powered mechanization, Railways	1829-40s	1848-50	1850-73
		1848-1873		1873-1895
3rd	Electrification, Steel, Heavy engineering	1875-93	1893-95	1895-1918
		1895-1918		1918-1940
4th	Motorization, Oil, Mass production system	1908-29	1929-43	1943-74
		1941-1973		1973-
5th	Computerization, ICT	1971-2001	2001-	-----
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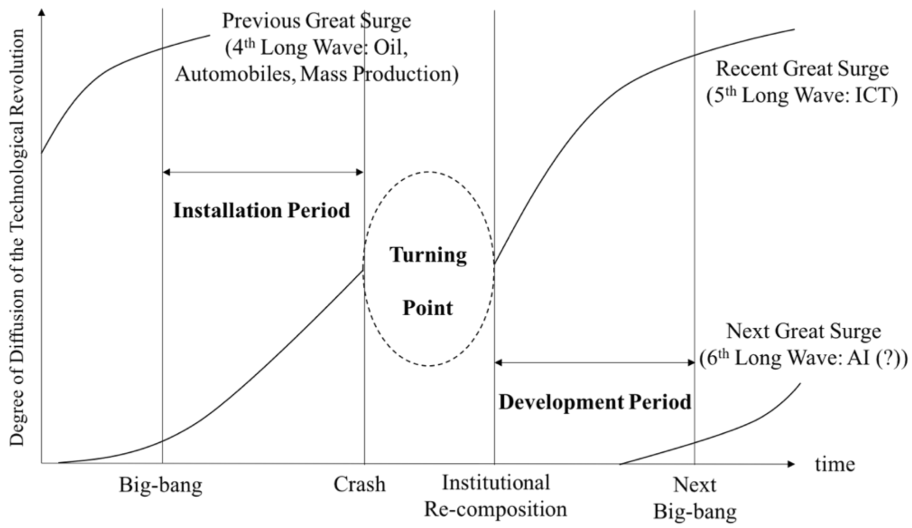
Sources: Perez (2002), p. 57 (upper column: *) and Freeman and Louçã (2001), p. 141 (lower column: **).

Figure 1: A theoretical framework of the ICT paradigm



Considering a division of historical periods of techno-economic paradigms and a transitional process of each paradigm, we can identify our present position as a transitional period between the 5th ICT paradigm and the next new techno-economic paradigm. Then we assume that we are driven under the pressure of institutional reconstruction towards the 'knowledge paradigm'. According to Perez, once again, although a main organizational principle in the 4th manufacturing paradigm was an 'analytical model' which focused on parts and factors of its process, a basis of the 5th ICT paradigm is a synthetic characteristics which focuses on a mutual connectivity for a total techno-economic adjustment. Then, how we should reconstruct or design an institutional framework for the knowledge paradigm just coming. We bring out some policy implications by applying Neo-Schumpeterian approach to the present Japanese government policies.

The rest of the paper is organized as follows. In section 2, we show our analytical framework on the NIS in knowledge capitalism at a general level. In section 3, we consider characteristics of recent Japanese government policies towards the knowledge paradigm and confirm their institutional factors towards our model building in the next section. In section 4, we formulate our system dynamics model step by step and propose some policy implications of our model by comparing with actual policies considered in a previous section. A final section is a brief summary.

2. The NIS in Knowledge Capitalism

In modern Neo-Schumpeterian economics or the economics of innovation, NIS has been confirmed as one of analytical frameworks for studying innovative processes since 1980s[1]. NIS has been defined in various ways as same as the definition of an institution[2]. Through so many contributions have been developed since 1980s, a concept and meanings of NIS have been made clearer. In Chaminade et al. (2018), which is one of the latest contributions on NIS, this concept is defined at two phases by distinguishing between a narrow aspect and a broad aspect. The former is defined as science and technology policies that aim at linking research institutions to users in the private and public sector, the latter is defined as a wider set of policies including industrial policy and policies related to competence building such as education and labour market policy.

For this paper, in particular, Bengt-Åke Lundvall's contribution (Lundvall et al. 2006) is more useful for considering the role of internal institutions of NIS. He divides a term of NIS into three words and defines them respectively. At first,

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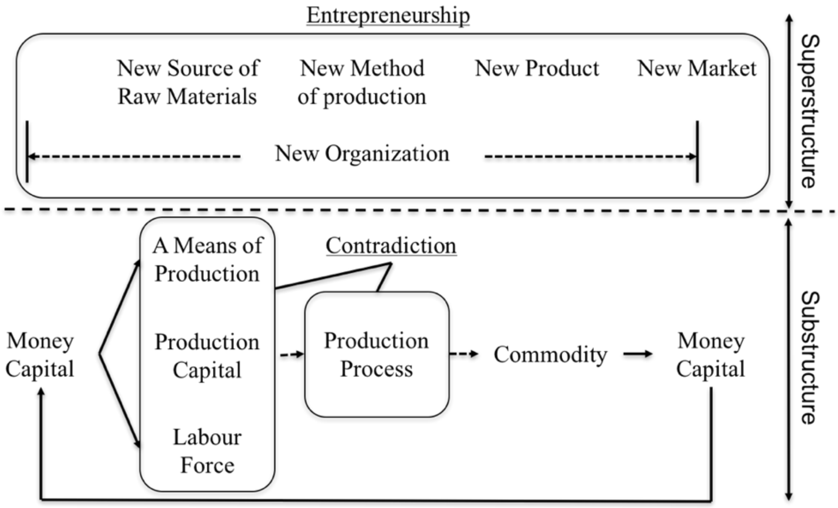
[1] According to Chaminade et al. (2018), this concept was first used in an unpublished paper by Christopher Freeman (1982, 2004) where he linked the concept to a critical discussion of the free trade doctrine and referred to Friedrich List as a predecessor of the concept.

[2] Three early contributions on NIS defined this framework as follows:
(1) "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies". (Freeman 1987, Introduction and Summary)
(2) "a system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge and that a national system encompasses elements relationships, either located within or rooted inside the borders of a nation state". (Lundvall 2010, p. 2)
(3) "a set of institutions whose interactions determine the innovative performance, in the sense above [a well-articulated and verified analytic framework linking institutional arrangements to technological and economic performance], of national firms". (Nelson 1993, p. 4, My square bracket.)

although a concept of 'national' has been regarded as the most dubious element because it brings in, *ex ante*, a level of analysis that might not be the most adequate for understanding the process of innovation, he insists, in contrast, that it has become even more important to be explicit about the national dimension as 'globalization' becomes a major trend. Therefore, the analysis of how various countries differ in terms of institutional set-ups supporting innovation and learning is important in this dimension. A national dimension focuses on the role of government and public institutions in NIS framework. Then, a concept of 'system' is also characteristic. This is considered as a stationary self-reproducing set of elements with interrelationships. So, a change of one system means internal institutions, which are those related to the production, diffusion and use of knowledge, is a process where one constellation of institutions is turning into a different constellation of institutions (Lundvall et al. 2006, p. 1).

In another perspective, there is thus little doubt that both Freeman and Lundvall saw the national innovation system concept as a challenge to neoclassical economics. In other words, they focused on a capitalist production system like Marxian economics and Schumpeter's work. Then, we have discussed about Marx's and Schumpeter's notion of 'economic evolution'. Although the main internal factor for Karl Marx and Joseph A. Schumpeter was endogenous technological changes, on one hand, Marx focused on contradictions between the development of productivity and the relations of production, on the other hand, Schumpeter focused on new combinations (or creative destructions) by individual entrepreneurs. In other words, as to the source of economic evolution, Marx considered it a revolutionary change in the substructure and Schumpeter considered a discontinuous change in the superstructure.

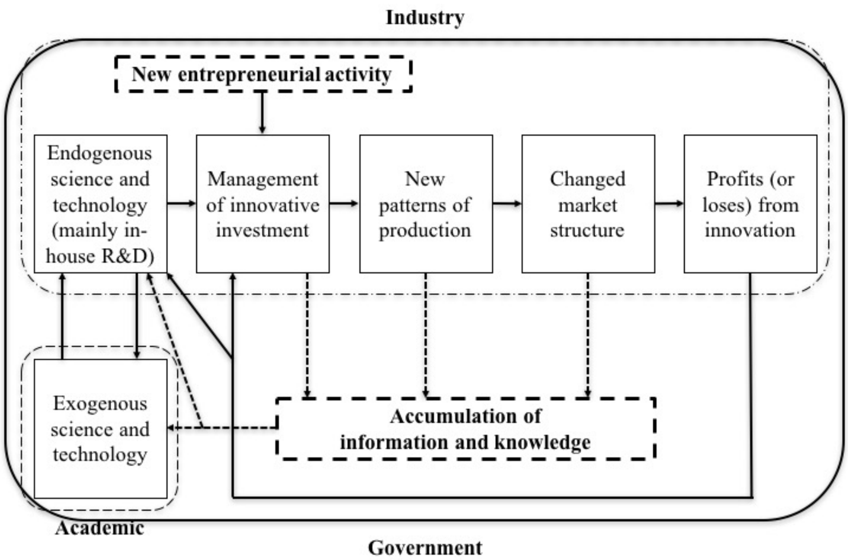
Figure 2: Marx-Schumpeter Capitalist Process



This endogenous economic evolution will be able to describe in one figure (see Figure 2). We call it a 'Marx-Schumpeter capitalist process'. There is a strong point that Schumpeter's five forms of new combination can be located in the same framework of Marx's capitalist reproduction process[3]. So far as a main element which transform the structure of capitalism, Marx, on one hand, insisted the contradiction between a productive force and various relationships in a production process at the substructure as a foundation of capitalist system, but on the other hand, Schumpeter emphasized a role of entrepreneurs at the superstructure. Although both their focal points are different, they shared the perspective that one of the driving forces of economic evolution in capitalism is innovation. Schumpeter who inherited a vision of economic evolution from Marx did not have a theory of innovation. He said much less about the demand side and he assumed that uses would adjust to the innovations coming from producers and suppliers. Moreover, he made few references to government intervention which suggested that he was not in favour of it[4].

Figure 3: A combination Schumpeter Mark III with NIS

[3] I think this diagram will be supported by Heinz D. Kurz. He said that "Marx's account of the way capitalism develops comprises practically all the items contained in Schumpeter's list and considers innovation as a major weapon in the competitive struggle." (Kurz 2012, p. 69)
[4] See Chaminade et al. (2018), p. 25.



We think a prominent source of NIS will be the so-called Schumpeterian hypotheses. 'Schumpeter Mark I' and 'Schumpeter Mark II' have been discussed by respectively referring to Schumpeter's early work of *The Theory of Economic Development* (1934 [1926]) and his later work of *Capitalism, Socialism and Democracy* (1942), and these two hypotheses were illustrated in Freeman et al. (1982). After that, discussions on these hypotheses have been developed and Ken-ichi Imai (1989) proposed Schumpeter Mark III as a new version, which was reflected changes towards an information society or a knowledge-based economy. On the basis of this hypothesis, we suggest a comprehensive illustration to grasp Schumpeter Mark III and NIS together (see Figure 3). In this figure, 'new entrepreneurial activity' and 'accumulation of information and knowledge' are additional new factors. The former is reflected the transition of the agents of innovation from an individual entrepreneur and an organizational R&D to a new individual entrepreneur. This new agent seems to be a manager of internal and external information and knowledge. As far as the latter function, it seems to have a role like a knowledge pool which is regulated between knowledge flow and knowledge stock through a network mechanism.

But because the above framework of NIS in Figure 3 is only a general one, it does not reflect differences in characteristics of each NIS. Thus, although we construct a framework of our system dynamics model based on this diagram in Figure 3, we follow recent science and technology policies and white papers in Japan before doing it. We will find characteristics of a recent Japanese NIS through them.

3. Recent Policies towards Knowledge Capitalism in Japan

In previous section, I located the government in NIS framework as a subject who regulate the interdependence internal elements for good performance as a whole and make innovations promote, diffuse over the system. However, why does government need to intervene innovative in NSI and to sustain private firms' R & D activities? There are some reasons for government policies[5]. According to a research by the Innovation Research Center of Hitotsubashi University, those reasons are

[5] Cooms, R., Saviotti, P. and V. Walsh (1987) summarized in eight reasons: First of all, the scale of capital investment or R & D investment required for industries based on new technology, especially 'high technology', has often been such that individual firms cannot raise the necessary funds or accept the high risk involved in the development of the new technology. Secondly, governments have also provided funds to support industry in the face of international competition; either to support sectors which for strategic reasons the government believes should be competitive, or to protect others, that are not. Thirdly, there are many areas of activity of importance to industry or to society as a whole, such as energy, transportation or telecommunications, where an individual enterprise may not necessarily benefit from making an investment in technological change. Fourthly, basic knowledge is likely to be useful to industry in the long term. Fifthly, there are many areas of basic academic research which cannot be said to result in discoveries that lead directly to technological advances. Sixthly, in sectors with very small units such as agriculture, it is now generally accepted that the market alone does not generate all the technical change that is economically and socially desirable or necessary. Seventhly, in some service areas such as health, it is now widely argued that access to and provision of health care should not be governed (or solely governed) by the market mechanism. The eighth area is defense, by definition a topic for government policy. (pp. 207-208)

summarized in three points. Firstly, government is responsible for sustaining qualities of public goods and services such as public health, national defense and for checking their cost as an only supplier. Secondly, government must support R & D activities in which the rate of social profitability is more than the rate of private profitability. Thirdly, government must support the progress of general and basic technologies (Innovation Research Center of Hitotsubashi University ed. 2001, pp. 310-311). Because the NIS is considered different in each countries at the point of institutional set-ups, a role of government seems to be certainly important. Then, in below consideration, we focus on two cases of the engineering paradigm and the ICT paradigm as the Japanese innovation system. Following Perez's way of division, periods of two paradigms are assumed that the former is a period from early 1900s before the World War I to the first half of 1970s which the oil crisis occurred, and the latter is a period the first half of 1970s to the present. According to previous evaluations on the Japanese innovation system in the period, it was highly successful in catching up but it was less successful in operating at the frontier of science-based technologies (Lundvall et al. eds. 2006, p. 5). We reconsider this evaluation and confirm it.

3-1 Japanese innovation system in the engineering paradigm

Concerning the engineering paradigm, we have a best contribution by Christopher Freeman (1989). His research question is why Japan succeeded rapid technological and economic catch-up during the high growth of the economy in 1950s-60s. His research method is a framework of NIS which is the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies. Through historical and statistical investigations, he summarized Japanese specific characteristics in four points[6]. The first is the role of the Ministry of International Trade and Industry (MITI)[7]; this means that a strong impetus from central government is needed to promote modernization of the Japanese economy. The second is the role of corporate research and development

[6] See Freeman (1989), p. 4 and p. 32.

[7] The Ministry of Economy, Trade and Industry (METI) as it is known today since 2001.

strategy in relation to imported technology and 'reverse engineering'; reverse engineering is one of the ways to acquire a world-wide high technologies. So Japanese private firms and government made effort to import and whenever possible to improve upon the best available technology in the world. The third point is the role of education and training and related social innovations which are key factors in the modernization. The fourth point is the conglomerate structure of industry; this structure contributes to build a close co-operation between government and large industrial concerns.

Through analyzing several indexes on science and technology, as a result, Freeman concluded that "one of the most notable features of the Japanese system has been the speed with which Japanese firms and Japanese policy-makers in MITI and elsewhere identified the importance of information and communication technology (ICT) and embarked on measures to diffuse the new technology very rapidly to more traditional industries, such as machinery and vehicles" (ibid., p. 5). I think one of the noticeable suggestions by Freeman on Japanese innovation system is the interdependence between government-led institutional set-ups and private firms innovative activities. Thus, a positioning of government in the context of NIS has a great influence in shaping a long term pattern of structural change. Therefore, government has a responsibility to lead NIS towards an appropriate direction by its reasonable expectations and well-timed judgements.

As Perez pointed, when the type of structural and institutional inertia problems are acute, government policies and institutional reforms are especially important. In the engineering paradigm, Japanese innovation system seemed to function well because of a forecasting system in Japanese government agencies[8], which was formed by the interrelated elements with respect to the role of central and local government, the organizational of firms for the management of innovation and the role of education

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[8] More concretely, Freeman pointed five reasons which the Japanese innovation system well adapted to take advantage of the potential of ICTs; (1) the systems approach to process and product design; (2) the flexibility of the industrial structure; (3) the capacity to identify crucial areas of future technological advance at national and enterprise level; (4) the capacity to mobilise very large resources in technology and capital in pursuit of strategic priorities; (5) the horizontal flow of information within and between firms. (Freeman 1988, p. 334)

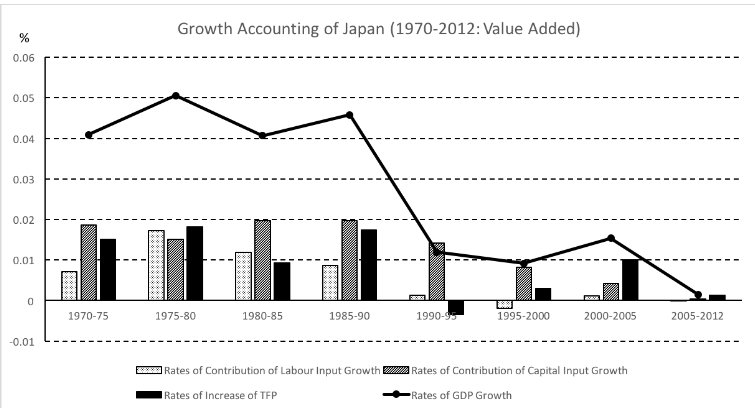
and training (ibid, pp. 341-344).

3.2 Japanese innovation system in the ICT paradigm

There is, on one hand, an evaluation that Japanese innovation system was farsighted (ibid, p. 333), on the other hand, it is less successful in operating at the frontier of science-based technologies because of an institutional mismatch between the existing Japanese institutional framework and the environmental changes (Lundvall et al. eds. 2006, p. 5). In particular, enormous environmental changes have been growing importance of knowledge and learning and the increasing international interdependence. I think these changes form the 'turning point' in the Perez's framework. Therefore, the existing Japanese innovation system, which contains long-term inter-firm relationships, patient capital, and long-term employment contracts, and so on, has faced in the period of institutional reforms for the new knowledge-based innovation system.

Then, I check the data whether Japan has been in the 'turning point' of the ICT paradigm. As representative examples, I previously show two quantitative indexes below. Figure 4 shows a transition of the data of growth accounting in Japan during 1970-2012.

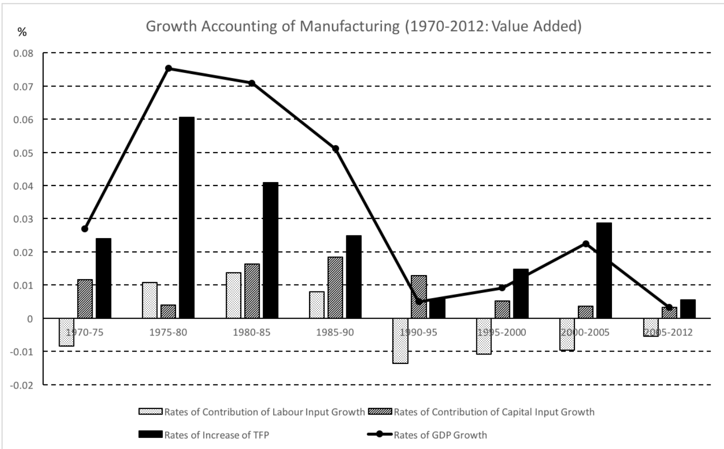
Figure 4: Growth Accounting of Japan (1970-2012)



Source: JIP Database 2015 (Japan Industrial Productivity Database 2015)
http://www.rieti.go.jp/jp/database/JIP2015/index.html

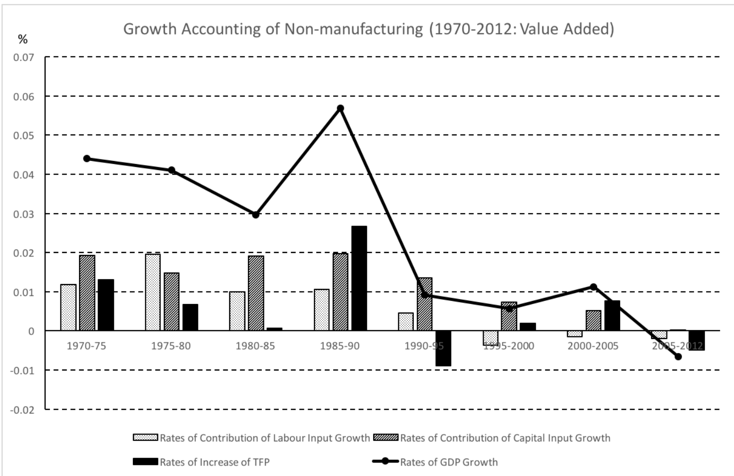
We can understand, on one hand, the rate of GDP growth rapidly declined in first half of 1990s, because of the minus rate of growth of TFP. On the other hand, the decline of growth rate was result from the minus rate of contribution of labour input growth in the manufacturing sector. Then, we distinguish the data of growth accounting between a manufacturing industry and a non-manufacturing industry (Figure 5 and 6). From these two figures, we can grasp a decline of growth rate was result from a rapid decline of the rate of increase of TFP. On the whole, the fluctuation of the growth rate seems to be linked with the movement of the rate of increase of TFP in the non-manufacturing sector.

Figure 5: Growth Accounting of the Manufacturing Industry (1970-2012)



Source: JIP Database 2015

Figure 6: Growth Accounting of the Non-manufacturing Industry (1970-2012)



Source: JIP Database 2015

Lundvall suggested that there are certain prerequisites that need to be present in order to benefit from recent globalization as a circumstance around the NIS. The first factor is skilled people and technological capability[9]. The second factor is a certain degree of political control over the process of internationalization. The third is coherence in society with acceptance of certain rules of the game so that not everyone in society goes after immediate private legal or illegal benefit (ibid., p. 7).

It seems that Japan has been facing a turning point of the ICT paradigm since 1990s. The early 1990s, Japan experienced the collapse of the economic bubble, and has been in the periods of long stagnation which is called the 'lost twenty years'. Hiroyuki Odagiri placed this periods as a transitional periods of Japanese innovation system towards a science-based industries (SBIs)[10]. I think Odagiri (2006) is one of a few contributions which has been considered on the institutional transition of Japanese innovation system. He pays attention to the government policies up to the 1980s and analyzes institutional changes since the 'Science and Technology Basic Plan (STBP)' since 1996[11]. This STBP is a set of government policies every five years. Now, the 5th STBP has been in progress since 2016.

According to Odagiri (2006), Japanese firms invested heavily not only for licensing but also for own R & D to assimilate and apply imported technology, although, gradually, the weight of R & D shifted from the improvement of imported technologies to the invention of original technologies. After he summarized the important roles of government policies in three points; investment in the education system, the provision of infrastructure, and the government secured to demand to domestic firms through procurement, he pointed the government policies in those days were not as successful or effective as the provision of infrastructure or the

[9] With regard to skilled labour, Fuchs (2010) investigated from the perspective of Marxian economics. After confirming the production and exploitation of surplus value are the heart of class structuration and capitalism, he was concerned about who the producers of surplus value are in an information age. This problem is related to the relationship of class and knowledge labour. Fuchs

[10] See Odagiri (2006), p. 208. SBIs contains four areas, in particular, life science, information and telecommunication, environment science, and nanotechnology and materials in the 2nd STBP.

[11] It is the 2nd STBP that Odagiri was based on.

support of demand. In this way, the role of government is important for preparing the basis of interaction among internal various elements. Odagiri concluded that "Japan's development was essentially industry-led with the government providing the necessary infrastructure and occasional (but not necessarily successful) intervention" by using the data on the proportion of public R & D expenditure in total R & D expenditure(ibid., p. 206).

Now, recently, Japanese government has been becoming to recognize an importance of a perspective of NSI as an future analytical framework. In *2016 White Paper on Information and Communications in Japan*, the ICT innovation paths by which the IoT, big data, AI, and other new forms ICT contribute to our nation's economic growth from both the supply side and the demand side. Also, in *Annual Report on the Japanese Economy and Public Finance 2017*, it is focused on responses to technological innovations and its impacts. According to the Cabinet Office's survey, 36% of companies have introduced at least one of the new technologies among IoT/big data, AI, robots, 3D printers, or cloud computing, and 24% of companies are considering doing so. Companies which actively introduce new technologies have following characteristics. Firstly, company age is young. Secondly, high decentralization of authority regarding decision-making. Thirdly, ICT chief is highly involved in management. Finally, young companies are willing to conduct open innovation with companies in other industries. Moreover, in *The Investments for the Future Strategy 2017*, the realization of "Society 5.0" is stated as the core of the Growth Strategy. The concept of 'Society 5.0' means the fifth chapter after the four major stages of human development: Society 1.0 is a 'hunter-gatherer' society, Society 2.0 is an agrarian society, Society 3.0 is an industrial society, and the present Society 4.0 is an information society. In the next Society 5.0, we will take advantage of innovations created through the 'Fourth Industrial Revolution,' such as Internet of Things, big data, AI and robotics, and apply them across all industries and in all aspects of daily life. According to this agenda, Japan will overcome social challenges such as a decrease in the productive-age population, aging of local communities and energy and environmental issues and make better the human life.

In this way, Japanese government seems to struggle to lead Japanese innovation system to fit it knowledge-based innovation system through overcoming institutional mismatch in the present turning point. Practically, in the present 5th STBT (from 2016 to 2020) the policy authorities seem not to simply aim the development of science and technologies by traditional following in the footsteps of the West, but to independently challenge unexplored frontier and to solve current problems like the decreasing birthrate and aging of the population. In other words, the recent Japanese government policies shifting from a type of information capitalism to that of knowledge capitalism.

4. Some Implications on the Status of Knowledge Capital in System Dynamics Model of NIS

4.1 System dynamics modeling with STELLA

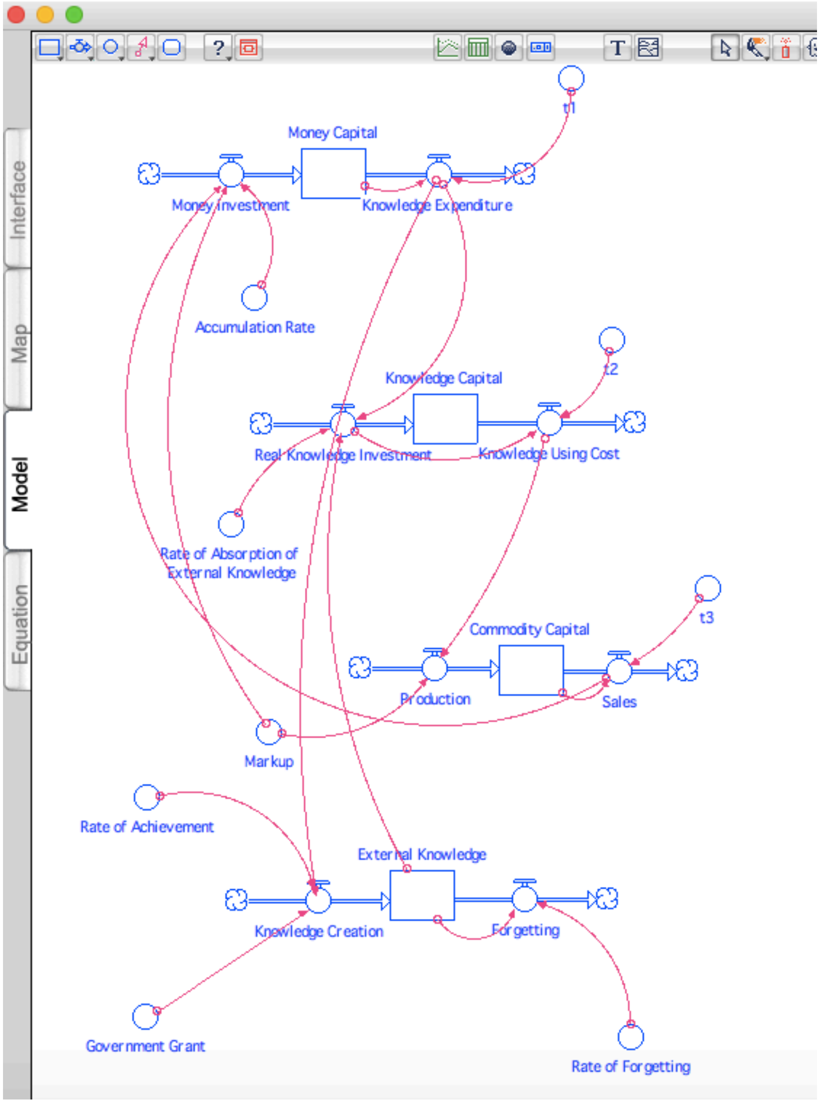
System dynamics modeling in economics and management has been developed since 1950s. Especially, Jay Forrester has largely contributed its development in the field of industrial management and Khalid Saeed has reformulated economic theories as system dynamics models. One of the most useful characteristics of system dynamics modeling is that it can represent correlations among stocks and other variables visually.

STELLA, which I use in this research, is one of the major tools for practicing system dynamics modeling. The underlying computational process in a model can be expressed as a set of ordinary nonlinear integral equations. We can construct a visual model with icons and connections. Two basic components are a stock (a rectangle) and a flow. Information links from stocks to flows define decision rules. Intermediate computations transforming information in stocks into decision rules are represented by converters which have two functions as an algebraic function of stocks and a constant parameter and are connected by a arrow icon[12].

[12] Saeed (2008), pp. 4-6. More detailed information can be found the website of isee systems (https://www.iseesystems.com)

In my previous unpublished paper, I constructed my system dynamics model of the knowledge capitalism based on the Marx and Schumpeter capitalist process by using STELLA. At the first step, I constructed Marxian diagram of turnover of capital. This diagram contained three kinds of capital stock; 'Money Capital,' 'Productive Capital," and 'Commodity Capital', and a volume of each capital stock fluctuates both inflow and outflow. Then they were correlated with each other by action connector arrows. At the next step, I simply replaced 'Productive Capital' to 'Knowledge Capital.' Of course, I understood that this operation was excessively simplified. However, if I recognized that knowledge was embodied in a productive capital, it would be permitted that every productive capital seemed to be considered knowledge capital. As a third step, I explicitly introduced 'External Knowledge Capital' in the above framework. In this extended model I introduced three additional conditions. The first was that the external knowledge stock was created by two inflows; 'Government Grant' with 'Rate of Achievement' and a part of 'Knowledge Expenditure' from 'Money Capital.' The second was external knowledge capital might be lost by the outflow of 'Forgetting.' I thought this outflow seemed to be interpreted as depreciation of knowledge capital. The third condition was that 'Knowledge Capital' was also reflected by 'External Knowledge Capital' and 'Rate of Absorption of External Knowledge.' Under the state that other conditions were unchanged, I finally proposed a system dynamics model on the knowledge-based capitalism (see Figure 7).

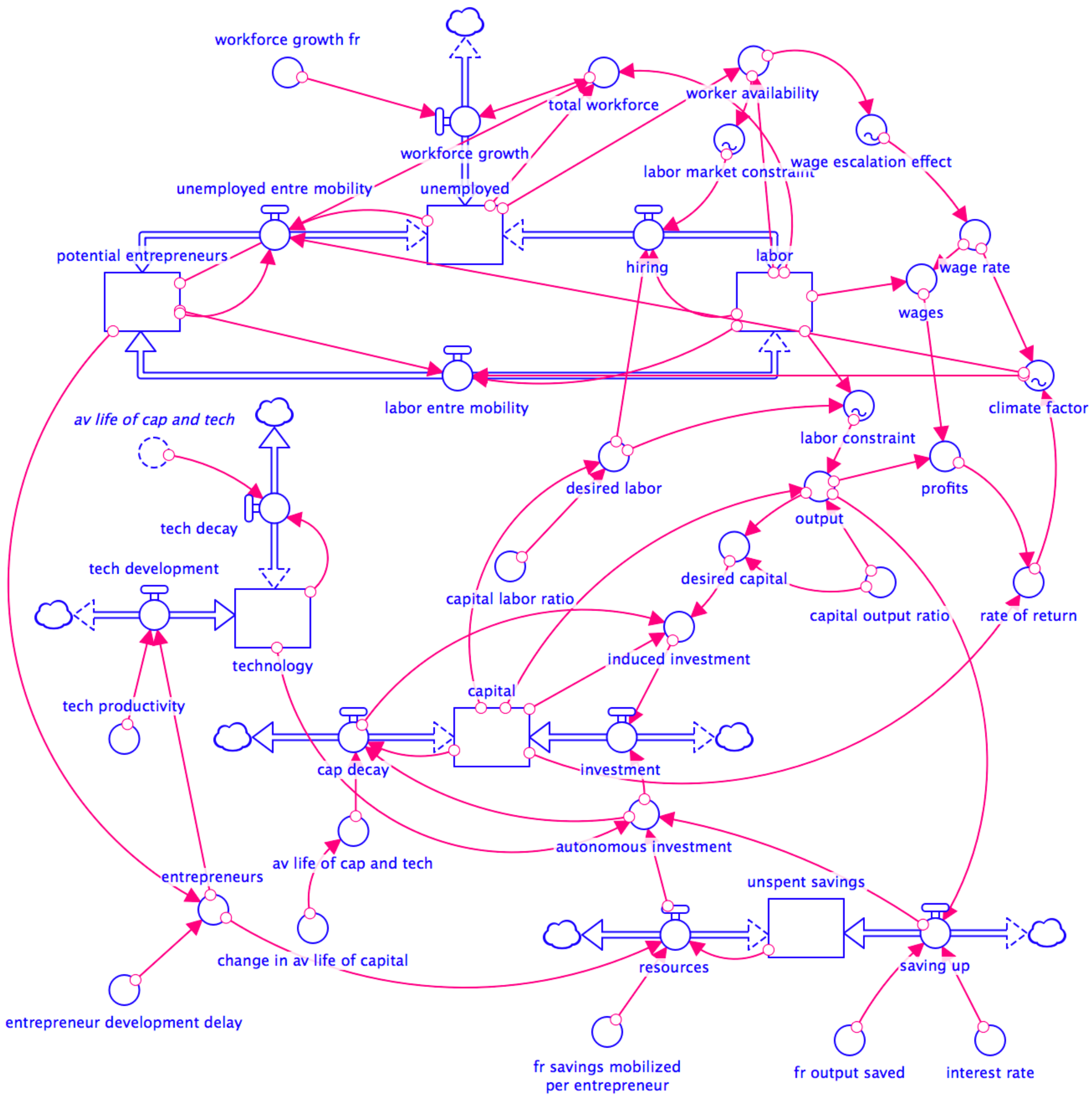
Figure 7: A System Dynamics Model of Knowledge Capitalism



Although I could suggest that growth rates of three capital stocks was more increased by introducing knowledge capital, I think that this first modeling have two critical week points. Firstly, this model is constructed excessively in dependence on Marx's theoretical framework, so Schumpeter's main characteristics of creative destruction is hardly reflected. Secondly, in this model, knowledge capital is expressed as if it is given externally only by government policy ('Government Grant') so that internal knowledge creation process is not enough to express an internal characteristics of economic evolution by Marx and Schumpeter.

Then, in this paper, I try to reconstruct a revised model by referring to a newly contribution of Saeed (2008) and (2010). Saeed models are concerned with some growth models of classical economics and are constructed by a buildup approach like us from Adam Smith, Ricardo, Malthus and Marx to Schumpeter. So, a system dynamics model of in Saeed (2010) representing Schumpeter's concept of creative destruction is contained some important characteristics of capitalistic production systems considered by above four classical economists. For the purpose of understanding the framework and characteristics of Saeed's model, we reproduce in Figure 8.

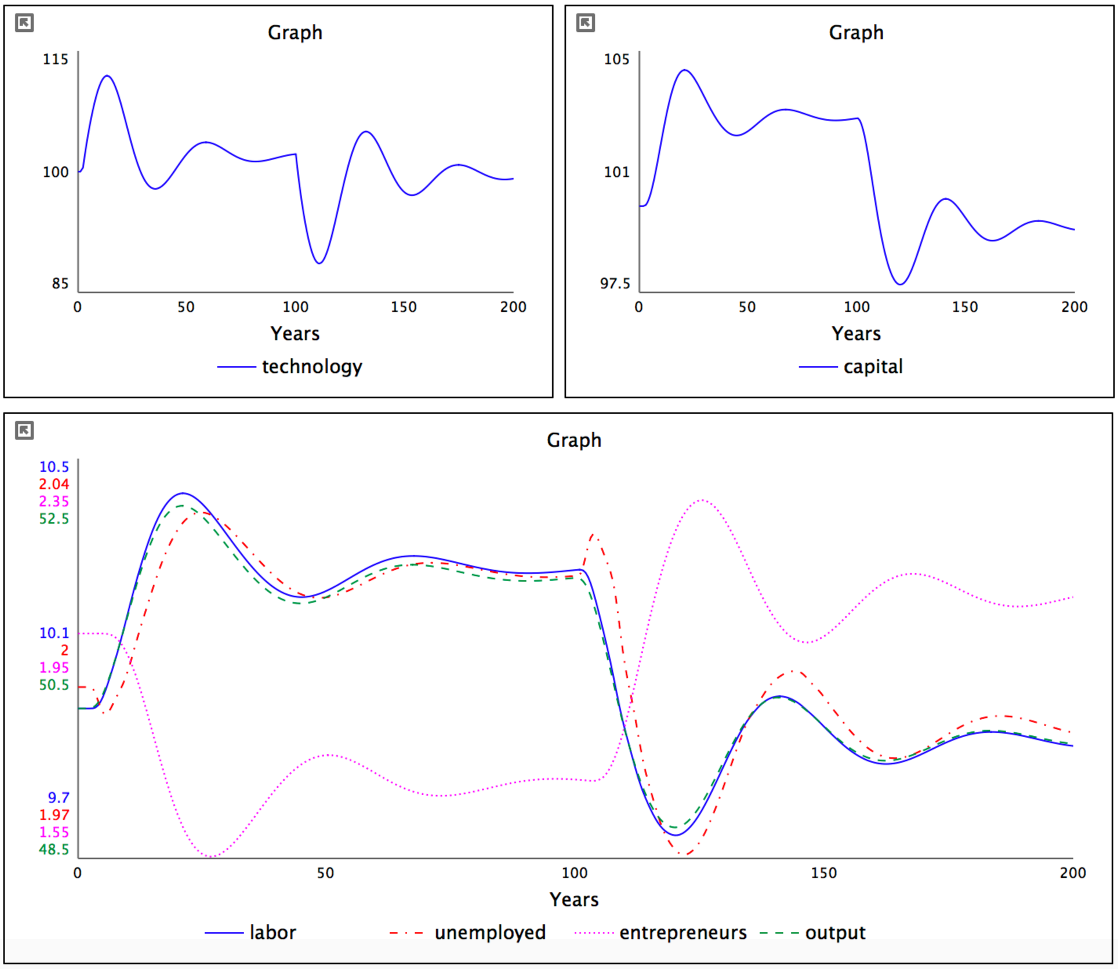
Figure 8: Saeed's model of Schumpeter's concepts of entrepreneurship and creative destruction



Note: Saeed (2010), p. 9.

Although Figure 8 seems to be quite complicated, we can understand additional Schumpeter's characteristic parts are especially in following three; a stock of 'potential entrepreneurs,' a stock of 'technology,' via two decays of entrepreneur development and technology, and two types of investment, that is to say, 'induced investment' and 'autonomous investment.' Saeed demonstrated one important proposition shared by Marx and Schumpeter by practicing a simulation of this model . The proposition is that new entrepreneurs could emerge from the ruins of a fallen capitalist system. Figure 9 shows a simulation result.

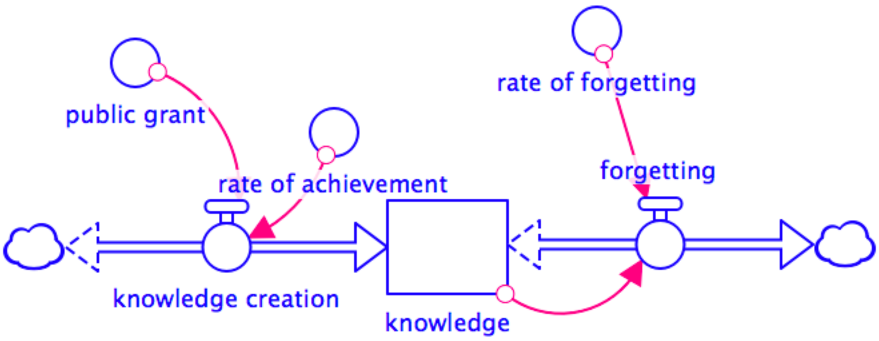
Figure 9: Some results of a simulation of Saeed (2010) model



To develop this Saeed's model, I introduce a 'knowledge' as an additional stock variable and take over some institutional backgrounds around a stock of 'knowledge' from our previous system dynamics model of a knowledge-based innovation system.

This new stock and its causal relationships are shown as Figure 10.

Figure 10: Knowledge stock and related factors

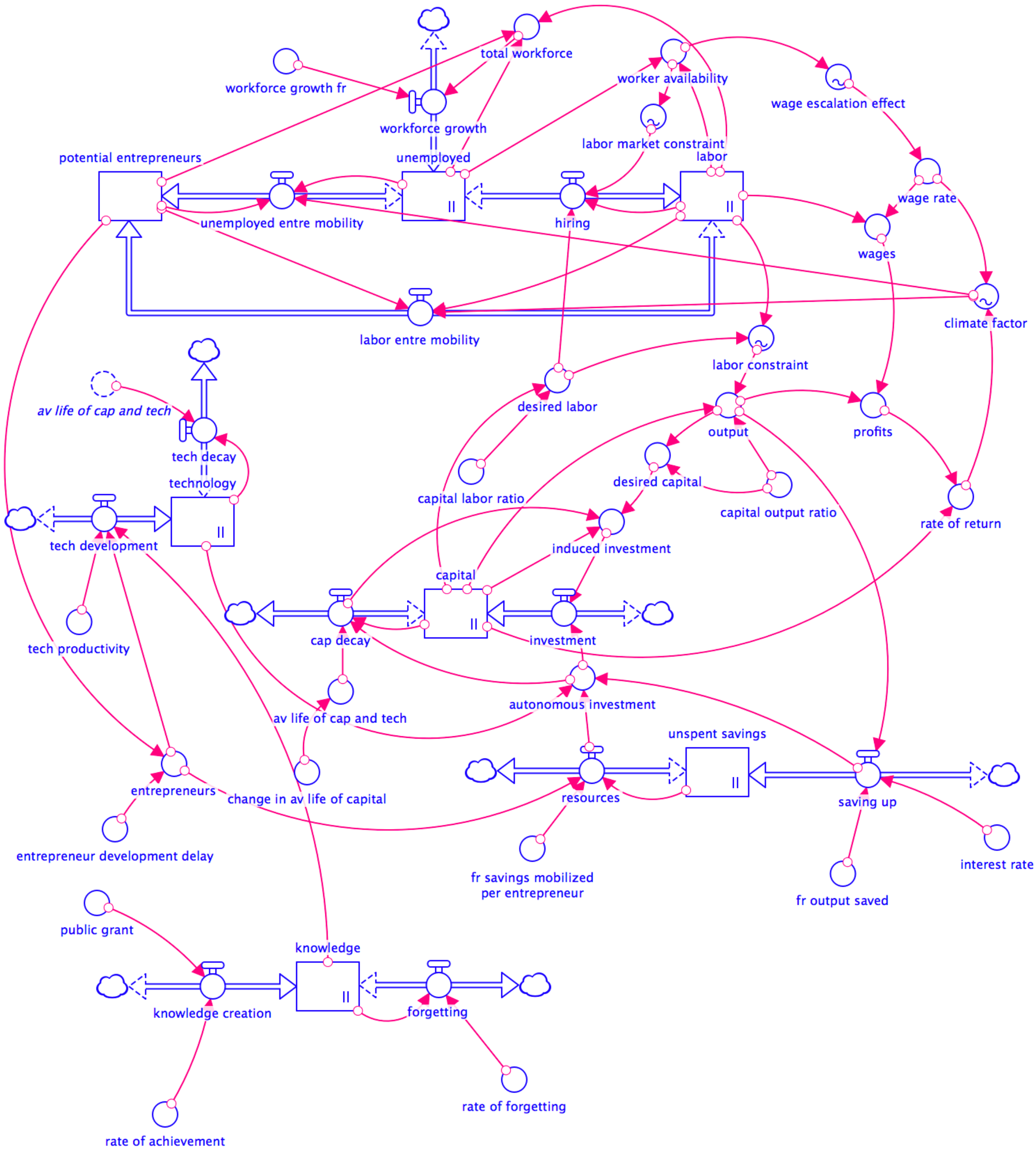


We could get an important basis by depending on Saeed's contributions for revising our previous model.

4.2 A revised version NIS in knowledge capitalism: internalization of knowledge stock

Our revised model of NIS in knowledge capitalism is constructed by integrating a knowledge stock in Figure 10 with Saeed's Schumpeterian system dynamics model as following Figure 11.

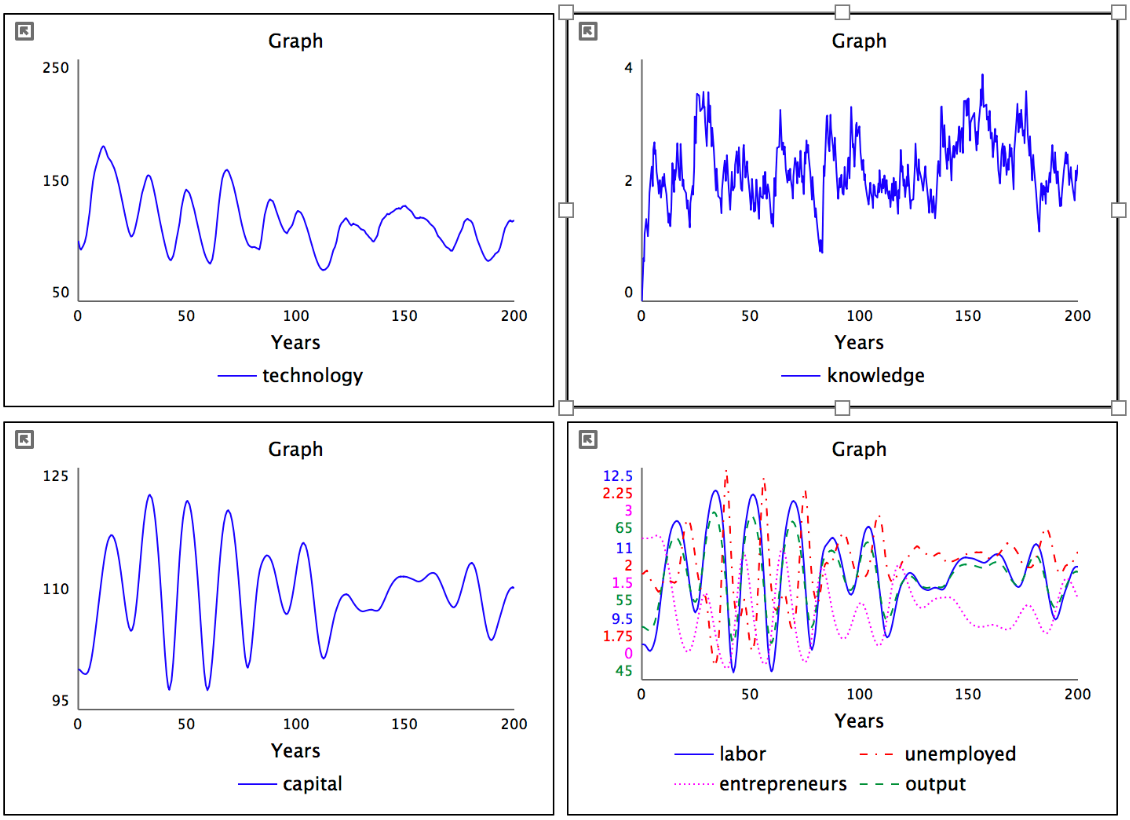
Figure 11: Our revised system dynamics model of NIS in knowledge capitalism



In this model, although a stock of 'knowledge' is connected only with a flow of 'tech development,' this means that a 'knowledge' stock and its related factors are assumed as external factors for this knowledge capitalistic system as the same as our previous model. But I think this assumption is adequate for considering the role of science and technology policies and government visions like a case of Japan in previous section. In this revised model, we assume a 'rate of achievement' follows Poisson' distribution. This means that a 'rate of achievement' reflects an evolutionary characteristics of the so-called 'drawing a lottery' model in Nelson and

Winter (1982) which represented essential difficulties and uncertainties of innovative behaviour. A result of simulation shows in Figure 12.

Figure 12: Simulation results of Figure 11: external knowledge



Subsequently, we try to connect an 'autonomous investment' with a flow of 'knowledge creation' icon as in Figure 13. I think this means an internalization of a stock of 'knowledge' and related causal factors. A volume of a stock of 'knowledge' is affected not only by an external role of the government policies, but also by an internal private firm's investment decision. One case of simulation results is shown in Figure 14.

Figure 13: Internalization of a stock of 'knowledge' and its creation process

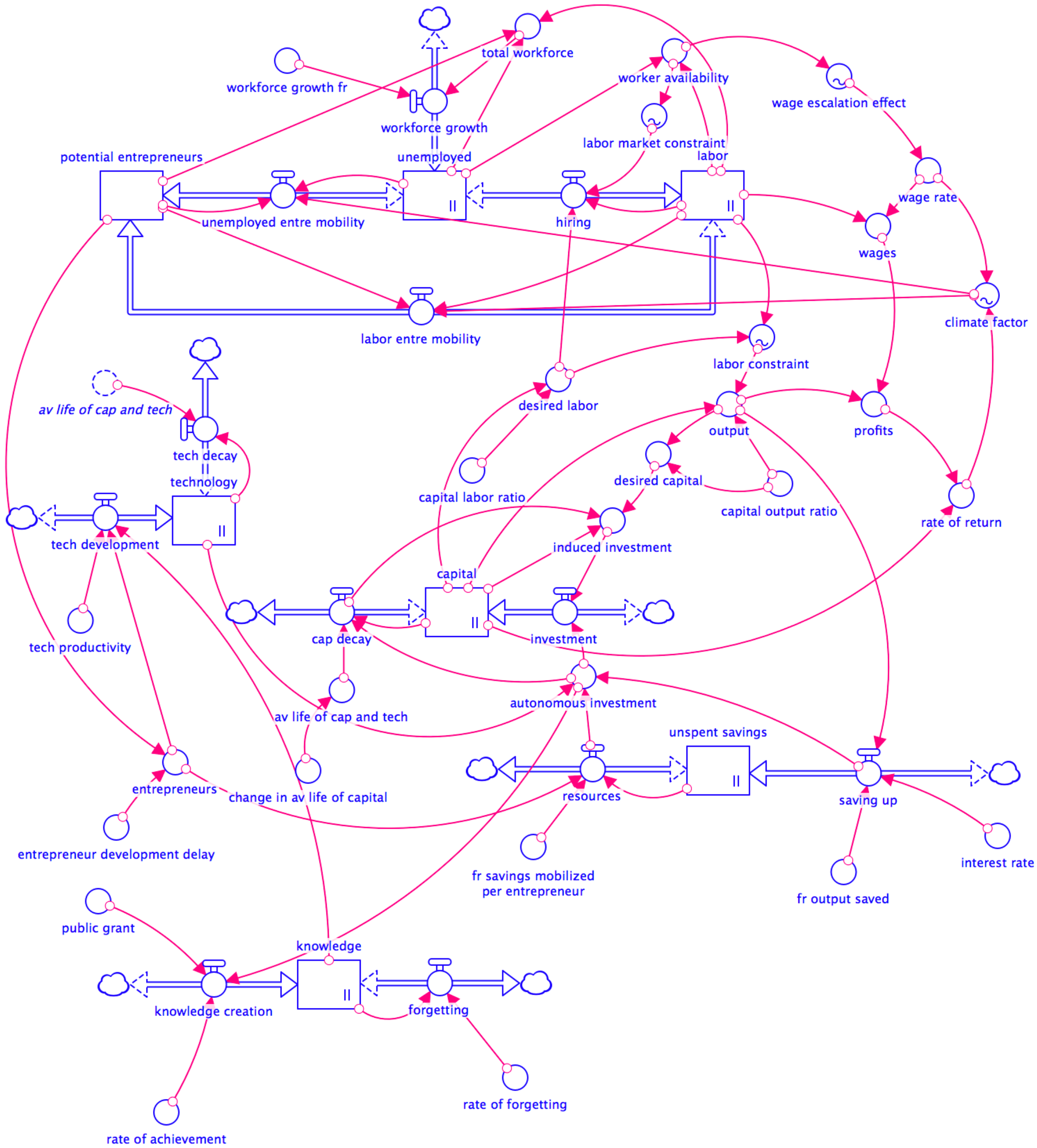
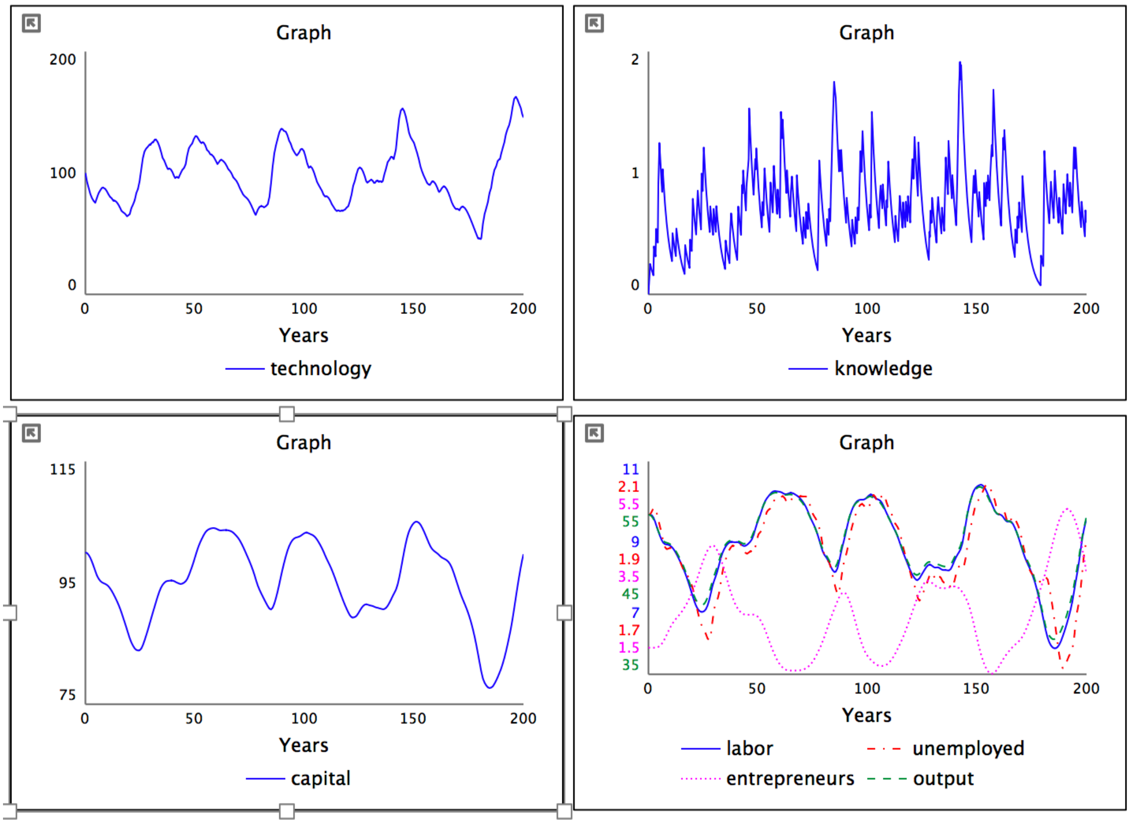


Figure 14: Simulation results of Figure 11: external and internal knowledge



Here, I point out some characteristics of these simulation results of two types of our revised models in Figure 11 and Figure 13. The first is an introduction of statistical probability distribution. In the case of simply external knowledge stock, its changing process through time is completely determined by a probabilistic factor. However, if private sectors' internal investment decision making processes have been to affect the external 'knowledge' stock which seems to be a internalization of an external knowledge stock, changing processes of stock variables apart from a 'knowledge' stock seem to describe more cyclical movement such as Schumpeter's business cycle theory. The second is that internal factors such as 'autonomous investment' seem to contribute to the realistic sustainable growth. In other words, an external interventional functions and government policies seem to have important roles to impose autonomous positive feedback effects. Therefore, I suggest that, to begin with, 'the status of knowledge capital in NIS' are sustained by government policies for supporting its effective and adequate emerging.

A Brief Summary

Present policies on science and technology by Japanese government seems to be aware of the necessity on conditions of structural or institutional change. It will be pointed two dimensions. Firstly, Japan has been in "Turning Point" of the 5th techno-economic paradigm and must overcome this institutional mismatch towards the "Development Period". In present, Japan will grope for the way to reform the existing institutional environment. I think this situation will be reflected in a series of the "Science and Technology Basic Plan". Although the early plans seem to be intended for SBIs according to Odagiri (2006), but the present 5th plan seems to shift emphases towards construction of a systemic virtuous cycle of human resources, knowledge, and funding innovation. I think this shift is correspond to the concept of "Learning Society" by Stiglitz and Greenwald (2015). If this is the case, the elements within NIS should be more individual. Therefore, the networks formulated by individual elements will be useful for grasp knowledge flow and knowledge stock. Actually, a new organizational device like as a coworking space is recognized and spread as a new method of knowledge interaction. It may be effective to formulate sub-systems about knowledge capital and afterwards construct knowledge-based innovation system by combining several sub-systems. System dynamics model is useful to cope with like this situation.

References

Antonelli, C. (2001) *The Microeconomics of Technological Systems*, Oxford University Press.

Antonelli, C. ed. (2011) *Handbook on the Economic Complexity of Technological Change*, Edward Elgar.

Antonelli, C. (2017) *Endogenous Innovation: The Economics of an Emergent System Property*, Edward Elgar.

Burton-Jones, A. (1999) *Knowledge Capitalism: Business, Work and Learning in the New Economy*, Oxford University Press.

Chaminade, C., Lundvall, B.-Å. and Haneef, S. (2018) *National Innovation Systems*, Edward Elgar.

Coombs, R., Saviotti, P. and V. Walsh (1987) *Economics and Technological Change*, Macmillan.

Dolfsma, W. (2008) *Knowledge Economies*, Routledge.

Dolfsma, W. and Soete L. eds. (2006) *Understanding the Dynamics of a Knowledge Economy*, Edward Elgar.

Dosi, G. (2018) "Appendix to Chapter 2: Formal Modeling of Problem Solving and Knowledge Accumulation," in Dosi et al. (2018), 74-84.

Dosi, G., Freeman, C., Nelson, R. R., Silverberg, G. and Soete, L. eds. (1988) *Technical Change and Economic Theory*, Pinter Publishers.

Edquist, C. ed. (1997) *Systems of Innovation: Technologies, Institutions and Organizations*, Routledge.

Foray, D. (2000) *Economics of Knowledge*, The MIT Press.

Freeman, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*, Pinter Publishers.

Freeman, C. (2008) *Systems of Innovation: Selected Essays in Evolutionary Economics*, Edward Elgar.

Freeman, C., Clark, J. and Soete, L. (1982) *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*, Greenwood Press.

Freeman, C. and C. Perez (1988). "Structural Crises of Adjustment, Business Cycles, and Investment Behaviour," in Freeman (2008), 39-46.

Fuchs, C. (2010) "Labor in Informational Capitalism and on the Internet," *The Information Society*, 26, 179-196.

Hanusch, H. and Pyka, A. eds. (2007) *Elgar Companion to Neo-Schumpeterian Economics*, Edward Elgar.

Hayek, F. A. (1937) "Economics and Knowledge," in Hayek (1948), 33-56.

Hayek, F. A. (1945) "The Use of Knowledge in Society," in Hayek (1948), 77-91.

Hayek, F. A. (1948) *Individualism and Economic Order*, The University of Chicago Press.

Higgins, B. (1959) *Economic Development: Principles, Problems, and Policies*, Revised Edition, Constable and Company Limited.

Kurz, H. D. (2012) *Innovation, Knowledge and Growth: Adam Smith, Schumpeter and the Moderns*, Routledge.

Lundvall, B.- Å., Intarakumnerd, P. and J. Vang eds. (2006) *Asia's Innovation Systems in Transition*, Edward Elgar.

Lundvall, B.- Å., Intarakumnerd, P. and J. Vang (2006). "Asia's innovation systems in Transition: an introduction." in Lundvall, B.- Å. et al. eds. (2006), 1-20

Lundvall, B.-Å. ed. (2010) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Anthem Press.

Metcalfe, J. S. (2014) "Capitalism and Evolution," *Journal of Evolutionary Economics*, 24, 11-34.

Mokyr, J. (2002) *The Gifts of Athena: Historical Origins of the Knowledge Economy*, Princeton University Press.

Nelson, R. R. and Winter, S. G. (1982) *An Evolutionary Theory of Economic Change*, The Belknap Press.

Nelson, R. R. (1990) "Capitalism as an Engine of Progress," *Research Policy*, 19, 61-87.

Nelson, R. R. ed. (1993) *National Innovation Systems*, Oxford University Press.

Nelson, R. R., Dosi, G., Helfat, C., Pyka, A., Saviotti, P. P., Lee. K., Dopfer, K., Malerba, F. and Winter, S. G. (2018) *Modern Evolutionary Economics: An Overview*, Cambridge University Press.

Nonaka, I. and Teece, D. J. eds. (2001) *Managing Industrial Knowledge: Creation, Transfer and Utilization*, SAGE Publications.

Odagiri, H. (2006). "Advance of science-based industries and the changing innovation system of Japan." in Lundvall, B.- Å. et al. eds. (2006), 200-226.

OECD (1996a) *The Knowledge-based Economy*, OECD.

Perez, C. (2002) *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*, Edward Elgar.

Perez, C. (2015). "From long waves to great surges: continuing in the direction of Chris Freeman's 1997 Lecture on Schumpeter's Business Cycles." *European Journal of Economic and Social Systems*, n° 1-2, 69-79.

Rosenberg, N. (2000) Schumpeter and the Endogeneity of Technology: Some American Perspectives, Routledge.

The World Bank (1998) *World Development Report: Knowledge for Development*, Oxford University Press.

Saeed, K. (2008) "Limits to Growth in Classical Economics," Working Paper, Worcester Polytechnic Institute, Worcester, MA.

Saeed, K. (2010) "Economic Development, Creative Destruction and Urban Dynamics," *Proceedings for the 28th International System Dynamics Conference*, System Dynamics Society: Seoul, Korea, July 25-29, 2010.

Stiglitz, J. E. and Greenwald, B. C. (2014) *Creating a learning society: a new approach to growth, development, and social progress*, Columbia University Press.