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Regional Resilience of Industrial Ecosystem in Financial Crisis: Comparison between Toyota-Kariya Automotive Subcontractor Cities and Hamamatsu Start-Up City

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Abstract Japan's manufacturing is mostly dependent on the automotive industry in Toyota-Kariya cities. However, the nearby city of Hamamatsu is the home of a start-up ecosystem known as Japan's Silicon Valley. How is it possible to evaluate the innovative potential of each regional industry? What kind of guidelines exist for continuing R&D investment when companies' net incomes are negative in the face of the 'Valley-of–Death' or financial crisis? Is it possible to measure the regional resilience ability in the context of the financial crisis? Entrepreneurial innovation is defined as a real-option portfolio consisting of investment decision to commercialize R&D findings. The subcontractor system implies a vertical and tight industrial group. However, a start-up ecosystem means a platform for horizontal and flexible partnership. In this research, the data include the financial indices of each of 18 public companies in both regions between FY2009 and FY2017. The objective of this paper is to clarify the call option or resilience function of equity for R&D investment in the context of the financial crisis in both regions by using Bayesian MCMC analysis.

Keywords Start-up ecosystem, subcontractor ecosystem, real options, Bayesian MCMC analysis, regional resilience

I. Introduction

The manufacturing industry in Japan is mostly dependent on the automotive industry in Toyota city based on measurement of added-value concentration. However, Toyota Motor Co. itself has also opened the Toyota Research Institute, a laboratory for artificial intelligence at Silicon Valley in 2016 in search of a global edge innovation climate in the start-up ecosystem there. As compared with nearby Toyota city, specialized in the unified automotive industry by a vertical hierarchically type subcontractor system, Hamamatsu

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city has offered more flexible diversity in the horizontal relation structure of industry with a start-up ecosystem described as Japan's "Silicon Valley".

Constitutive of this background is the future potential for each region's main industry as Toyota city's automotive industry, including fuel cell vehicle (FCV) and electric vehicle (EV) and Hamamatsu city's photonics? If so, what kind of rational guidelines exist for carrying on research and development (R&D) investment when companies' net incomes are negative as the automotive export companies are facing difficult market conditions with the subprime mortgage crisis or as start-ups face the 'Valley-of-Death' (initial negative profits period)? And is it possible to quantitatively measure regional flexibility or resilience against the economic risk like such a financial crisis?

As key concepts for these research questions, entrepreneurial innovation is defined as a real-option portfolio consisting of patient investment decision to commercialize long-term R&D findings under uncertainty. The subcontractor system implies a vertical, relatively tight, and patient industrial group engaged in the development and production of products made of many parts. But start-up ecosystem means a platform for horizontal, flexible, and enduring partnership to overcome the 'Valley of Death.' The data used here include the financial dataset of each of 18 public companies in the Toyota-Kariya cities and in Hamamatsu city from public database EDINET (Electronic Disclosure for Investors' Network) at two points in time - FY2009, under the impact of the subprime mortgage crisis (also referred here as the Lehman Brothers shock), and the most recent FY2017. The financial indices treated here are selected to analyze the relationship between the R&D investment and the real options as index of patient entrepreneurial decision. The 18 companies are wholly listed companies in each region, and the Bayesian MCMC (Markov Chain Monte Carlo) analysis can overcome sample size problems by sampling simulation function.

As one of the methodologies, real-options analysis, which is using financial-engineering tool to evaluate the option value of real assets like patents, is applied to find an enduring R&D investment criterion even in the negative profits period of tough market conditions. Bayesian MCMC analysis is used to confirm a signaling function under the information asymmetry. Thus, the signaling of Bayesian MCMC analysis can contribute to clarify the option value at a turbulent period for subcontractors or for start-ups at an early stage.

The objective of this paper is using Bayesian MCMC analysis to clarify the call-option function of the equity as one of real options for R&D investment and for each region's different resilience function from a financial crisis in Toyota-Kariya cities and Hamamatsu city.

The structure of this paper consists of section 2: review of literature; section 3: theoretical framework-option theory; section 4: data and preliminary analysis; section 5: Bayesian MCMC analysis, and section 6: conclusion.

II. Review of Literature

One of the global start-up ecosystems for technological innovation is Silicon Valley, whose success factors have been studied compared with Chicago or Detroit, mainly from a sociological perspective. A limited number of success stories shared with people inside the region can become a 'myth' drawing outside unfamiliar interest to migrate or invest.

For example, as a benchmark for comparison by previous representative studies on start-up ecosystem, Rogers and Larsen (1984) pointed to the entrepreneurship culture and organizational networks based on information technology as success factors behind Silicon Valley as the semiconductor incubator from a perspective of technology diffusion. Rogers's team, Carayannis et al. (1998) also focused on technology diffusion and commercialization process as a high-tech spin-off from US federal laboratory.

Secondly, Saxenian (1990) emphasized the reliance and resurgence of 1980's Silicon Valley economy in semiconductor based on dense regional networks of universities, start-ups, and supporting agencies from Japanese companies' competitors. Similarly, Saxenian (1983), Saxenian (1985), Saxenian (1991), Saxenian (1996a), Saxenian (1996b), Saxenian et al. (2001), Gambardella et al. (2001), Saxenian (2002), and Saxenian et al. (2002) analyzed the success of Silicon Valley's technological industry from the perspective of regional and international human network.

Thirdly, Kenny (2000) focused on the social structure of Silicon Valley in the history, institutions, and general topics as culture of ecosystem, trust on performance, and start-up-based innovation. Florida and Kenney (1988a), Florida and Kenney (1988b), Florida and Kenney (1990), Feldman and Florida (1994), Florida (1995), Florida (1999), Kenney and von Burg (1999), Florida (2003), and Florida and Gates (2003) analyzed this emerging regional economy from the perspective of humanities as human resources and creative jobs.

Fourthly, Kerr (2010) combined the arrival of foreign immigrant talents like Indian and Chinese engineers and breakthrough locations such as San Francisco Bay Area and Boston by using demographic and patent citation statistics. Klepper (2010) analyzed the cascading spin-offs based on some specific hubs as a wave of agglomerating new industrial companies like the automobile industry in Detroit and the semiconductor industry in San Francisco Bay Area.

However, the leadership about new conceptual ideas and the enthusiasm of innovators and entrepreneurs, but also the objective capital investment decision of chief financial officers or venture capitalists are hardly been investigated as critical to the success of start-ups. Then, it is no coincidence that the locations of the start-up ecosystem are concentrated within relatively short return flight distances from the main offices of venture capital firms. There is little financial analysis literature about R&D investment, except venture capital flow as done by Hambrecht (1984), Fried and Hisrich (1984), Black and Gilson (1998), Hellmann and Puri (2000), and Ferrary and Granovetter (2009).

Additionally, there are similar technical innovation clusters, not only at Silicon Valley in the USA and at Cambridge in the UK, but also in the Hamamatsu area in Japan. And Kosai in greater Hamamatsu area is the birthplace of the Toyota Motor group, which has deployed a fixed vertical subcontractor system around Toyota-Kariya cities near Hamamatsu. For example, there are many studies on the automobile subcontracting production system around Toyota city as its pioneer, Ohno (1988), his followers, Sugimori et al. (1977), and outside observers, Sheard (1983), Cusumano (1988), Kenney and Florida (1988c), Asanuma and Kikutani (1992), Miyashita and Russell (1994), Miwa and Ramseyer (2001), and Fujiwara (2013). However, there are very few studies about the start-up ecosystem in Japan, except Glasmeier (1988), Takeda et al. (2008), and Fujiwara (2014). For example, Fujiwara (2013) explained the history of Toyota group's founder Mr. Sakichi Toyoda for loom business and his son Ki-ichiro's automobile business, in terms of both as never-discouraged, determined inventors and entrepreneurs. Fujiwara (2014) also compared Japan's two main industrial agglomeration regions - Toyota city's manufacturing industry (where almost 90% focuses on the automobile industry) and Hamamatsu city, Japan's Silicon Valley - as birthplaces of many global companies like Toyota, Honda, Suzuki, Yamaha, Hamamatsu Photonics, and Raland DG. While Toyota city concentrates on the automotive industry through a hierarchical small and medium-sized enterprises (SMEs) subcontractor system, Hamamatsu city features a more flexible and diversified industrial structure as a start-up ecosystem.

Thus, there is a gap in the literature about R&D investment in Japan's start-up ecosystem from a perspective of financial engineering as compared with sociological study on Silicon Valley, its venture capital flow, and Toyota automotive subcontracting system. Therefore, this study's original contribution is an attempt to verify the validity and implication of signals such as growth option or real options identified by the Bayesian MCMC analysis model regarding the characteristics of entrepreneurial decision-making for R&D investment in times of financial crisis and how they apply to Toyota-Kariya cities and Hamamatsu city. Bayesian MCMC analysis is used to classify each characteristic of the vertical subcontractor companies involved in the automobile industry at Toyota-Kariya cities and in the horizontal relationship of the start-up ecosystem in Hamamatsu city modeling the fitted standard deviation for both of them.

III. Theoretical Framework

1. Option Theory

There is a formula of a European option of Black and Scholes (1973), and Merton (1973), which is accepted in the financial market to evaluate and price the financial-option value with the parameters including the underlying asset by both buyers and sellers. One of first simple and original ideas of real option was proposed by Myers (1977) as the equity value being a sort of call option if one assumes that the asset, as company value, is an underlying asset and the debt is an exercise price on a balance sheet on the assumption of limited liability. Except risk mitigation at bankruptcy, this concept seems like a unfair game, because debt holders also have to endure the downside burdens without ability to share stockholders' upside opportunities. However, debt interest is usually higher than risk-free rate, reflecting a kind of contract risk.

Present call option price C_0 is evaluated by following the famous Black-Scholes formula:

$$C_0 = S_0 N(d_1) - X e^{-r_f T} N(d_2)$$

$$d_1 = \frac{ln\left(\frac{S_0}{X}\right) + \left(r_f + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma T$$

where S_0 = present stock or underlying asset's price, $N(\cdot) =$ standard normal cumulative distributive function, X =exercise price, r_f =risk-free rate, $T =$ maturity time, and σ = volatility.

This paper examines the growth option function of equity in real options to carry on R&D investment for the start-up firms in the face of the 'Valley-of-Death' conditions and automotive subcontracting companies facing financial risks of severe global product market conditions. Additionally, this study attempts to confirm the real-option function of cash equivalents in the very severe financial condition as the subprime mortgage crisis.

IV. Data and Preliminary Analysis

1. Data

This paper collected the data of 18 public companies both in Toyota-Kariya cities and in Hamamatsu city where their respective head offices and main production operations are located (Table 1 & Table 2). Virtually all those companies are listed on the stock exchange, while the shares of the majority of companies are unlisted in these two regions. The methodology of Bayesian MCMC analysis is possible to overcome this kind of sample size problem from its random sampling function by simulation. Their financial data are available from the Japanese government agency, Financial Services Agency's EDINET (2017).

Table 1 Public companies in Toyota city / Kariya city (Data: EDINET, 2017)

	FY2017(March: JYN Million)						FY2009(March: JYN Million)				
Company Name	Security Code	Cash Equivalents	Shareholders' Equity	Revenues	Net Income	R&D Expenses	Cash Equivalents	Shareholders' Equity	Revenues	Net Income	R&D Expenses
Toyota Motor Co.	7203	2,995,075	7,514,812	27,597,193	1,831,109	1,037,528	2,444,280	10,061,207	20,529,570	-436,937	904,075
Toyota Boshoku Co.	3116	162,335	251,455	1,357,913	45,359	1,110	51,206	177,125	979,775	-5,064	28,968
Taiho Kogyo Co.	6470	20,194	60,045	108,953	4,577	3,549	10,814	43,711	90,152	-1,812	1,404
Aisan Industry Co.	7283	24,601	82,066	203,769	2,934	10,922	11,454	61,254	158,583	-5,723	7,491
Chuo Spring Co.	5992	16,098	43,431	81,500	2,180	223	5,560	35,730	81,071	-3,993	361
Trinity Industrial Co.	6382	14,827	21,250	32,990	1,550	477	5,314	17,846	39,147	580	648
Tokai Rika Co	6995	40,009	204,069	476,202	6,515	25,006	16,060	153,069	337,417	1,063	17,907
Fuji Machine MFG. Co.	6134	53,956	121,028	86,397	7,060	6,788	42,171	99,729	69,485	1,001	5,158
Futaba Iudustrial Co.	7241	24,768	45,396	412,383	5,257	3,235	12,479	34,372	385,892	-38,054	2,181
Fuji Seiko Ltd.	6142	4,845	15,542	20,388	361	76	2,082	13,171	16,762	-1,184	92
Aiphone Co.	6718	15,786	42,402	43,854	2,073	3,134	11,373	41,067	35,635	391	1,812
Aska Co.	7227	2,215	4,828	20,135	104	63	456	4,486	23,307	274	63
Shinwa Co.	7607	10,327	19,778	46,028	2,063	30	4,928	13,985	27,458	310	10
Hagiwara Electric Co.	7467	5,445	25,267	101,755	2,198	162	5,393	15,712	58,725	424	28
Denso Co. *	6902	793,550	3,312,724	4,527,148	273,895	409,223	386,177	1,829,978	3,142,665	-84,085	297,148
Toyota Industries Co. *	6201	243,685	2,240,293	1,675,148	137,565	69,524	169,743	548,264	1,584,252	-32,767	23,610
Aisin Seiki Co. *	7259	394,559	1,236,385	3,562,622	180,031	167,700	72,586	618,398	2,214,492	-25,149	1,159
Jtekt Co.*	6473	71401	478,531	1,318,310	50,363	48,213	53,206	333,840	1,017,071	-11,954	10,026

Note. Symbol * shows the companies are located in neighboring Kariya city.

This paper focuses on the following financial indices: cash and cash equivalents, total stockholders' equity, total revenues, net income, and R&D expenditures in FY2009 and in FY2017 (at each March-end time point). The reason for these indices selection comes from the application of real options analysis to R&D investment. That is, the objective of the analysis is to compare both regions' different industrial clusters' entrepreneurial risk-taking characteristics, as automotive subcontracting system and start-up ecosystem, for R&D investment between the time of the financial crisis (subprime mortgage crisis) and the present time as benchmark.

Table 2 Public companies in Hamamatsu city (Data: EDINET, 2017)

		FY2017(March: JYN Million)					FY2009(March: JYN Million)				
Company Name	Security Code	Cash Equivalents	Shareholders' Equity	Revenues	Net Income	R&D Expenses	Cash Equivalents	Shareholders' Equity	Revenues	Net Income	R&D Expenses
Suzuki Motor Co.	7269	693,952	1,149,548	3,169,542	197,616	313,500	136,915	751,812	3,004,888	3,287	114,961
Hamamatsu Photonics K.K.	6965	74,503	172,800	121,852	14,467	11,873	41,507	118,819	71,976	1,791	9,520
Yamaha Co.	7951	105,859	295,507	408,248	46,876	24,415	41,373	245,298	459,284	-20,615	23,218
Yamaha Motor Co.	7272	107,617	550,331	1,615,350	60,023	91,312	133,906	501,011	1,603,881	1,851	85,100
Enshu Ltd.	6218	2,735	3,424	20,846	-791	224	1,830	5,303	41,562	-636	183
Roland DG Co.	6789	10,003	21,554	44,112	2,705	3,158	6,936	27,312	39,047	2,892	2,061
Stanley Electric Co.	6923	101,840	299,300	388,560	33,545	13,800	40,621	185,986	283,302	12,128	4,087
F.C.C. Co.	7296	23,474	111,624	157,217	7,498	3,713	15,424	73,330	121,279	3,882	3,253
Yutaka Giken Co.	7229	28,136	73,850	157,176	7,195	2,890	7,297	38,900	205,049	45	2,752
Kyowa Leather Cloth Co.	3553	7,060	28,147	46,773	2,772	688	2,197	24,506	30,665	-942	577
ASTI Co.	6899	1,168	13,394	42,655	1,421	181	1,069	12,395	32,243	-367	89
Kawai Musical Insruments Manufacturing Co.	7952	9,821	22,079	66,548	1,646	672	5,265	12,358	61,593	-784	778
Sakurai Ltd.	7255	1,224	5,298	4,438	243	14	540	5,728	6,520	267	9
Freund Co	6312	6,982	12,410	21,164	1,064	640	2,985	7,899	13,478	619	261
Tokai Senko K.K.	3577	2,028	7,154	15,825	947	160	1,962	5,792	17,253	-855	119
Univance Co.	7254	3,452	17,071	60,024	78	1,124	5,146	15,711	60,945	-5,592	1,536
Yamazaki Co.	6147	1,163	1,833	2,843	23	37	1,355	1,889	4,541	28	52
Pulstec Industrial Co.	6894	893	2,250	2,163	339	48	961	2,663	3,236	-557	267

2. Preliminary Analysis of Data

2.1 Shift of Net Income Between FY2009 and FY2017

The net incomes of the companies in Toyota-Kariya cities have significantly shifted between FY2009, during the subprime lending shock, and FY2017, at present comfortable time - with a series of changes with the parent company as the lead, the homogenous and consistent transition, and large financial amount of shift especially from negative to positive profits (Fig.1). However, in Hamamatsu city, there were some exceptional companies with high operating performances in addition to companies in deficit, reflecting the diversification of the risk due to a variety of industries as the flexible portfolio in the region even in FY2009 at the time of the Lehman Brothers shock (Fig.2).

2.2 Productivity of R&D Investment

(1) Shift of R&D Investment of Two Cities between FY2009 and FY2017

The total trend of R&D expenditures between two the fiscal years is almost directly proportional with the slope of 1.171 (x axis is FY2009 R&D expenditures and y axis is FY2017 R&D expenditures) while reflecting Pareto distribution regarding outliers.

Concerning the data of companies in Toyota-Kariya cities, the first and second-tier firms sit in direct proportion between the two fiscal years, but companies from the third and subsequent places are concentrated in low positions in both fiscal years, while a few companies are experiencing a big increase in FY2017 R&D expenditures (Fig.3). Thus, it is possible to understand that R&D expenditures in the category companies are largely expanding.

Concerning the companies in Hamamatsu city, there is a big difference in the transition pattern between the top three companies. However, the average increase trend is relatively steeper - 2.15 against the 1.47 slop in the category of companies in Toyota-Kariya cities (Fig.4). Meaning, it is possible to consider that this industrial region offers greater diversity, and its entrepreneurial enthusiasm for R&D investment is also more pronounced.

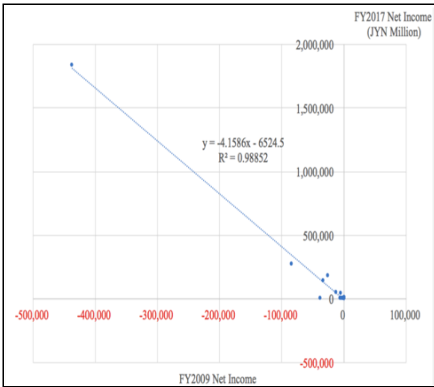

Figure 1 Toyota - Kariya cities

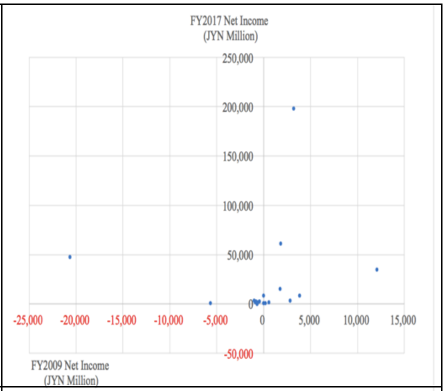

Figure 2 Hamamatsu city

Net income shift in FY2009-FY2017

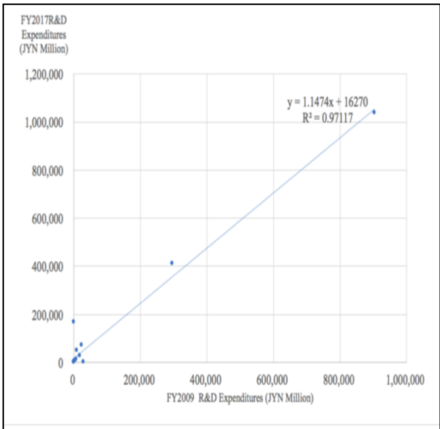

Figure 3 Toyota - Kariya cities

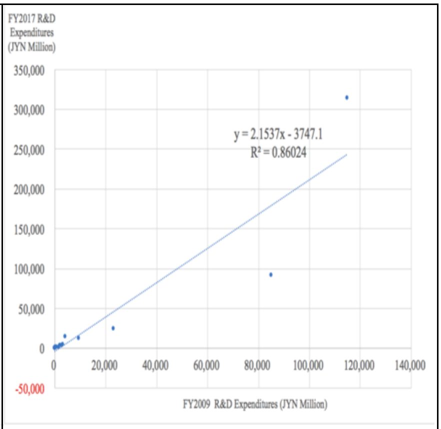

Figure 4 Hamamatsu city

Shift of R&D investment in FY2009-FY2017

(2) R&D Investment and Net Income

R&D investment of the two major companies is exceptionally large and aggressive despite the deficit in Toyota-Kariya cities; other companies have also recorded somewhat similar net losses throughout this region in FY2009 under the impacts of Lehman Brothers shock (Fig.5). Thus, many other companies seem to have had no clear and strong intention to invest in R&D, maybe due to their deficit condition. They seem to navigate without proper strategies.

As to the sample of enterprises in Hamamatsu city, there are variations in business results reflecting the diversity of industries at the time of Lehman Brothers shock of FY2009 (Fig.6). The size of the R&D investment is also variable regardless of sign and size of each net income.

The R&D expenditures and the net income seem proportional in both regional areas in FY2017 (Fig.5 & Fig.6). Looking closely, the magnitude of the net income is not necessarily directly proportional to the size of the R&D expenditures of companies in Toyota-Kariya cities. The R&D expenditures of the first-ranked company are certainly overwhelmingly large in the region, but the slopes of the second and third-tier companies are much steeper.

Regarding the enterprises in Hamamatsu city, the third and fourth-largest firms have relatively bigger R&D expenditures in regards of their profits, but the others are in direct proportion as a whole (Fig.6). In the most recent stable economic environment, the R&D expenditures are roughly proportional to the net incomes. And if the economy is stable as at the present time, similar trend in R&D investment can be expected in both regions.

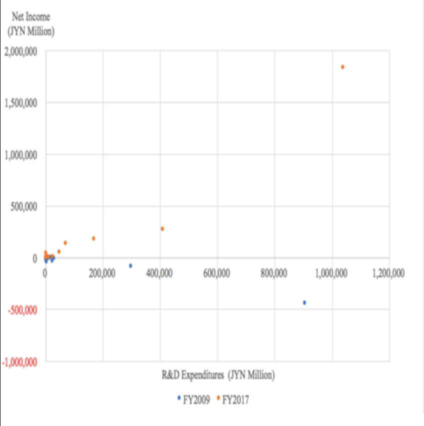

Figure 5 Toyota - Kariya cities

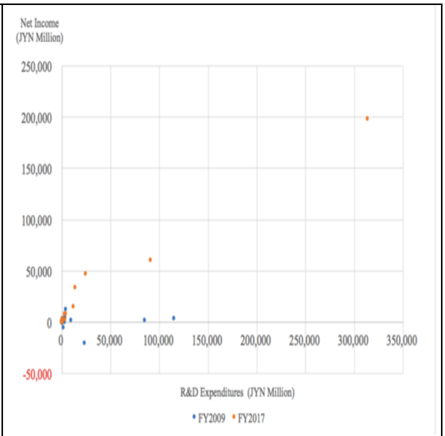

Figure 6 Hamamatsu city

R&D investment and net income in FY2009-FY2017

On the one hand, the R&D expenditures of companies in Toyota-Kariya cities have been directly influenced by the economic risk because the whole region specializes only in the automobile industry. On the other hand, Hamamatsu city's whole region has the same function as the call option in real options, since companies there adjust flexibly to the economic fluctuation due to the diversity of industries. In other words, it can be considered that the Hamamatsu city's start-up ecosystem has a call option function as both hedging against downside risk and still enjoying an upside opportunity.

(3) R&D Investment and Stockholders' Equity

Unlike the relationships between the net incomes and the R&D expenditures, relationships between the R&D expenditures and the shareholders' equities in both regions' target companies are almost positively correlated in FY 2009 (Fig.7 & Fig.8). Even so, in the group of companies in Toyota-Kariya cities, except for the top one and two companies, there are large variations, no definite relationship is seen, and the intention to use the total shareholders' equity as a call option equivalent to a guideline for R&D investments cannot be expected. It may be due to less entrepreneurship at lower tiered companies during hard times (Fig.7). In Hamamatsu city, except for one company which has experience a big jump, there is a great correlation between both variables (Fig. 8).

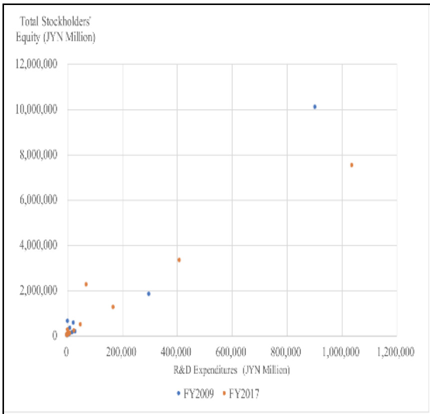

Figure 7 Toyota - Kariya cities

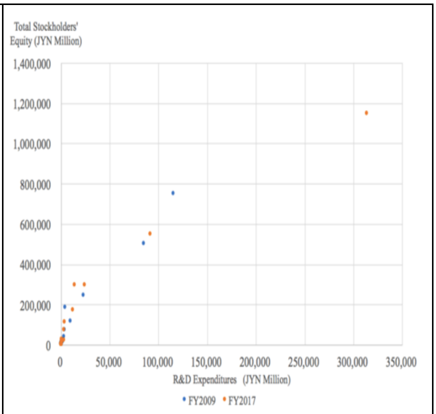

Figure 8 Hamamatsu city

R&D investment and stockholders' equity in FY2009-FY2017

In FY2017, for the group of companies in Toyota-Kariya cities, there is a rough correlation between both variables, while the variation in all the target companies is more uneven than in FY2009 (Fig.7). Even if the influence of the top three companies is significant as outliners, the slope of Toyota-Kariya cities companies is 7.24 in the linear equation, which can be considered to be much larger than 3.69 in the Hamamatsu city's group of enterprises. Additionally, as regards the group of companies in Toyota-Kariya cities, the homogenous trends are seen except for the top fourth company. Thus, in upside economic conditions, this group can enjoy this opportunity.

As regards the group of companies in Hamamatsu city, the Pareto distribution is a concave curve rather than a linear regression one, since the R&D expenditures are higher for the upper layer. However, this kind of risky investment is avoided for the lower layer companies with respect to the total shareholders' equity.

(4) R&D Investment and Stockholders' Equity with Cash Equivalents

In comparison with the transition in the relationships between the input - the R&D expenditure - and the two outcomes - the stockholders' equity and the cash equivalents, in Toyota-Kariya cities between FY2009 and FY2017, the top rank company is reducing its shareholders' equity value even if it increases its cash equivalents in response to the increase in R&D expenditures. While some companies increase the cash equivalents by retaining them as the internal reserve in anticipation of risks or just because of their inability to find investment opportunities, there might be concern for declining potential, if the growth rate of shareholders' equity value is lower than that of cash equivalents.

From the data of companies in Hamamatsu city, the top-ranking company has taken risks by significantly increasing R&D expenditures against the increase in the shareholders' equity value or the cash equivalents. The investment in R&D basically draws the Pareto distribution higher regarding the outcomes.

Then, next, we will discuss the application of Bayesian MCMC analysis mainly to the relationship between the R&D investment and the stockholders' equity.

V. Bayesian MCMC Analysis

This paper uses the software R version 3.4.1 and RStan version 2.14.2 based on MacOS version 10.12.1 and CPU 4 GHz Intel Core i7, and applies for Bayesian MCMC analysis in each fiscal year the following hierarchical linear regression model:

$$Y_n \sim Normal\left(a\left[Region[n]\right] + b\left[Region[n]X[n]\right], \sigma_Y\right) \quad (1)$$
$$n = 1, \cdots, N$$
$$a[k] = a_{Total\ Avg} + a_{Regional\ Res}\,[k] \quad k = 1, \cdots, K \quad (2)$$
$$a_{Regional\ Res}\,[k] \sim Normal \quad (0, \sigma_a) \quad k = 1, \cdots, K \quad (3)$$
$$b[k] = b_{Total\ Avg} + b_{Regional\ Res}\,[k] \quad k = 1, \cdots, K \quad (4)$$
$$b_{Regional\ Res}\,[k] \sim Normal \quad (0, \sigma_b) \quad k = 1, \cdots, K \quad (5)$$

Where

Avg = average; Res = residual
Y = random variable (r.v.) of stockholders' equity,
X = r.v. of R&D expenses,
a = r.v. of intercept, b = r.v. of slope,
n = each real data of total sample population,
N = total real data of total sample population,
k = each real data of each reginal sample,
K = total real data of each reginal sample,
$Region = 1$ (Toyota-Kariya cities),
$Region = 2$ (Hamamatsu city),
$Region = 0$ (Whole area), and
σ =standard deviation.

1. FY2009

All the variables had the r-hat values less than 1.1 by re-parameterizing method for 2 levels of hierarchical Bayesian MCMC analysis consisted of two groups as the group of companies at Toyota-Kariya cities and their counterparts at Hamamatsu city in the whole sample. Then, this simulation is considered as converging with simulation sampling (Table 3, Figs.9-11).

As a result, in the case of the group of companies in Toyota-Kariya cities, the simple linear regression analysis between the independent random variable - the R&D expenditures - and the dependent random variable - the total shareholders' equity - had the average intercept Japanese Yen (JYN) - 33,822.74 million (2.5%: JYN - 317,298.36 million to 97.5%: JYN 250,188.32 million) and the average slope being 10.09 (8.78 to 11.42). Next, in the group of companies in Hamamatsu city, the average intercept was JYN 8,000.44 million (JYN - 269,516.31 million to JYN 287,992.92 million), and the average slope was 7.26 (- 1.08 to 14.55), respectively.

Table 3 FY2009 print (fit)

4 chains, each with iter=2000; warmup=1000; thin=1;
post-warmup draws per chain=1000, total post-warmup draws=4000.

	mean	se_mean	sd	2.5%	25%	50%	75%	97.5%	n_eff	Rhat
a0	1468.62	79622.63	761291.36	-1753119.17	-253000.96	1158.79	267732.17	1651791.20	91	1.05
b0	9.12	0.53	10.12	-10.98	4.82	9.45	12.73	30.27	371	1.00
a_raw[1]	-0.06	0.05	0.70	-1.49	-0.48	-0.05	0.36	1.36	236	1.03
a_raw[2]	0.02	0.05	0.70	-1.35	-0.40	0.01	0.43	1.42	223	1.04
b_raw[1]	0.15	0.02	0.72	-1.24	-0.33	0.12	0.61	1.59	907	1.00
b_raw[2]	-0.15	0.02	0.71	-1.59	-0.59	-0.17	0.30	1.28	882	1.00
s_a	1580140.17	125416.31	2298026.94	18284.66	200239.63	686207.15	2014700.60	8455715.27	336	1.01
s_b	14.67	3.17	15.31	0.43	3.97	9.46	20.65	55.35	23	1.06
s_Y	591052.74	2818.29	79468.30	467127.92	535985.00	580382.57	634054.36	777824.70	795	1.00
a[1]	-33822.74	4325.85	144289.53	-317298.36	-127233.57	-32372.16	60333.64	250188.32	1113	1.00
a[2]	8000.44	2480.38	140343.92	-269516.31	-82698.89	6520.74	101856.45	287992.92	3201	1.00
b[1]	10.09	0.01	0.68	8.78	9.64	10.08	10.54	11.42	3802	1.00
b[2]	7.26	0.11	3.96	-1.08	4.72	7.66	9.95	14.55	1347	1.00
lp__	-467.87	0.15	3.01	-474.40	-469.70	-467.65	-465.84	-462.50	411	1.01

Samples were drawn using NUTS(diag_e) at Mon Jul 24 17:58:59 2017.
For each parameter, n_eff is a crude measure of effective sample size,
and Rhat is the potential scale reduction factor on split chains (at
convergence, Rhat=1).

From this result, it can be considered that the group of companies in Toyota-Kariya cities has seriously damaged the option value in R&D investment immediately after the Lehman Brothers shock, especially in comparison to the intercepts with Hamamatsu city's counterparts. Also, the limited-range slope can possibly show the homogenous and limited productivity of the R&D investment. Next, as to the group of enterprises at Hamamatsu city, the base of R&D investment is relatively stable with each average and range of the intercept, and the state is not strongly influenced by the Lehman Brothers shock. Thus, its position can be seem as relatively calm. In addition, although the average value of the slope as R&D productivity is lower than that of the counterpart group in Toyota-Kariya cities, it can be considered that the risk is diversified due to structural flexibility since the distribution is wider than that of the counterpart.

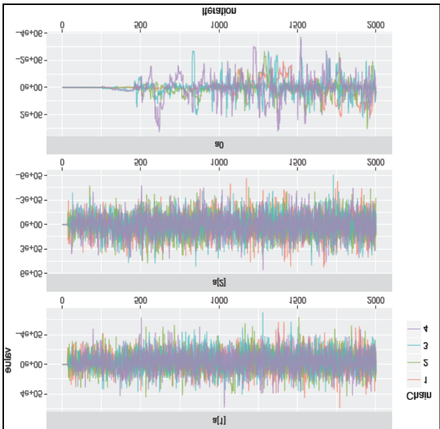

Figure 9 FY2009 trace-plot of intercept

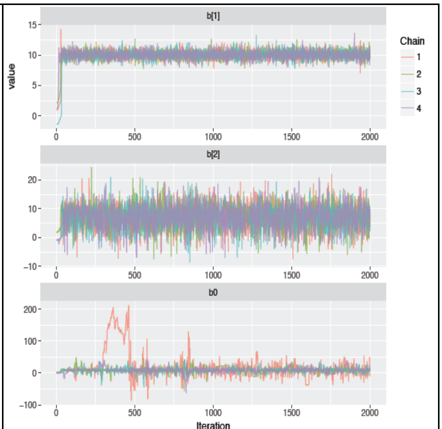

Figure 10 FY2009 trace-plot of slope

2. FY2017

As the r-hat values of all the variables were lower than 1.1 by re-parameterizing method, the simulation result converged like in FY2009 (Table 4, Figs.12-14). Parameter values reflecting each region's characteristics were also obtained as a result of Bayesian MCMC analysis by hierarchizing both the company group at Toyota-Kariya cities and the company group at Hamamatsu city similarly under the total group to the analysis of FY2017.

In the same way, as in FY2009, simple linear regression analysis between R&D expenditures - independent variable - and the total shareholders' equity - dependent variable, on the Toyota-Kariya cities group of companies showed that the average intercept was JYN 143,198.40 million (JYN - 6,509.27 million to JYN 303,382.26 million) and the average slop was 7.25 (6.65 to 7.85). And, on the counterpart group of companies in Hamamatsu city, the average intercept was JYN 66,327.74 million (JYN - 90,341.86 million to JYN 213,484.83 million), and the average slope was 3.76 (1.64 to 5.92).

Table 4 FY2017 print (fit)

4 chains, each with iter=2000; warmup=1000; thin=1;
post-warmup draws per chain=1000, total post-warmup draws=4000.

	mean	se_mean	sd	2.5%	25%	50%	75%	97.5%	n_eff	Rhat
a0	-55657.81	135457.96	1313264.10	-3862384.96	-228806.38	87819.44	232558.00	2887952.05	94	1.03
b0	6.65	0.78	9.35	-13.32	2.59	6.15	11.92	27.59	143	1.04
a_raw[1]	0.17	0.03	0.68	-1.16	-0.23	0.18	0.56	1.61	629	1.00
a_raw[2]	0.01	0.03	0.70	-1.53	-0.41	0.07	0.46	1.34	417	1.02
b_raw[1]	0.23	0.04	0.70	-1.04	-0.18	0.18	0.66	1.75	353	1.02
b_raw[2]	-0.29	0.03	0.67	-1.78	-0.68	-0.22	0.14	0.95	533	1.01
s_a	1919987.50	402741.03	3287071.89	15247.76	117659.74	548368.86	2105269.83	11178303.71	67	1.06
s_b	18.48	3.79	18.65	1.34	4.83	10.83	24.82	63.87	24	1.19
s_Y	320314.00	2462.24	40716.80	251493.06	289294.69	316967.73	348269.28	413667.32	273	1.02
a[1]	141673.26	2718.44	76811.33	-4538.96	90877.51	139364.76	189424.40	294855.85	798	1.01
a[2]	68644.34	4443.86	74958.00	-81208.50	18141.95	70268.06	122984.21	203440.10	285	1.01
b[1]	7.25	0.01	0.30	6.65	7.06	7.26	7.45	7.85	2729	1.00
b[2]	3.74	0.03	1.06	1.53	3.05	3.75	4.44	5.76	1297	1.01
lp__	-445.87	0.18	2.92	-452.20	-447.65	-445.75	-443.86	-440.65	275	1.03

Samples were drawn using NUTS(diag_e) at Mon Jul 24 18:37:39 2017.
For each parameter, n_eff is a crude measure of effective sample size,
and Rhat is the potential scale reduction factor on split chains (at
convergence, Rhat=1).

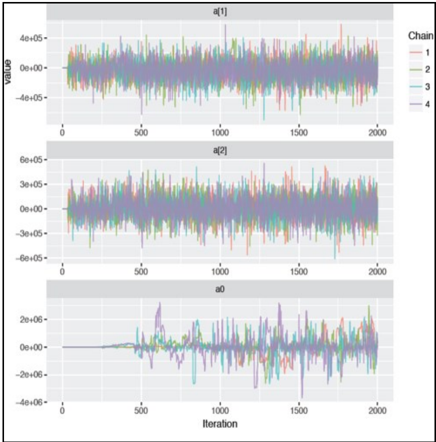

Figure 11 FY2017 trace-plot of intercept

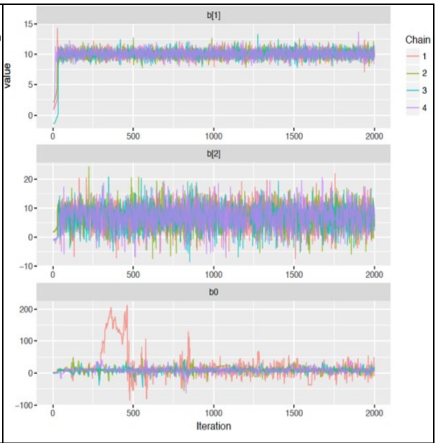

Figure 12 FY2017 trace-plot of slope

From the recent favorable economic conditions of the group of companies in Toyota-Kariya cities, it is possible to understand the good conditions of both the productivity base of R&D investment and the option value from the average and width of the intercept. Regarding the counterpart companies at Hamamatsu city under the relevant normal condition, from the average and width of the intercept, it is relatively easy to understand that the state is uncompetitive with the group of companies in Toyota-Kariya cities. It reflects the favorable conditions for higher mass-manufacturing capacity and the consistent decision style as being in the same boat. However, even though the slop's average is lower and the value at the 95% level of the width is also inferior, its standard deviation is larger and the table's range of the width is also wider. Then as a system of risk diversification for the future, this regional innovative potential is still expected as high especially under condition of uncertainty.

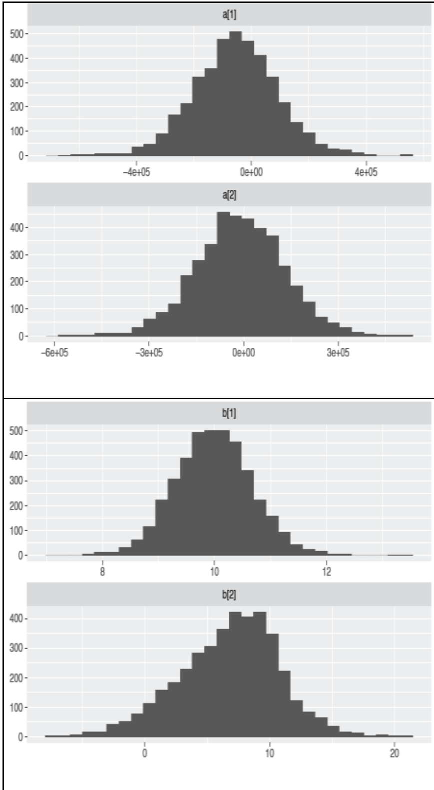

Figure 13 FY2009 fit-summary

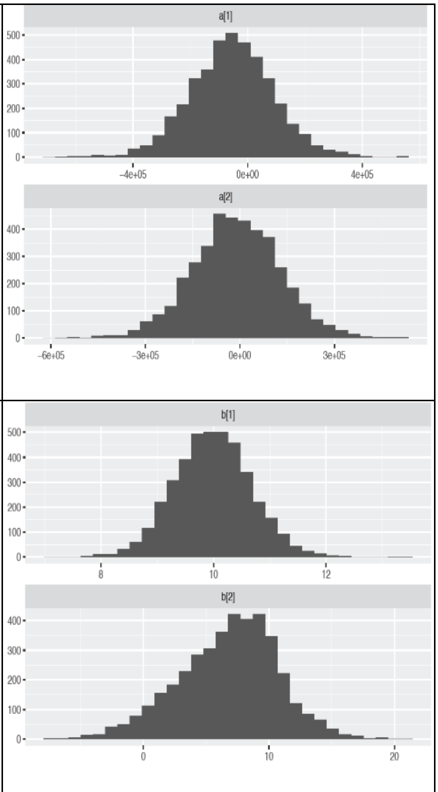

Figure 14 FY2017 fit-summary

VI. Conclusion

This study applies Bayesian MCMC analysis on the R&D productivity for the total stockholders' equity as potential in the two different regional industry systems - the Toyota-Kariya cities' automobile subcontracting system and the Hamamatsu city's start-up ecosystem between the financial crisis in FY2009 and present FY2017. One of the main findings regarding the Toyota-Kariya cities' vertical, subcontracting system's R&D investment, is confirmation that both the condition and the productivity of the R&D investment are greatly influenced by the economic environment as large value fluctuations of the intercept and the slope of the linear regression analysis on the R&D expenses and the total stockholders' equity. With respect to the Hamamatsu city's horizontal start-up ecosystem, the range of exploratory R&D is much broader and the state of R&D investment is much more stable especially during the

Lehman Brothers' financial crisis in the intercept and the slope of the same analysis due to start-up ecosystem's flexibility.

Secondly, the total shareholders' equity value can be a guideline for continuing R&D investment as a growth option of call option, even if the net income is a deficit as the start-ups faced the 'Valley-of-Death' before starting production or the automobile part makers facing with severe market condition. In addition, the cash equivalents themselves can also play a role in the call option in extremely hard condition. Then, regardless of start-ups, SMEs, or even large companies, the entrepreneurial decision makers can take risk in R&D investment in radical innovation even in negative profits condition by using the guideline of real options.

From the perspective of regional economy resilience from risk, the Toyota group companies have an inclination to make similar consistent decisions with fellow members through vertical communication regardless of booming or depression periods. Then, these companies have a tendency to be directly exposed to risk and opportunity. However, in Hamamatsu city, the resilience of start-up ecosystem can be confirmed due to regional flexibility as a horizontal and diversified industry documented by Bayesian MCMC analysis. And regional flexibility to economic condition can also be estimated by fitted standard deviation as a measurement of volatility.

As regards Toyota Motor, the leading company in the automobile industry in Toyota-Kariya cities, which has reduced the total shareholders' equity value even if it increases the cash equivalents, the potential evaluations of the group companies possibly seem to be declining by the capital market except some main subsidiaries such as Denso. Then, they need to invest more in R&D regarding not only FCV (fuel cell vehicle), but also artificial intelligence and EV (electric vehicle) technology for next-generation automotive or vehicle.

In Hamamatsu city, not only transport vehicle industry actors Suzuki and Yamaha Motor, but also new technology leaders Hamamatsu Photonics and Roland DG recorded positive profits even in FY2009, during the financial crisis. The increase of total stockholders' equity is much higher in R&D investment than that of cash equivalents. And, as Pareto distribution shows, leaders such as Suzuki, Yamaha, Yamaha Motor, Hamamatsu Photonics, and Roland DG have invested very aggressively in R&D as compared with stockholders' equity. This shows the entrepreneurship atmosphere based on this region's historical culture. Thus, although at present Japan's manufacturing industry depends mainly on Aichi prefecture's automobile industry, leading company group Toyota Motor also has to continue R&D investment in next-frontier innovation in order to improve their total stockholders' equity value. For carrying on each company's R&D investment, the stockholder's equity as real option can be a guideline even under negative profits condition. As regards the regional resilience of the start-up ecosystem, Bayesian MCMC analysis can be used to estimate the flexibility barometer as regional company group's simulated standard deviation or volatility to flexible or diversified economic conditions.

As a practical implication, the total stockholders' equity or sometimes the cash equivalents can play the role of growth option as patient capital or the guideline to continue R&D investment for contracting SMEs in harsh time or start-ups facing the 'Valley-of-Death.' And Bayesian MCMC analysis is useful for finding the signaling function of the R&D productivity or the flexibility of project portfolio to investment due to the range or mean of the slope of linear regression from a perspective of each company manager or regional policy maker level.

As next challenges, the following topics can be considered: firstly, integrating real optional analysis with Bayesian MCMC analysis to evaluate regional flexibility value by the parameter estimation and financial engineering, and secondly, undertake a covariance structural analysis to highlight the decision and chance event path directions.

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