An Analysis of Exploration and Exploitation of Technological Knowledge for Software and Service

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1

Abstract

This paper argues how firms explore and exploit technological knowledge for software and service through quantitative analysis.

The present investigation deals with quantitative measurements of patent information in firms of telecommunication industry and software industry in Japan.

Based on patent information related to R&D alliance, technological diversity, or technological fusion in the firms, the status of exploration and acquisition of technological knowledge in the firms is described. The items that I used to describe the activities were as follows: joint patent application, IPC (International Patent Classification) code allocated for each patent, co-occurrence of the IPC among several patents, and so on.

By referring to the relationship among patent information, from perspective of balancing exploration and exploitation in organizational learning, I grasp the technological trend and the activity of competitions about the concerned industry, and the applicable strategic technology management is also discussed.

2

INTRODUCTION

- The Background of theory is the exploration-exploitation framework:
- The exploration-exploitation framework distinguishes two broad patterns of learning behaviors.
- March ([1], p. 71) defined them as follows:
  - "Exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation"
  - "Exploitation includes such things as refinement, choice, production, efficiency, selection, implementation, execution"
- March ([1], p. 85) claims them as follows:
  - "The essence of exploitation is the refinement and extension of existing competencies, technologies and paradigms. "
  - "The essence of exploration is experimentation with new, uncertain alternatives."

3

INTRODUCTION

- A great deal of research has been conducted, and suggested the importance of well-balanced, exploration and exploitation.
- Little is known about the organizational mechanisms that drive firms' tendencies in software industry in Japan.

Domains of Exploration-Exploitation (Source: [2])

Domain	Function	Structure	Attribute
Answers the question	What value chain function does the alliance serve?	Whom does the firm partner with?	To what extent does the partner differ from prior partners?
Focus	Alliance type	Network structure	Partner profile
Exploration	Forming a knowledge-generating R&D alliance	Forming an alliance with a new partner that has no prior ties to the firm	Forming an alliance with a partner whose organizational attributes differ from those of prior partners
Exploitation	Forming a knowledge-leveraging marketing/production alliance	Forming recurrent alliances with a partner that has prior ties to the firm	Forming an alliance with a partner whose organizational attributes are similar to those of prior partners

4

Research Objective

In order to get supplemental means to assist understanding for innovation of software and service in Japan, I set the research objectives as follows:

- To test the applicability of the exploration-exploitation framework to software industry in Japan
- To examine the differrence of R&D activity among the software firms in Japan, from perspective of balancing exploration and exploitation

5

HYPOTHESES

- Hypothesis 1.
- Expanding search in software company will be contribute to accumulating diverse knowledge in an organization
  - like in the other industry reported in previous work(e.g.[3])
  - Expanding search in research and development (R&D) allows to strengthen the function of absorbing uncertainty, diversifying technological knowledge, and enhancing flexibility to a volatile environment. which increases the survival probability of an organization. [3]

6

HYPOTHESES

- I perform comparison between SI software and package software in Japan, referring to classification of IT-based service development tasks in previous works[5, 9].

		Complexity of Service		
		Low	Medium	High
Complexity of IT or Software Technology	Low	Routine Development	Service Engineering	
	Medium	Software Engineering	Co-development or Co-design of IT and Service	
	High	Patent application of package soft	Patent application of SI Software	

Fig.1-1 IT-based Service development tasks（Based on source[5,p41][9, p15])
(referred with some expressions changed in order to be associated with patent activity)

HYPOTHESES

- Hypothesis 2.
- Exploitative activity in R&D for package software will be more efficacious and relatively superior value.
  - Because, in developing package software, software technology is the main value driver and applies it to a service with relatively low complexity, then deep technological knowledge of self software domain is important.
- Explorative activity in R&D for SI software will be more efficacious and relatively superior value
  - Because, in SI, customer integration and service engineering relatively grow in value and develop new or improved services which are supported by a new knowledge based on customer, and therefore, the development process of system integrator is characterized by modifying the software system adjusted to the individual uncertain needs of the customer in some cases.

8

Method

Research Setting

For these empirical tests, I present investigation deals with quantitative measurements of patent information in firms of telecommunication industry and software industry in Japan.

- The patent metrics is limited to explain the R&D activity. However, I consider that it is enough to discuss within the scope of this research objective, due to its large quantities data suitable to objective analysis.

Data Sampling

- Patent database using JPO(The Japan Patent Office) patents IIP PATENT DATABASE[4]

9

Method

Research Setting

- Measures
  - Measure for Exploration or Exploitation in previous research
    - Counts of Citation Own Patent
      - Increases of self-cite counts are associated with a increase in exploitation.

      cf. In previous empirical research,
      - » Patents have been differentiated by whether they self-cite or not(e.g.[7]).
      - » Self-cite is coded as exploitative[6].
      - » Increases of other-cite counts are associated with an increase in exploration[3].
    - Counts of Co-applicant
      - alliances formed with new partners are considered exploration[2]

10

Method

- Measures
  - Counts of Co-applicant
    - alliances formed with new partners are considered exploration from "structure domain" perspective[2]

	Domain		Definition(Source: [2])	This work
1	Function			
2	Structure	Explore	Forming an alliance with a new partner that has no prior ties to the firm	・Joint application with new co-applicants
		Exploit	Forming recurrent alliances with a partner that has prior ties to the firm	・Joint application with recurrent co-applicants ・Sole application
3	Attribute			

11

Method

Research Setting

- Measures
  - Measure for diverse technological knowledge
    - IPC(International Patent Classification) Counts(IPC is technology classification)

- Analysis
  - Descriptive levels
  - Correlation For eliminating bias
    - every variable is normalized to the mean number per application counts.
    - this procedure is similar to be treating firm size as a control variable.
    - because tend to have higher numbers of patent applications than larger firms(e.g.[8])

12

Method

- Hypothesis 1. can be paraphrased by using the measures as the following Hypothesis 1´.

- Hypothesis 1:
- Expanding search in software company will contribute to accumulating diverse knowledge in an organization.

- Hypothesis 1´:
- Within a firm, when the co-applicant counts are increased, the IPC counts are increased.
  - IPC Counts is represented technology diversity.
  - Alliances formed with new partners, considered exploration, increase Co-Applicant Counts

13

Method

- Hypothesis 2. can also be paraphrased by using the measures as the following Hypothesis 2´.

- Hypothesis 2:
- A) Exploitative activity in R&D for package software will be more efficacious and relatively superior value.

- Hypothesis 2´:
- A) In a package software firm, when back citation counts to own patent are increased, the registration counts are increased compared to a SI software firm
  - Registration Patent is relatively superior value
  - Back Citation Counts to Own Patent is relatively exploitative

14

Method

- Hypothesis 2. can also be paraphrased by using the measures as the following Hypothesis 2´.

- Hypothesis 2:
- B) Explorative activity in R&D for SI software will be more efficacious and relatively superior value.

- Hypothesis 2´:
- B) In a SI software firm, when the co-applicant counts are increased, the registration counts are increased compared to a package software firm.
  - Registration Patent is relatively superior value
  - Alliances formed with new partners, considered exploration, increase Co-Applicant Counts

15

Method

Research Setting

- Sample Target
  - 148 SI・Software Firms and 52 Package software Firms
    - Classified businesses by industry in Kaisha-Shikiho(TOYO KEIZAI INC. in Japan)

  - I focus on firms that have 1 or more application patents applied in period of the analysis.
  - In the analysis of citation information, I focus on firms that have 1 or more registered patents that were applied in period of the analysis
    - because, IIP Patent Database includes citation data only in Patent Gazett for registered patents[4]

16

Method

Research Setting

- Sample Target
  - 148 SI・Software Firms and 52 Package software Firms
    - Classified businesses by industry in Kaisha-Shikiho(TOYO KEIZAI INC. in Japan)

Number of Target Firms used for this analysis

Target Firms used for this analysis		Applied Year	
		1996-2000	2001-2005
Package Software	firms that have 1 or more application patents	21	35
	firms that have 1 or more registered patents	15	19
SI・Software	firms that have 1 or more application patents	71	86
	firms that have 1 or more registered patents	44	45

17

Results

Descriptive Statics (Package Software Firms)(2001-2005) [n=35]

Variables	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Application Counts	1	1	3	14.63	11	221
Sole Application Counts	0	1	3	13.60	10.5	216
Joint Application Counts	0	0	0	1.03	1	11
Co-Applicant Counts	0	0	0	1.09	1	8
IPC(Class) Counts	1	1	1	2.34	3	12
IPC (Group)Counts	1	1	2	5.34	7	39
IPC(Class) Counts in Joint Applications	0	0	0	0.71	1	5
IPC (Group)) Counts in Sole Applications	0	1	1	2.09	3	12
Sole Application Counts[per Application counts]	0.00	0.86	1.00	**0.90**	1.00	1.00
Joint Application Counts[per Application counts]	0.00	0.00	0.00	**0.10**	0.14	1.00
Co-Applicant Counts[per Application counts]	0.00	0.00	0.00	0.12	0.15	1.00
IPC(Class) Counts[per Application counts]	0.05	0.21	0.50	0.59	1.00	2.00
IPC (Group)Counts[per Application counts]	0.12	0.50	1.00	0.77	1.00	2.00
IPC(Class) Counts in Joint Applications [per Application counts]	0.00	0.00	0.00	0.10	0.11	1.00
IPC (Class) Counts in Sole Applications [per Application counts]	0.00	0.17	0.50	0.54	1.00	2.00

18

Results

Descriptive Statics (Package Software Firms)(2001-2005) [n=84]

Variables	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Application Counts	1	2	5.00	24.65	13	544
Sole Application Counts	0	1	2.50	20.31	9	537
Joint Application Counts	0	0	1.00	4.35	4	47
Co-Applicant Counts	0	0	1.50	3.20	3	35
IPC(Class) Counts	1	1	2.50	5.08	6	53
IPC (Group)Counts	1	2	4.00	9.99	9	155
IPC(Class) Counts in Joint Applications	0	0	1.00	2.19	3	14
IPC (Class) Counts in Sole Applications	0	1	2.00	3.73	4	52
Sole Application Counts[per Application counts]	0.00	0.31	0.71	**0.62**	1.00	1.00
Joint Application Counts[per Application counts]	0.00	0.00	0.29	**0.38**	0.69	1.00
Co-Applicant Counts[per Application counts]	0.00	0.00	0.20	0.42	0.66	3.00
IPC(Class) Counts[per Application counts]	0.06	0.33	0.57	0.66	1.00	2.00
IPC (Group)Counts[per Application counts]	0.19	0.61	0.85	0.83	1.00	2.00
IPC(Class) Counts in Joint Applications [per Application counts]	0.00	0.00	0.20	0.31	0.50	1.00
IPC (Class) Counts in Sole Applications [per Application counts]	0.00	0.12	0.33	0.41	0.50	2.00

Results

Correlation between Variable A and Variable B,
B is IPC(Class) Counts [per Application counts]

*$P < 0.05$ **$P<0.01$

Variable A	Package software Firms	SI・Software Firms
Co-Applicant Counts [per Application counts]	①**0.48*** ②0.01	①**0.36**** ②**0.29****
Sole Application Counts [per Application counts]	①▲0.2 ②▲0.04	①▲0.41 ②▲0.14

①: 21 Package software Firms and 71 SI・Software Firms in 1996-2000
②: 35 Package software Firms and 86 SI・Software Firms in 2001-2005

- Both Package software Firm and SI Software Firm
  - IPC Counts and Co-Applicant Counts are positively related
    - IPC Counts is represented technology diversity.
    - Alliances formed with new partners, considered exploration, increase Co-Applicant Counts

20

Results

Correlation between Variable A and Variable B,
B is Registration Counts[per Application counts]

*P < 0.05 **P<0.01

Variable A	Package software Firms	SI・Software Firms
Co-Applicant Counts [per Application counts]	①▲0.09 ②▲0.11	①**0.21** ②**0.21**
Sole Application Counts [per Application counts]	①▲0.06 ②▲0.01	①▲0.19 ②▲0.16

①: 21 Package software Firms and 71 SI・Software Firms in 1996-2000
②: 35 Package software Firms and 86 SI・Software Firms in 2001-2005

- In comparison Package software Firm to SI Software Firm,
  Registration Counts and Co-Applicant Counts are positively related in only SI Software firms
  - Registration Patent is relatively superior value
  - Alliances formed with new partners, considered exploration, increase Co-Applicant Counts

21

Results

Correlation between Variable A and Variable B,
B is Registration Counts[per Application counts]

*P < 0.05 **P<0.01

Variable A	Package software Firms	SI・Software Firms
Back Citation to Own Patent [per Registration Counts]	①**0.96**** ②**0.46***	①0.18 ②0.27

①: 15 Package software Firms and 44 SI・Software Firms in 1996-2000
②: 19 Package software Firms and 45 SI・Software Firms in 2001-2005

- In comparison Package software Firm to SI Software Firm,
  Registration Counts and Back Citation Counts to Own Patent are more positively related in Package Software firms
  -Registration Patent is relatively superior value
  -Back Citation Counts to Own Patent is relatively exploitative

22

Discussion and Conclusion

- Both Package software Firm and SI Software Firm
  - IPC Counts and Co-Applicant Counts are positively related
    - IPC Counts is represented technology diversity.
    - Alliances formed with new partners, considered exploration, increase Co-Applicant Counts
  - From the result of correlations and descriptive statics, Expanding search in software company contributes to accumulating diverse knowledge in an organization.
    - Hypothesis 1 is not denied.

23

Discussion and Conclusion

- In comparison Package software Firm to SI Software Firm,
- Package Software
  - Registration Counts and Back Citation Counts to Own Patent are more positively related
    - Registration Patent is relatively superior value
    - Back Citation Counts to Own Patent is relatively exploitative
  - From the result of correlations and descriptive statics, exploitative R&D more effective in package software development.

24

Discussion and Conclusion

- SI Software
  - Registration Counts and Co-Applicant Counts are positively related
    - Registration Patent is relatively superior value
    - Alliances formed with new partners, considered exploration, increase Co-Applicant Counts
  - From the result of correlations and descriptive statics, exploratory R&D more effective in SI software development.
  - In comparison Package software Firm to SI Software Firm, Hypothesis 2 is not denied.

25

Discussion and Conclusion

■Additional analysis, from "attribute domain" perspective, of software development for mobile phone

	Domain		Definition(Source: [2])	This work
1	Function			
2	Structure			
3	Attribute	Explore	Forming an alliance with a partner whose organizational attributes differ from those of prior partners	・Joint application by small software firm, with non-small firm or non-software firm (Joint Application Type1)Co-applicant is a non-software firm, such as manufacturer of device equipped with the ability to develop a service (Joint Application Type2)Co-applicant is a service provider, such as large SI firm or mobile phone carrier

26

Discussion and Conclusion

■Patent Activity of several success SI software firms for mobile phone

- The firm size is small, but their software has been used in mobile phone carrier's innovative service in Japan.
- The patent activity is seem to be explorative from “structure” and “attribute” domain perspective, and be useful to get demands of clients.

Firm ID	Application Year			Patent Metrics
	Step1 (Exploitation)	Step2 (Exploration)	Step3 (Exploration)	(1)All Application Counts (2)All Joint Application Counts
1	1996	1997	2002	(1)45 (2)12
2	1997	-	2004	(1)8 (2)2

Step1: first patent application, that is sole application
Step2: first joint application with manufacturer of device equipped with the ability to develop a service (i.e. Joint Application Type1)
Step3: first joint application with mobile phone carrier or large SI firm, that is a service provider (i.e. Joint Application Type2)

27

Discussion and Conclusion

■R&D of several success SI software firms for mobile phone

- The quantitative patent data implies that the effective balance by selective use of exploration(“ExR” in Fig.1-2) and exploitation(“ExT” in Fig.1-2) has promoted absorption of technological knowledge for software and service in the success mobile phone SI software firms.

		Complexity of Service		
		Low	Medium	High
Complexity of IT or Software Technology	Low	Routine Development	Service Engineering	
	Medium	Software Engineering	Co-development or Co-design of IT and Service	
	High			

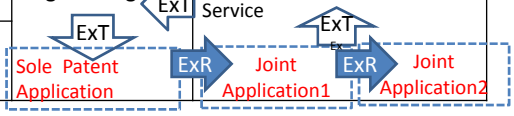

Fig. 1-2 IT-based Service development tasks（Based on source[5,p41][9, p15])
(referred with some expressions changed in order to be associated with propensity to patent)

28

Limitations

- It is possible that omitted variables result in the observation of spurious associations.
- The patent metrics is limited to explain innovative activity, but other variables not directly analyzed, such as the client demands.
  - However, this work has indicated that the degree of the depth of the relationship with the demands for services, can be explained indirectly, by the attributes of co-applicants.
  - Direct analysis of the other variables is a future work.
- The information on citation are given by patent examiner, not inventor. It is important to understand the quality and the limitations of the citation data in the IIP database explained above when researchers try to use it[4].

29

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30

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31