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Abstract

This paper is a quick announcement of the results of an analysis that was conducted to identify how innovation is affected by the fixation of borders in inter-organizational networks that make up regional systems for innovation. The data used in the analysis was taken from a questionnaire survey about finished projects from the Ministry of Economy, Trade and Industry's "Consortium R&D Projects for Regional Revitalization." The analysis shows that for a project undertaken by an inter-organizational network, the probability that its results will be successfully implemented has a U-shaped relationship to the rate of fixation among its participants. This finding suggests that greater fixedness is not necessarily always advantageous for innovation. Meanwhile, since path dependence exists among the configuration of the network's participants, the tendency for boundaries to become fixed can emerge at any time. To bring attention to this point, I have chosen to call the phenomenon identified in the analysis "the trap of boundary fixation."

Keywords: Inter-organizational networks, regional innovation, system boundaries

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1. Introduction

This paper is a quick announcement of the results of a survey and analysis that was conducted to identify the factors that determine the borders of inter-organizational networks that make up regional systems for innovation. In particular, it discusses the results of an analysis on how innovation is affected when the boundaries of inter-organizational networks become "fixed."

In what follows, I will first state the purpose and theoretical background of this analysis, with prior research as a starting point. Then, after explaining how we collected the data we used, I will describe the results of the analysis and extract from them a few implications and issues for the future.

2. The objective and background of this study

The concept of national innovation systems (hereinafter, NIS), which was prominent from the late 1980s into the beginning of the 90s, provided the key to comprehensively understanding the factors that make the process of innovation different in each country (Freeman 1987; Dosi et al. 1987; Lundvall, ed. 1992; Nelson ed., 1993). Later, this concept came to include analyses from the perspective that an innovation system at the national level cannot be spatially homogenous, from which the concept of regional innovation systems (hereinafter, RIS) was derived. The conceptual construct of RISs is nearly identical to that of NIS, as can be seen in Cooke (1998), and can be interpreted as an NIS whose spatial scale has been shrunk. However, while discussions about NIS have tacitly assumed that the nation is the administrative unit that prescribes the boundaries of the system, the identification of some administrative unit (for example, state/prefecture/city/etc.) cannot be considered self-evident in RIS, since "region" has a multi-dimensional meaning. The interpretation of the boundary in RIS has thus remained a theoretical challenge.

To address this, I have proposed a perspective that interprets the boundary of an RIS as being created self-referentially through the operations of the actors responsible for innovative activity rather than being defined via an artificial given like an administrative unit (Nagata and Shinozaki 2005; Nagata and Hirata 2013). This perspective has been advocated by Maturana and Varela (1991) in the domain of living systems theory and is based on the concept of autopoietic systems developed by Luhmann (1996) in the domain of social systems theory.

When we adopt this perspective, we are naturally confronted with new issues. First, which factors stipulate the operations of the actors that create the boundary of an RIS (that is, the regional extent of their operations)? Second, how is innovation affected by the breadth of the inter-actor network that demarcates the boundary of the RIS?

The clue to solving the first issue was found in the work of social network analysis. Prior research in this field has detected two kinds of advantages: (1) Cases where an inter-actor network has an open characteristic, and the boundary of its social system tends to expand; and (2) cases where, on the contrary, the network is closed, and its social system has the characteristic of a cohesive group.

Studies indicating that there is an advantage to an open network have pointed out that beneficial new information is brought in by the weak ties that make up an extensive network. This finding is summed up in Granoveter's theory of "the strength of weak ties" (1973). Furthermore, focusing on the dearth of mutual connections between highly cohesive groups, Burt (1992) used the term "structural hole" to describe this phenomenon and showed that the existence of actors in a position to bridge such holes brings diverse new information to the group.

Meanwhile, the advantage of a closed network has been indicated in empirical studies analysing the relationship between inter-actor geographical proximity and innovation. These studies, which are based on citation analyses used in patent data, show that knowledge spillover has a strong tendency to occur within a single region (Jaffe, et al., 1993; Almedia and Kogut, 1999).

Another advantage of a closed network is suggested in a study by Coleman (1988), which focused on the degree of reciprocity among participants of a cohesive network. More recently, a study by Owen-Smith (2004) that used a patent database and a study by Uzzi and Spiro (2005) that used a database of scientific papers both indicated that cohesive networks are advantageous for the circulation of ideas.

The findings that can be taken from this prior research can be summarized as follows: When an inter-actor network has an open characteristic, this is advantageous because it allows diverse new information being brought in; conversely, when a network has a closed characteristic, this is advantageous because it encourages the diffusion of knowledge within the network. This leads to the hypothesis that the boundary of an RIS expands to the degree that its participating organizations pursue the advantages of an open network and shrinks to the degree that they pursue the advantages of a closed network.

The above discussion also leads to a hypothesis about the second question about how innovation is affected when an inter-actor network becomes more extensive. An extensive, open network operates in a way that is advantageous for acquiring diverse new information, but the speed of knowledge diffusion can decrease when the network's cohesion is damaged. If we take the acquisition of new information and the diffusion of knowledge as important factors along with innovation, then we can suppose that open networks have ambivalent effects on innovation.

The above working hypothesis is supported by the result of an analysis by Nagata and Hirata (2013), which indicated that innovation can suffer if an inter-actor network is too heavily concentrated and also if it is too thinly spread out. This finding implies that it is critical that networks for fostering regional innovation become moderately open so that they can simultaneously pursue the benefits of extensiveness and the benefits of cohesion.

However, even if a network is extensive enough to foster regional innovation, there is no guarantee that the boundary of the network will converge on such an equilibrium point. Rather, there is path dependence in the process of network formation. This causes its boundary to become fixed as cohesion among its participants increases over time, increasing the likelihood that the degree of network openness will deviate from the equilibrium point.

This likelihood is also implied in traditional discussions on the determination of boundaries between firms. Factors that determine the boundary of a firm, which denotes the extent of the business conducted within that firm, have been studied in terms of both transaction costs (Coase 1937) and governance costs, which are related to the integration of various functions (Langlois and Robertson 1995). With regard to the former, Williamson (1975) cites the bounded rationality of the transacting entities, the complexity and uncertainty of transactions, opportunism, and information asymmetry among the factors influencing transaction costs.

The factors Williamson names could also be factors that make it difficult for an inter-organizational network to find and recruit new participants that it needs. In an innovation process, participants are, above all, expected to have advanced specialized functions, and at various stages in the process, the bounded rationality of the contracting entities, the complexity and uncertainty of the process, or information asymmetry could become problematic and hinder the appropriate control of the network's boundaries. Furthermore, if an inter-organizational network working on regional innovation does actually face such a problem, identifying the situation may make it possible to propose policy tasks for avoiding the loss of opportunities for innovation that the fixation of boundaries entails.

Based on this awareness of the issues at play, we conducted a survey and analysis with the goal of empirically identifying the effect of boundary fixation on inter-organizational networks working toward the creation of regional innovation.

3. Data

Since the objective of this analysis is derived from the issues that were left unresolved in Nagata and Hirata (2013), we had planned to take the data for it from the same source as that study: finished projects from the Ministry of Economy, Trade, and Industry's "Consortium R&D Projects for Regional Revitalization." However, while that study made use of microdata obtained from a follow-up survey about finished Consortium Projects, the data needed for this analysis cannot be taken from the follow-up survey dataset. Hence, we decided to create our own questionnaire survey with which to collect the data.

Launched in 1997, "Consortium R&D Projects for Regional Revitalization" is a competitive fund that invites research proposals from the public with the goal of facilitating "implementation-oriented advanced research and development to be conducted within a structure (consortium) for collaborative research between industry–academia–government that utilizes new technologies, talent, and findings from universities to create new enterprises and industries for regional revitalization." The Regional Technology Division METI Regional Economic and Industrial Policy Group's *Materials for Assessing Consortium R&D Projects for Regional Revitalization* (March 2009)[3] includes a table of 326 commissioned projects and 153 subsidized projects undertaken between FY2005 and FY2007.

For this study, we chose to examine the 326 commissioned projects. The aforementioned table contains the name, region, and managing entity of each project. Ninety-five of the managing entities managed only one project, while the rest are associated with multiple projects. As the locations and contact information of the managing entities are unknown, we procured that information from publicly available materials. In doing so, we found that some managing entities had ceased to exist (as of the date of this study) due to breakups, mergers, or the like. The final number of projects for which the managing entity's location and contact information could be found and which could be extracted for use in the study was 307.

I conducted both mail-in surveys and online surveys and finished sending and disseminating them in the beginning of December 2020. We set December 23 as the first deadline and the number of responses we ultimately received by the beginning of January 2021 was 132. The response rate was 43.0%. However, since thirteen years had passed since the end of the project at the time of the survey, there are sporadic missing values in the data. The number of valid responses varies by question and ranges from 114 to 129.

In addition to the attributes of the managing entity and project, the questions in this questionnaire survey included items needed to examine the working hypothesis (which will be explained below); that is, the composition of participating organizations by attributes and location/region, the number of participating organizations who had a relationship before the project began, changes in the participating organizations during the project, the recognition of insufficiencies in the participating organizations, the reason for those insufficiencies, and the result of the project.

4. Working hypothesis

Below, I will present a working hypothesis to examine the causal logic that can be derived from findings from prior research regarding the effect of participants' fixedness on a network's characteristics.

4.1. The effect of participants' fixedness on a network's characteristics

In this paper, I use *fixedness* with regard to inter-organizational networks to refer to a state in which new participants (participating organizations) rarely join the network, current participants rarely leave, and the boundary of the network concerned does not change over a long period of time.

Even if actors who could provide information and functions useful for realizing innovation were to exist outside of the region where a such a network is predominantly active, its boundaries could not expand

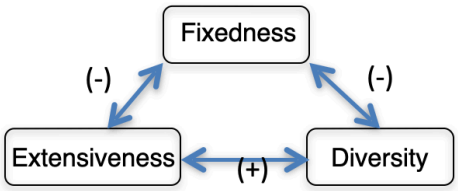
[3] https://www.meti.go.jp/policy/tech_evaluation/c00/C0000000H20/090309_conso/conso_7.pdf

beyond regional borders if they are fixed. Hence, a network's fixedness can be thought of as having an inverse relationship with its *extensiveness*.

Fixedness would also be expected to have a tendency to run counter to the diversity in terms of participants' functional attributes. In contrast, since *extensiveness* and *diversity* are characterizations of the results of participants' expansionary changes from different perspectives, they should have a positive correlation with one another.

These relationships among the characteristics of a network are as shown in Fig. 1

Fig. 1. Working hypothesis:
Correlations between network characteristics



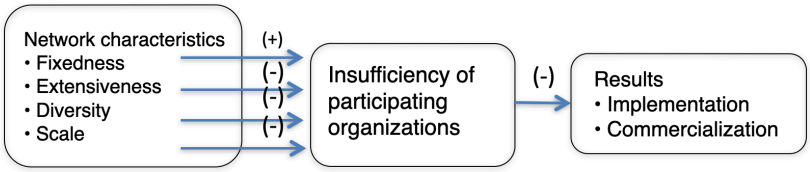
4.2 Recognition of insufficiencies in the participating organizations

When some sort of insufficiency occurs in implementation, commercialization, or some other process tied to innovation, and that state of insufficiency is adequately recognized by the core participants, it should be possible to statistically examine the relationship between that recognition and the success or failure of innovation.

Furthermore, while there is generally little possibility of participant insufficiencies becoming a problem if the network is large-scale, highly extensive, and highly diverse, that possibility should increase when the participants are fixed.

The above relationships are as shown in Fig. 2.

Fig 2. Working hypothesis:
Relationship between network characteristics and project results

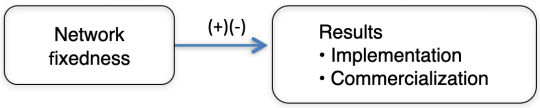


However, if there is inadequate recognition of participant insufficiencies due to factors such as the complexity/uncertainty of the project or information asymmetry, no effort will be made to expand the network's membership in order to resolve those insufficiencies. Consequently, there should be a reverse causal relationship such that the participants become fixed and there is no change in extensiveness or diversity. The possibility of endogeneity due to this reverse causal relationship will be examined in the next section, based on the reasons for participant insufficiencies seen in the survey results.

4.3. The effect of a network's fixedness on innovation

Regardless of the existence of an awareness of participant insufficiencies, a state in which the participants are fixed will end up having some kind of effect on innovation. However, as stated previously, prior research has found that the extensiveness of a network, which is thought to be inversely related to its fixedness, has ambivalent effects on innovation; therefore, fixedness cannot be assumed to have an unambiguous effect on innovation either. Sometimes the degree of cohesion that results from the fixedness of a network's participants has a positive effect on innovation, while in other cases, the impaired ability to take in useful information and functions from outside the network has a negative effect on innovation (Fig. 3). Hence, there is expected to be a nonlinear relationship between fixedness and extensiveness.

Fig. 3. Working hypothesis: Effects of network fixedness



5. Analysis

In what follows, before examining the working hypothesis stated in the previous section, I will provide an overview of the survey results, explain the configuration of variables used to examine the hypothesis, and then state the results of the analysis.

5.1. Overview of survey results

5.1(a) Attributes of the commissioned managing entities

Looking at the breakdown of the 129 valid responses about the type of managing entity that was commissioned for the corresponding project, the most common was "incorporated foundation (*zaidan hōjin*) / Specified Nonprofit Corporation (*tokutei hi-eiri hōjin*)" (90 responses, 69.8%), followed by "corporation" (23 responses, 17.8%). These two categories made up close to 90% of the responses.

5.1(b) Project attributes

Thirteen years had passed since the end of the adopted Consortium R&D Projects for Regional Revitalization at the time of the survey. Hence, if it was difficult for a survey respondent to give a response with regard to their adopted project, they were allowed to respond with regard to a subsequent joint research and development project led by the same managing entity. However, looking at the breakdown of the 123 valid responses to this item, the majority of responses turned out to be about the adopted projects (115 responses, 89.1%), with the remaining 8 (6.2%) being about a subsequent project.

Consortium R&D Projects for Regional Revitalization could be conducted in a variety of industrial fields, and the responses regarding the business domain in which the project's results were implemented likewise tended to be highly varied. Business domains that appeared in the responses with comparatively high frequency included "manufacturing of electronic goods, devices, or circuits" (19 responses), "manufacturing of pharmaceuticals" (13 responses), "construction industry" (11 responses), "manufacturing of food products" (9 responses), and "electronic equipment and electric measuring instruments" (8 responses).

5.1(c) Number of participants

Looking at the number of participants in the final fiscal year of the projects by type of organization regarding 129 valid responses, project participants consisted of 2.9 “corporations,” 1.3 “universities,” and 1.1 “others" on average, with an average total of 5.3 participants.

When looking at average numbers of participants by location, projects had an average of 1.8 participants “in the same municipality” as the managing entity, 1.9 participants “in the same prefecture,” 0.9 participants “in the same regional block,” 0.6 participants “in a different regional block,” and no participants “in another country.”

5.1(d) Changes in participants

There were 125 valid responses about the number of participants in each project who already had a business relationship with the managing entity before the start of the project. The average number of such participants was 2.8, or in other words, 3 out of 5 participants for the projects for which valid responses were received had a prior business relationship with the managing entity on average.

Furthermore, of the 122 valid responses regarding whether or not any new participants joined midway through the project, 9 responses (7.4%) stated “Yes,” and of the 121 valid responses regarding whether or not any participants withdrew midway through the project, 6 responses (5.0%) stated “Yes.”

5.1(e) Recognition of participant insufficiencies

Of the 119 valid responses to the question “Did the project lack the participation of an organization that could provide necessary information or technology?”, 7 responses (5.9%) stated “Yes.”

Furthermore, of the 119 valid responses to the question “Did the project lack the participation of an organization that could implement or commercialize the results of the project?”, 7 responses (5.9%) stated “Yes."

The aggregate results for the above two items about insufficiencies are the same, but this is not because there was a perfect correspondence between the way a respondent would respond to the two items. Out of the 7 responses, only 4 stated “Yes” to both insufficiencies; the remaining 3 stated “Yes” to only one of the two.

5.1(f) Reasons for participant insufficiencies

For projects that suffered from a participant insufficiency, respondents were asked about the reason for the insufficiency.

There were 6 valid responses that stated a reason that the corresponding project “lack[ed] the participation of an organization that could provide necessary information or technology.” Among these, 2 respondents chose “There are so many organizations that may be able to provide the necessary information or technology that we could not decide which one to have participate,” 2 respondents chose “Other,” 1 respondent chose “We did not know where to find an organization that could provide the necessary information or technology,” and 1 respondent chose “We did not notice the absence of an organization that could provide the necessary information or technology during the project.” No respondents chose “We knew where to find an organization that could provide the necessary information or technology but could not get them to participate.”

There were 7 valid responses that stated a reason that the corresponding project “lack[ed] the participation of an organization that could implement or commercialize [its] results.” Among these, the majority of respondents (5 responses) chose “There are so many organizations that may be able to implement or commercialize [the project’s] results that we could not decide which one to have participate.” One respondent chose “We did not know where to find an organization that could that could implement or commercialize [the project’s] results,” and 1 respondent chose “Other.” No respondents chose “We knew

where to find an organization that could implement or commercialize [the project's] results but could not get them to participate" or "We did not notice the absence of an organization that could implement or commercialize [the project's] results during the project."

Since a participant insufficiency was recognized in no more than approximately 6% of all projects, the data on reasons for insufficiency is limited to the above. However, at the very least, the data does show that (1) the cases where a lack of necessary participants was not noticed during the project are very rare, and that (2) there were absolutely no cases where participants knew where to find the participant they needed but could not solicit their participation. Consequently, the reverse causal relationship from Section 4.2 (the reverse of the causal relationship in the working hypothesis)—in other words, where no effort is made to resolve a participant insufficiency because it is not adequately recognized, causing the participants to end up becoming fixed—is arguably unlikely to occur.

Furthermore, from this data, it seems that the information asymmetry of not knowing where to find the necessary participant is less dominant as a factor leading to participant insufficiency compared to project complexity/uncertainty, which the data suggested tended to lead to the inability to choose a participant even though many organizations existed that could have provided the necessary information or technology.

5.1(g) Project results

The success rates of the projects were as follows: 59 out of 114 valid responses (51.8%) stated that a technical paper about the project was published; 42 out of 118 valid responses (35.6%) stated that a patent for the project was acquired; 60 out of 117 valid responses (51.3%) stated that the results of the project were implemented; 28 out of 115 valid responses (24.3%) stated that the results of the project were commercialized; and 101 out of 116 valid responses (87.1%) stated that a network was formed.

The big picture suggested by these results is that approximately half of projects will make it to implementation, while no more than a quarter of projects will survive to see commercialization.

5.2. The configuration of variables related to network characteristics

The variables describing network characteristics needed to examine the working hypothesis stated in Section 4 were configured as follows.

As a measure of the fixedness of participants, we used a *fixation rate* calculated by dividing (1) the number of participants that had business relationships with the project's managing entity prior to the project by (2) the total number of participants.

As a measure of the extensiveness of participants, we used a weighted index, whereby participants in the same municipality as the project's managing entity were assigned a weight of 1; participants in the same prefecture, a weight of 2; participants in the same regional block, a weight of 3; and participants outside of that regional block, a weight of 4.

As a measure of the diversity of participants, we used the Herfindahl–Hirschman Index (HHI) as defined by the sum of the squares of participants' component ratios by attribute (corporation, university, other). As this value approaches 1, that indicates that participants are increasingly concentrated in a single attribute; hence, diversity can be represented by the distance of the HHI from 1.

As a measure of the scale of an entire network, we used the number of ties that could be established between its participants rather than the number of participants. This value was calculated according to the formula.

$$\frac{\text{num. of participants} \times (\text{num. of participants} - 1)}{2}$$

Table 1 shows the descriptive statistics for each variable.

Table 1. Indices of organizational network characteristics (descriptive statistics)					
	Incidence	Minimum	Maximum	Mean	Std. dev.
Fixedness	125	0.00	1.00	0.58	0.33
Extensiveness	129	1.00	35.00	10.72	6.73
Diversity	129	0.33	1.00	0.49	0.12
Scale of ties	129	0.00	153.00	14.98	18.88
Fixedness: Num. of participants with prior business relationships / num. of participants					
Extensiveness: Weighted index; 1 = participants in the same municipality;					
2 = same prefecture; 3 = same regional block; 4 = outside of regional block					
Diversity: HHI based on participants' component ratios by attribute (corporation, university, other)					
Scale of ties: Num. of participants x (Num. of participants - 1) / 2					

5.3. Examination of the correlations among network characteristics

Table 2 shows the correlation analysis that was performed to examine the portion of the working hypothesis shown in Fig. 1.

Table 2. Correlations among organizational network indices							
	Fixedness		Extensiveness		Diversity		Scale of ties
Fixedness	1						
Extensiveness	-0.28	**	1				
Diversity	0.02		-0.07		1		
Scale of ties	-0.16		0.86	**	-0.06		1
**: Significant at a level of less than 1%							

The fixedness and extensiveness of a network are significantly negatively correlated with each other, as expected; however, no significant correlation was found between fixedness and diversity or between extensiveness and diversity. This suggests that making a network more extensive does not necessarily bring about diversification in its participants' attributes. On the other hand, a strong positive correlation was confirmed between extensiveness and the scale of ties.

Here, to see the way in which changes caused by participants joining a project midway through tend to affect the network's characteristics, we calculated the means of the network characteristic variables both when there was and when there was not a participant who joined midway through, and tested the differences for significance. The results are shown in Table 3.

According to this, mean extensiveness was higher in projects which had a participant who joined midway through than in projects that did not. Meanwhile, although the test result for mean diversity (inverse HHI) falls just below a 5% significance level, the data indicates that diversity was lower in projects that did not have a participant who joined midway through than in projects that did. This suggests that the entry of new participants midway through a project generally tends to diversify the attributes of the participants.

Furthermore, although the test result for mean fixedness also falls just below a 5% significance level, the data indicates that fixedness was higher in projects that did not have a participant who joined midway through than in projects that did. This suggests that there is path dependence in the configuration of the participants in projects organized on the basis of preexisting business relationships over the course of the project, which makes it difficult for new participants to join.

Table 3. Differences in network indices by whether or not a participant joined midway through					
	(a) Yes	(b) No	(a)-(b)	*t*-value	*p*-value (both sides)
Fixedness	0.37	0.59	-0.22	-2.10	0.06
Extensiveness	17.11	9.90	7.21	3.22	0.01
Diversity	0.44	0.50	-0.06	-2.00	0.07
Scale of ties	25.22	13.36	11.85	2.46	0.03
Heteroscedastic *t*-test					

5.4. Relationships among network characteristics, recognition of participant insufficiencies, and project results

To examine the portion of the working hypothesis pertaining to the relationship between network characteristics and recognition of participant insufficiencies (shown in the first half of Fig. 2), we calculated the means of the network characteristic variables both when there was and when there was not a recognized insufficiency, and tested the differences for significance. However, no significant differences were found for any of the variables. This suggests that no matter what level the network characteristics are at, they themselves are not associated with the recognition of participant insufficiencies in an unambiguous way. This can be interpreted as reflecting the reality that even in the case of projects relatively low in network extensiveness and participant diversity, for example, some exhibit insufficiency in relation to the project's objective of realizing innovation, while others do not.

To examine the portion of the working hypothesis pertaining to the relationship between recognition of participant insufficiencies and project results (shown in the second half of Fig. 2), we performed a cross-tabulation of the frequencies of responses indicating whether or not a participant insufficiency was recognized and whether or not the project's result was implemented or commercialized, then used a Fisher's exact test to test the relationship between the two variables. This analysis detected a relationship that conforms to causal logic between the recognition of insufficient "participation of organizations that could provide necessary information or technology" and the implementation of a project's result. As the results in Table 4 show, it is never the case that a project where insufficiency is recognized sees its results implemented; however, when insufficiency was not recognized, the component ratio of cases where the results were implemented is over 10 percentage points higher than that of the cases where the results were not implemented.

Table 4. Relationship between insufficiency of organizations to provide info/tech and rate of implementation				
	N	Not implemented (%)	Implemented (%)	Total (%)
Insufficiency	7	100.0	0.0	100.0
No insufficiency	104	43.3	56.7	100.0
Total	111	46.8	53.2	100.0
p-value of Fisher's exact test (both sides): 0.004				

Meanwhile, no significant relationship was found between the recognition of insufficiencies with regard to the "participation of organizations that could implement or commercialize the results [of the project]" and actual implementation/commercialization of the results. This may suggest that assessing the presence or absence of participants who could fulfil the required functions is more difficult than assessing that of participants who could simply provide necessary information or technology, because the process of bringing the results of a project to implementation/commercialization entails a high level of complexity/uncertainty.

5.5. Relationship between network fixedness and project results

To examine the portion of the working hypothesis shown in Fig. 3, we applied a logistic regression analysis, with the dependent variable being the binary variable indicating whether or not the project's results were implemented or commercialized. Under the assumption that a nonlinear relationship exists between fixedness and implementation/commercialization of results, fixedness and its squared term were set as the independent variables.[4] Furthermore, (1) the scale of ties and (2) a dummy variable distinguishing chosen Consortium R&D Projects for Regional Revitalization from subsequent projects were inserted as control variables.

This analysis produced estimated parameters for explanatory variables pertaining to the implementation of results, and as Table 5 shows, these parameters were significant at a level of less than 5% for fixedness and its squared term. The fact that the sign of the fixation rate is negative and the sign of its squared term is positive indicates that the rate of successful implementation has a U-shaped relationship to the rate of participant fixation. In other words, one can infer that projects with high rates of successful implementation are polarized between those with relatively high and relatively low rates of participant fixation. In addition, using the estimated parameters to calculate the fixation rate corresponding to the bottom of the U shape gives a value close to the mean value of 56.5%. That is, this result indicates that the fixation rates of networks with a high rate of successful implementation lie in regions far from the mean on either side.

Table 5. Effect of network fixedness of implementation of results (logistic regression analysis)

	B	Std. error	Wald	*p*-value	Exp(B)
Constant	1.56	1.00	2.41	0.12	4.76
Scale of ties	0.01	0.01	1.45	0.23	1.01
Fixedness	-5.40	2.45	4.85	0.03	0.01
Fixedness^2	4.78	2.12	5.08	0.02	119.20
Project dummy	-0.721	0.79	0.84	0.36	0.49
N			129		
Log-likelihood ratio			153.80		
Nagelkerke's R^2			0.08		

The same result was not obtained for commercialization of the results, which may be due to the fact that the process of bringing the results of a project to commercialization entails a higher level of complexity/uncertainty than bringing them to implementation and is influenced by diverse factors other than network characteristics.

6. Discussion

For this paper, we used data on the characteristics of regional networks organized for the purpose of creating innovation and the results of their projects to conduct an analysis focusing on the effect of participant fixedness on innovation. The main findings are as follows:

1. On average, the networks organized for the Consortium R&D Projects for Regional Revitalization chosen for the analysis consist of five participants, three of whom had a business relationship with the managing entity before the start of the project.

[4] If extensiveness and its squared term are used as independent variables, the model becomes the same as that used in Nagata and Hirata (2013). However, when we tried to use the data collected in this study to estimate the parameters, we did not obtain a significant result. This is likely due to differences in datasets, since the aforementioned paper makes use of follow-up survey data exclusively from the 114 finished projects from 2005. Further research is needed on this point.

2. It is difficult for new participants to join projects organized on the basis of prior business relationships during the project. In other words, there is path dependence in the configuration of the network's participants.

3. The fixedness of a network, which is defined as a state in which participants do not change over a long period of time, is inversely correlated with the network's extensiveness, which is the extent to which its participants cover distant locations.

4. In addition to making a network more extensive, the entry of new participants midway through a project generally tends to diversify the attributes of the participants.

5. Insufficiencies in the participation of organizations that could provide necessary information/technology or implement the project's results was recognized in no more than approximately 6% of projects each. There is little evidence to indicate that adequate recognition of participant insufficiencies is a hindrance.

6. The information asymmetry of not knowing where to find the necessary participant is less dominant as a factor leading to participant insufficiency compared to the complexity/uncertainty of the project itself, which makes it difficult to choose additional participants.

7. No matter what level the network characteristics are at, they themselves are not associated with the recognition of participant insufficiencies in an unambiguous way.

8. The overall picture relating to the results of the projects analysed is that approximately half of projects will make it to implementation, while no more than a quarter of projects will survive to see commercialization.

9. The recognition (or not) of the insufficiency of participants that could provide necessary information/technology is associated with the potential for the project to be implemented.

10. The rate of successful implementation has a U-shaped relationship to the rate of participant fixation. Rates of participant fixation in projects with high rates of successful implementation are polarized, lying far apart from each other on either side of the mean.

Of the above findings, the one that would be a controversial issue is #10, but the following interpretation would be congruent to it: In cases where a low fixation rate works advantageously for implementation, the technology to be developed is at a different level of maturity than in cases where a high fixation rate works advantageously for implementation. That is to say, when the technological domain of the project is highly mature, actors who possess the elemental technologies required to solve the issue have already been identified. This makes it possible to set up the project with fixed organizations, a formation that is congruent with the goal of implementing the technology. However, when the technological domain is still at the emergent stage, it is more congruent to use a method that selectively mobilizes participants who possess new and useful technologies; in such a case, a line-up of organizations dependent on prior joint business relationships has a negative effect on the accomplishment of results instead. These findings can be interpreted as being reflective of this state of affairs.

Proceeding from this interpretation, we can derive the following implications from the findings of this study:

- When assembling an inter-organizational network to pursue innovation in a new technological domain, participants are selected according to their technological potential rather than on the basis of prior joint business relationships. However, at the stage of identifying actors who could provide useful information and technology for the growth of the technological domain in question, incorporating those actors necessitates reorganization of the network. In addition, at the stage where the technological domain is mature, it is advisable to maintain a highly-cohesive network based on the participation of actors with

superior information/technology.

• However, while there is path dependence in the configuration of network participants, the process of innovation entails a high degree of complexity and uncertainty. For this reason, even after the growth stage of the technological domain, there is a strong possibility that early participants will remain as fixed participants, or that an incomplete reorganization of the network will happen. Such a tendency leads to the failure to build inter-organizational networks that conform to the growth stage of technological domains and have a negative effect on the implementation of the results of development.

• Accordingly, the core actors that make up a network need to have leadership that can decisively undertake network reorganization, in addition to a bank of knowledge and know-how for appropriately assessing and selecting participants that can provide information/technology that will be useful for the implementation of the technology.

With regard to the phenomenon indicated by the analysis in this paper that "rates of successful implementation of results in projects undertaken by inter-organizational networks are polarized between those with high and low rates of participant fixation," we have discussed that it is highly likely to arise from differences in the maturity of the technological domain and does not imply that a high degree of fixedness is advantageous in any situation. However, on the other hand, since path dependence exists among the configuration of the network's participants, the tendency for boundaries to become fixed can emerge at any time. To bring attention to this point, I have chosen to call the aforementioned phenomenon and tendency "the trap of boundary fixation" in inter-organizational networks.

7. Future research topics

While the analysis in this paper led to several new findings about the inter-organizational networks that make up regional systems for innovation, a not-insignificant number of research issues remain.

First, the analysis used data obtained from Consortium R&D Projects for Regional Revitalization, but further research must be conducted to examine how representative or idiosyncratic those projects are as examples of inter-organizational networks responsible for regional innovation, through a comparison with non-Consortium projects.

Furthermore, due to the restricted sample size, it was not possible to perform a deeper statistical analysis of the factors behind participant insufficiencies. A qualitative analysis should be conducted to supplement the data.

In addition, further research is needed to examine the validity of our interpretation of finding #10, which was the focus of this paper. It was too difficult to perform an analysis of the survey data in this study that went as far as the developmental state of the relevant technological domain for each case where the fixation rate was high or low; therefore, a qualitative analysis should be conducted on this point as well to supplement the data.

The most significant remaining challenge probably lies in the fact that it was not possible to find any significant relationship between network characteristics and whether or not commercialization was successful, since finding #10 only goes as far as the implementation stage of innovation. While the implementation stage has a success rate of 50%, the success rate of the subsequent commercialization stage does not exceed 25%; hence, explaining the complex factors that determine success or failure at that commercialization stage is a perennially difficult and challenging task in innovation research.

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