2014 Proceedings of PICMET '14: Infrastructure and Service Integration.

Mechanisms of Network Formation: A Structural Analysis of the Emerging Nanotechnology R&D Alliance Network in Japan

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Abstract--**This paper looks at the newly materializing nanotechnology industry in Japan, and attempts to answer the question of what processes shape the formation and change of the organizational field network. Nanotechnology is a loosely-coupled field and includes organizations from a diverse set of industries and fields that evolved through different historical pathways. To understand the boundaries of the industry, the authors compiled a relational database of nanotechnology R&D alliances during the 2005-2010 period including more than 600 Japanese organizations and 1784 unique alliances. Through examining the structural and dynamical properties of the network and performing a cluster analysis, the authors identified four underlying mechanisms that drive network formation and change: 1) force of existing relationships, 2) force of top-down systemizing discourse, 3) force of agency, and 4) force of geographical location. We argue that an accurate understanding of these forces is necessary to predict future trajectories in volatile high-tech industries, such as nanotechnology or biotechnology.**

I. INTRODUCTION AND THEORETICAL BACKGROUND

An organizational field and its underlying inter-organizational network are subject to various forces that govern their formation, change, and reproduction. Studying the formative years of a newly forming field has been a suitable way of identifying potential forces and processes that shape fields, networks, and industrial clusters [26, 8, 11]. One central question of any field or network formation is this: "Why does one relational space with a given set of actors form and not another?" [33]. In order to answer this question, it is necessary to identify the mechanisms that drive network formation and find out how these lead to a given outcome.

Reference [24], in their recent edition, collected studies that traced the similarities and differences in the emergence of organizations and markets by looking at early stages of market formation, transitions from centrally planned economics to market-governed, and the states of high-tech industries. Reference [4] traced the process of cluster formation in their book. They argued that while there is a certain amount of serendipity concerning which location might succeed in forming a new cluster, there are certain processes that either fuel cluster growth or dampen it. In the introduction of their book, they called for going beyond looking at successful clusters and identifying conditions for growth. Instead they proposed to study the actual underlying processes and forces that shape the formation of industry clusters. Reference [5] have turned their main focus from mere cluster policy and recipes of imitating the "Silicon Valley" model towards a much deeper analysis, putting more emphasis on the role of inter-organizational networks.

So what forces are at play? Reference [6], studied the regularities among successful ICT-based clusters. They added some underlying mechanisms to their 'recipe for success'. For example, an often mentioned ingredient is the highly-skilled labor force of the region in question. They identified different mechanisms related to a highly-skilled labor force that contribute to cluster growth through the role of underemployment, the liquidity of labor markets, and the role of large, world-class firms in instilling managerial and technical skills. Findings like this, however, have not been concerned enough with structural factors and more contextual factors.

The other approach to look at organizational field formation is to look at the network that gives the fundamental structure of the field. Studies focusing on alliance formation and partner selection might give some clues to what kind of actual forces are working within the network. Reference [12] found that firms with prior ties are more likely to form alliances and concludes that existing relationships are one way that might raise the probability of network tie formation. Reference [7] in their study of the US film industry found additional support that repeated ties are beneficial. Reference [30] found a 'prestige effect' where firms tend to form alliances with firms that are seen as prestigious and may offer valuable benefits to the focal firm. This prestige may also stem from a structural position within a network [25, 32]. Reference [26] has focused on the forces that shape networks and contrasted four types of attachment style: accumulative advantage (prestige and structural prestige), homophiliy, follow-the-trend, multiconnectivity. They found that in commercial biotechnology accumulative advantage and homophily were replaced with a desire for novelty and diversity. This kind of behavior can be seen as a kind of bottom-up agency from the part of individual firms driven by 'innovation' logic.

In our paper, our focus is on the development of an organization field and the underlying network of inter-organizational relations. Our analysis targets the nanotechnology field in Japan. Nanotechnology is a multi-disciplinary technology and thus many industries can benefit from it. This multi-disciplinary nature of the industry also means that the "nanotechnology" label is constructed and its boundaries are still being contested and in some cases replaced with different categories. The field of nanotechnology is, therefore, an interesting case for our investigations of forces that shape the industry's formative years. It is highly diverse in respect to participating industries and the structure of the industry may have multiple centers and a loosely-coupled structure. We focus on R&D alliances, because it is the most important activity in a science-based field in its generative phase [23]. Working within the above research strand that looks for processes behind field development, we attempt to analyze the Japanese nanotechnology alliance network in order to find clues about the probable forces and mechanisms that continue to shape its structure.

II. THE CASE OF JAPANESE NANOTECHNOLOGY

In the following, a brief overview of the research context is given. Before going into our detailed analyses, it is useful to understand the developments of the Japanese nanotechnology field in the past decade. The U.S. National Nanotechnology Initiative's definition of nanotechnology will be adopted, as used by [27], to define the vague boundaries of the newly emerging nanotechnology field. This definition is often adopted by scholars, and other government initiatives.

> *"Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications. The diameter of DNA, our genetic material, is in the 2.5 nanometer range, while red blood cells are approximately 2.5 micrometers. Encompassing nano-scale science, engineering and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. At the nano-scale, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter. Nanotechnology R&D is directed toward understanding and creating improved materials, devices, and systems that exploit these new properties."*

Nanotechnology research took off from the 1960s after the famous speech by Richard Feynman, "There's plenty room at the bottom", at Caltech in 1959. Several new tools helped its development such as the scanning probe microscope and the atomic force microscope. New tools made it possible not just to look at the nano-level, but even to manipulate single atoms. Major breakthroughs like the carbon nanotube, graphene, fullerenes. and nanoparticle technologies brought basic research closer to commercial utilization. The commercial activities gave rise to an emerging nanotechnology industry in various counties around the world. The Japanese nanotechnology industry too took off around 2000. Starting in the early 2000s the Japanese Ministry of Education and Science lunched its knowledge cluster creation initiative, while the Ministry of Economy Trade & Industry tried to establish local industrial clusters. While the results of these policies were not stellar, it had an effect of encouraging alliance activity. Although misguided policies and the financial downturn around 2007-2008 brought an end to the initial nanotechnology boom and investment enthusiasm, the industry has continued to develop, albeit in a state of flux still forming and evolving.

Next, we review 1) the industries that make up the field, 2) the government policy and organizations that influence its development, and 3) the alliancing behavior between them.

First, it must be stated that the development of the organizational field of nanotechnology incorporates many kinds of actors [20, 28]. Similar to the case of biotechnology, nanotechnology includes multiple sectors of industry, public research institutions, universities, and non-private organizations as well. In the case of nanotechnology the span of sectors and fields influenced is even greater than in biotechnology [27]. The field is still highly fractured moving into multiple directions [13, 14]. Reference [14] divided the field into four main areas, such as bionanotechnology, nano-electronics, nano-materials, and nano-manufacturing and tools.

Adopting this framework, it is possible to group the main industries involved in the Japanese nanotechnology field into these four main areas. The first, bionanotechnology, is represented in this paper by the biotechnology (e.g. Beacle Inc.), pharmaceuticals (Ono Pharma), cosmetics (Shiseido, JO Cosmetics) and food industries (Ajinomoto). The second, nano-electronics, consists of the electronics (Sharp, Panasonics, Sony), semiconductors (Rohm, Tokyo Electron, Toshiba), laser, and optics industries. The third main application area is advanced chemicals and nano-materials involving the chemical (Mitsubishi Chemical, Hitachi Chemical), fiber (Teijin, Toray, Toyobo, Gunze), rubber (Bridgestone), glass, ceramics, oil (Nippon Oil), metal (Hitachi Metals), and plastics industries. Lastly, there is the precision tools industry (SII Nanotechnology, Shimadzu) and the industrial machinery industry specialized in nano-level processing and measurement tools.

Apart from the above categorization, we can identify other industries, such as environmental and energy related industries (Osaka Gas), the automobile industry (Toyota, Nissan), and trading companies (Sumitomo, Mitsubishi, Mitsui, etc.). The automobile industry, for example, uses nanotechnology for battery development and nano-materials for weight reduction of parts among a wide-range of other applications. By and large, big trading companies found nanotechnology a promising future growth area making sizable investments. Finally, purely nanotechnology oriented venture companies are also began to appear as government policies began to encourage university ventures and entrepreneurial activities. Some of these startups are spin-offs or newly formed divisions of large enterprises (SII Nanotechnology, Frontier Carbon, GSI Creos) or joint ventures between larger organizations (e.g. Admatechs). Again there are several attempts at commercialization of university research.

After discussing the industries involved, it is important to highlight both universities and state founded research institutes that play a key role in this formative stage of nanotechnology. Reference [23] reviewing the Finish nanotechnology research scene also emphasized the importance of university-industry relationships.

To better understand the role of academia and government policy in network formation it is necessary to review the innovation framework that developed in Japan and the challenges it has to overcome. Reference [2] identified vital issues faced by the Japanese biotechnology industry and the institutional environment. He showed that the innovational framework in Japan has some rigidities, such as rigidities in government policy (i.e. government priorities and goals are sometimes too late, and vertical integration of ministries limits cooperation), academic context (i.e. professors are less motivated to patent because evaluation is based on scientific publications rather than economic potential), investment and financial context (i.e. no well-developed venture firm investment is available and Japanese companies prefer investing in western companies than in domestic firms), research orientations (i.e. there is still a preference for in-house R&D and protecting in-house research instead of acquiring rivals; focus is on product innovation, while firms often do not incentivize disruptive-type innovations because of the inherent risks), and lastly rigidities due to cultural norms.

A similar story can be told about the nanotechnology industry, however, lessons learnt from biotechnology was in some parts applied to nanotechnology. For example, in nanotechnology the government did recognize the potential of the field, although professionals from the field now claim that the government's emphasis on semiconductor technology was misplaced and led to misguided investments. Patenting by university professors has been more and more encouraged as our dataset indicates by the high centrality of universities. However, patenting is still seen as similar to scientific publications and many stop at an application of a patent, not caring whether it will be granted, or whether it will result in a successful commercial product. Some of the joint-research with industry is carried out only in order to gain access to funding.

In the early 2000s, the Japanese government designated nanotechnology as a primary growth sector and allocated substantial funds to support the industry. After the policy could not attain stellar growth results, the focus on "nanotechnology" has disappeared and a shift began to replace "nanotechnology policy" with more focused policy that although utilizes nanotechnology is labeled differently (e.g. green technology, energy and battery applications, materials, etc.). While the investment catchword "nanotechnology" has disappeared from the government's vocabulary, the focus on the field of nanotechnology has remained, but instead of an all-encompassing label, government agencies focus on particular areas.

The leading institutions of research that may be associated with nanotechnology-type research are main government research labs, such as the National Institute of Advanced Industrial Science & Technology (NAIST or AIST), National Institute for Material Science (NIMS), and Japan Science & Technology Agency (JST). As another agency that helps to manage R&D in this field, there is the New Energy and Industrial Technology Development Organization (NEDO). Other supporting organizations and frameworks for networking and collaboration were set up such as the Nanotechnology Business Creation Initiative (NBCI), or the Kansai Nanotechnology Initiative by the Osaka Science & Technology Center.

Furthermore, international nanotechnology-related conferences and expos were set up, such as the annual Nano Tech Japan trade show. Nano Tech Japan has been held every year since 2002 and is among the biggest nanotechnology related trade shows in the world. According to their report, in 2012, a total of 649 exhibitors (out of which there were 185 overseas exhibitors from 21 countries) welcomed about 45,000 visitors during the three-day exhibition period. The organizational field also contains numerous other actors the present study does not deal with, such as law firms, consultants, domestic venture capital firms and incubator initiatives.

Third, it is necessary to look at the state of alliancing in Japan to understand the dynamics of the field. Based on [16], it can be said that the Japanese inter-firm alliances are less numerous than that of the US. Most are facilitated by government consortia or university brokerage. Reference [2] highlights the problem that many firms in Japan prefer to work with overseas universities, and they invest more in these world-class institutes. In the case of our nanotechnology network, it can also be seen that most alliances include a university or a research institute, while the number of purely cross-industrial alliances is still low.

Against the backdrop of these national characteristics, the inter-organizational nanotechnology alliance network has expanded. Our aim now is to look at the underlying forces that shape the network.

III. DATA

The first step was to collect data from patents stored in the Japanese Patent Office's online database and assemble a relational database of research collaborations carried out in nanotechnology based on joint patents. The focus was on Japanese domestic companies, universities and research institutes in the period from 2005 to 2010. Our cutoff point of 2005 was selected because legislation in the previous year made public universities into legal entities. This legislative step had two effects: 1) names of universities has appeared on patents instead of names of individuals, and 2) increased the amount of university patenting. This made data collection more straightforward and reduced the chance of bias caused by undisclosed collaborative relationships (university professors gave patent rights to companies in exchange of funding).

As nanotechnology used to have no definite IPC code for patents in the past, the search was conducted by using keywords. These keywords were determined by the help of the literature and included words such as nano, nanotechnology, nanoparticle, nanotube, carbon nanotube, fullerene, nanofiber, nanocrystal, and words related to atomic force microscopy and scanning probing microscopy.

In total approx. 5000 patents were obtained this way from the database out of which 958 were joint patents. It is likely, however, that this does not entail the full population of joint nanotechnology patents, because some related patents might not contain the above keywords. Also this method excluded alliances that did not result in a patent application.

The second step was to create an actor-actor matrix containing 1784 ties between 604 nodes (of which there are 464 firms, 85 universities and 55 public research institutes and government institutions) based on the patent data between 2005 to 2010. Then, another three networks were created for each consecutive two-year periods. Due to limitations in the availability of the data the final sample was reduced to two cross-sectional panels from 2005-2006 and 2007-2008.

In spite of the drawbacks of our methodology mentioned above, this dataset contains most of the important players in the Japanese nanotechnology scene, although some firms having a heavy presence in the field were excluded from the database mainly because their lack of joint R&D patents (e.g. Kao).

IV. ANALYSIS

The research focuses only on inter-firm R&D collaboration in nanotechnology. The reasoning for looking at these collaborations is twofold. First, it is an important way for organizations to have a deeper perception of the actual technological capabilities of other players and develop a relationship with them. Second, in its present state nanotechnology is in the research development phase and thus R&D collaboration can be seen as a fundamental and defining activity of the field.

The network diagram in Figure 1 shows that major universities (e.g. *Tokyo, Osaka, Kyoto, Kyushu, Tohoku, Shinshu Universities*) and public research organizations (e.g. *AIST, NIMS, JST,* etc.) are at the center of the network throughout the five years from 2005 to 2010. It also shows that the core and main component of the network (the large circular shape excluding the small inner circle) centers around these main actors along with large industrial players that have a major role in the Japanese economy (e.g. Toyota Motors, Mitsubishi Chemicals).

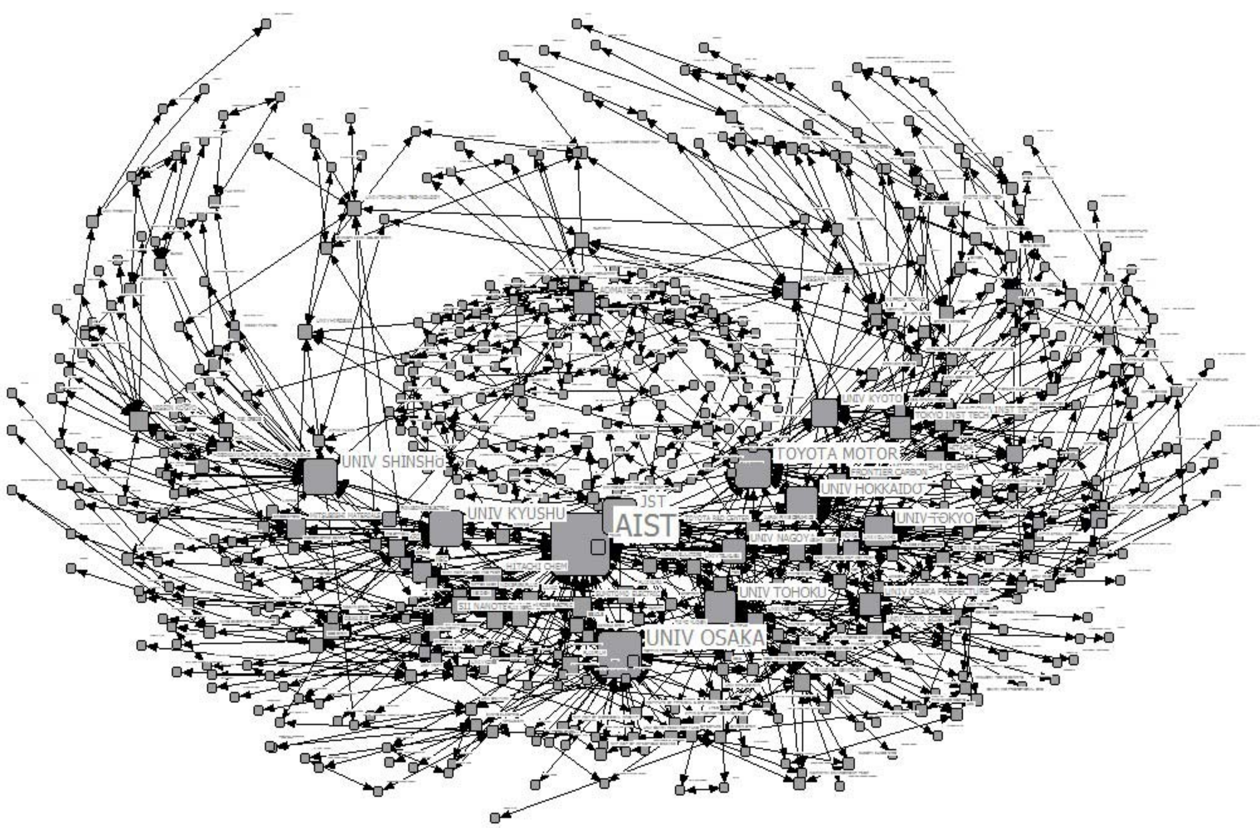


Figure 1 *The 2005-2010 network of alliances (with the most central nodes highlighted)*

TABLE 1. LIST OF THE MOST CONNECTED NODES

Most connected nodes by degree		
2005-2007	**2008-2009**	**2010-2011**
AIST	AIST	AIST
JST	Toyota Motor	Toyota Motor
Osaka University	Osaka University	Kyushu University
Frontier Carbon (Mitsubishi)	Kyoto University	Admatechs
Kyoto University	Shinshu University	Shinshu University
Nagoya University	Tohoku University	Tokyo Institute of Technology
Toyota Motor	JST	Tohoku University
Shinshu University	University of Tokyo	University of Tokyo
Mitsubishi Chemical	NEC	Hokkaido University
Kyushu University	Sumitomo Electric	Osaka University
Hitachi Corp	Hokkaido University	Nagoya University
Tohoku University	Nissin Kogyo	Kyoto Institute of Technology
Hokkaido University	Kyushu University	TDK
NIMS	SII Nanotechnology	NGK Insulators
Fujifilm	Hitachi Chemical	Panasonic Electric Works
Osaka Prefecture University	Fujikura	Mitsubishi Materials
Nagoya Institute of Technology	NGK Spark Plug	Tsukuba University
NTT	Fuji Xerox	Teijin
SII Nanotechnology	Hirose Electric	Taiyo Yuden

In Table 1, these most connected nodes are summarized by their degree number for each two-year period. This centrality is most likely driven by two main forces: the top-down efforts of government support and the basic research stage of the field. These are the first observations that can be made by a simple overview of the structure. A closer look at some ego networks or the patent data itself, however, reveals that many cross-industrial collaborative relationships include a university or government actor as well as a coordinator, which confirms our suspicion. Yet, the network does have other relationships and groupings and the forces that shape them need further investigation.

Before going into the analysis of the forces, we first have to look at the temporal changes within the network. Table 2 reports the averages of main network related variables and their change during the period of the investigation.

We found that the average number of ties stayed similar, but the alliances grew more diverse with a slight reduction in cohesion. This can be attributed to a general trend in Japanese industry. Traditionally cohesive structure of the Japanese corporate world and the risk-averse homophily that has been considered a feature has eased somewhat and the diversity of alliances has begun to rise. Cross-industry and industry-academia linkages became ubiquitous, although traditional supply chain relationships also play an important role in these, such as, for example, the chemical industries that supply the automobile or semiconductor industries. In these instances, while there are two different industries collaborating together, the diversity involved is in fact quite limited. This is because the relationship is based on a prior, existing buyer-supplier relationship. Nonetheless, it can be concluded that diversity did grow during the 2000s in high-tech R&D alliances.

TABLE 2. TEMPORAL CHANGE IN NETWORK VARIABLES

	2005-2006			**2007-2008**			**2009-2010**		
	Avg.	Std. Dev.	N	Avg.	Std. Dev	N	Avg.	Std. Dev.	N
Firm Age	-	-	-	-	-	-	56.69 yrs	30.03	414
Number of Ties	1.22	2.31	604	1.22	1.83	451			
Same industry ties	0.18	0.56	451	0.27	0.62	451	-	-	-
Diff. industry ties	0.39	0.91	451	0.49	1.05	451	-	-	-
University ties	0.30	0.62	451	0.32	0.71	451	-	-	-
Research inst. ties	0.14	0.83	451	0.13	0.38	451	-	-	-
Diverse ties	0.39	1.41	451	0.96	1.53	451	-	-	-
Eigenvector cent.	**0.0139**	0.0382	604	**0.0082**	0.0398	604	**0.0104**	0.0393	604
Structural holes	**0.89**	0.26	604	**0.88**	0.28	604	**0.88**	0.26	604
Clustering coeff.	**0.812**	0.82	604	**0.78**	1.26	604	**0.67**	0.61	604

TABLE 3 CHANGE IN NETWORKS: SIMILARITY BETWEEN NETWORKS IN EACH PERIOD

		2005-2006	2007-2008	2009-2010
2005-2006	Correlation	*1.000*		
	Jaccard coeff.	*1.000*		
2007-2008	Correlation	***0.384***	*1.000*	
	Jaccard coeff.	*0.103*	*1.000*	
2009-2010	Correlation	***0.104***	***0.226***	*1.000*
	Jaccard coeff	*0.030*	*0.059*	*1.000*
Cronbach's α for correlation		0.484		
Cronbach's α for Jaccard		0.171		

TABLE 4 FIRM STATISTICS AND TEMPORAL CHANGE IN VALUES OF SALES, RETURN ON EQUITY AND NUMBER OF EMPLOYEES

Sales	Avg.	Std. Dev.	N	Profit	Avg.	Std. Dev.	N	Size	Avg.	Std. Dev.	N
Sales 2006	741 789	1692767.74	224	**ROE 2006**	6.36	6.64	222	**Empl. 2006**	5450.38	9742.52	225
Sales2007	792 251	1793135.08	224	**ROE 2007**	7.12	8.13	222	**Empl.2007**	5484.83	9841.40	225
Sales2008	832 843	1890777.39	224	**ROE 2008**	6.26	6.37	221	**Empl. 2008**	5541.81	9850.86	226
Sales2009	732 766	1657152.38	225	**ROE 2009**	-4.51	17.74	217	**Empl.2009**	5689.78	10070.74	224
Sales2010	612 831	1296890.874	225	**ROE 2010**	0.65	31.39	220	**Empl. 2010**	5577.51	9947.72	227

Note: figures are only given where data were available; sales figures are given in millions of yen.

Table 3 presents precise measures of similarity (correlation and Jaccard coefficients calculated with UCINET [3]. Here, we can see that the network retained parts of its structure in the period of 2007-2008, but it has changed even more in 2009-2010 further distancing itself from the original network. This means that there are many new participants in the network and the weight of some of the major actors shifts (e.g. the troubles of Panasonic can also be discerned from the patterns of collaboration as the number of alliances of Panasonic affiliated firms declines sharply in the third period). Government consortia and policy driven efforts seems also to dissipate over time. Firms, in several cases, do not carry on their established relationships after the projects and government efforts have ended. On the other hand, universities remain in the focus of action and even expand their collaborations.

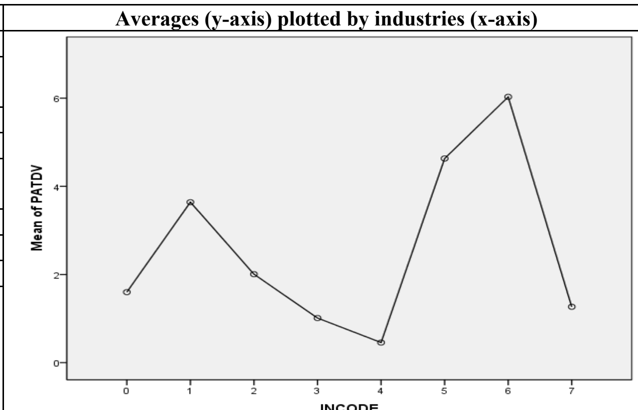
To give an overview of the scale and performance of the companies included in our sample, we have listed three measures in Table 4. It shows that there was a slow growth in sales and the number of employees over time, but as one may expect, there was a decline during and after the economic downturn. The 'return on equity' numbers reflect this in a more pronounced way.

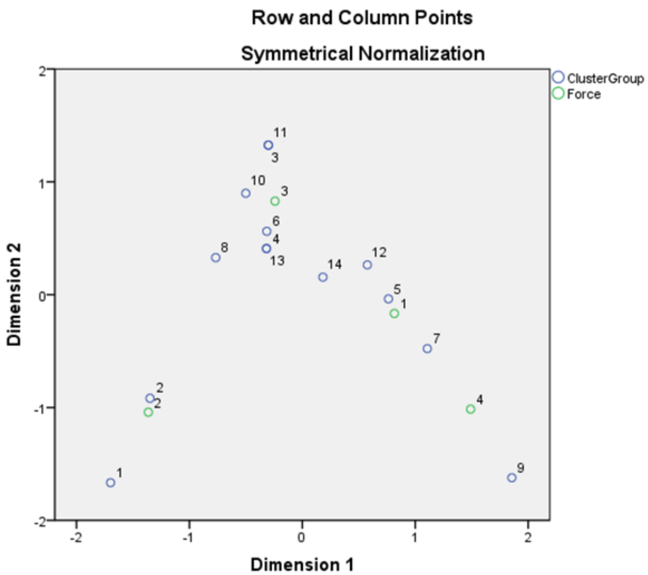
Last, we have looked at the average number of patent applications by industries in the whole five year period. The number of firms in each industry is somewhat different, representing the diverse nature of the field. We have to add, that here we have grouped industries not by SIC code, or a similar Japanese system, but by mainly relying on the major nanotechnology fields mentioned above, so there is a certain level of arbitrariness. Nevertheless, we can see that the dominant industries are the electronics (nano-electronics) and chemical (nano-materials) industries with the most number of firms represented.

In order to identify the main forces working in the formation of the Japanese nano- technology R&D alliance network, we first performed a cluster analysis on the network using UCINET. This gave us the major groups within the network that form cohesive clusters. We identified the firms and other organizations in each group and the corresponding patents that were the result of the alliances. After this first step, we numbered each cluster and created two of variables: type of network forming force and main industries involved. Fourteen different cluster groups have been identified and are listed in Figure 2. We have chosen arbitrary names that we felt described the main influence on the cluster. Some were named after geographical regions, others after main organizations that influenced them.

TABLE 5 PATENT APPLICATION AVERAGES BY SECTOR

Industries	N	Avg.	Std. Dev.	Averages (y-axis) plotted by industries (x-axis)
Other and services(0)	60	1.60	2.901	
Electronics, semiconductors, precision tools and optics (1)	206	3.64	10.092	
Chemicals (2)	280	2.01	5.908	
Nanotechnology (3)	86	1.01	1.812	
Pharmaceuticals, cosmetics, food & biotech (4)	68	.46	.742	
Automobile and parts (5)	38	4.63	10.383	
Textiles and fibers (6)	34	6.03	13.148	
Machinery and industrial equipment (7)	56	1.27	1.931	
Total	**828**	**2.39**	**7.199**	





Groups
1 NAIST group
2 JST and Kansai group
3 Kansai group
4 Nissan Motor group
5 Mitsubishi and Kyushu group
6 Tohoku-Kanto group
7 Toyota and Aichi group
8 Hokkaido group
9 **Nara group**
10 Nagoya-Tokyo academic group
11 Mitsubishi and Hitachi group
12 Hitachi group
13 Osaka and Okayama group
14 Non-classified

Forces
1 Existing ties & past relationships
2 Top-down agnecy
3 Bottom-up agency
4 Geographic distance

Figure 2 Correspondence analysis results for forces and groups

After reviewing the groups, the alliances and the firms that make up of these groups, we have identified the most likely forces that shaped the alliancing behavior of organizations: 1) existing ties, 2) top-down agency, 3) bottom-up agency, and 4) geographic proximity. These basic forces are also suggested by the literature as mentioned above.

Several studies show that firms are more likely to form ties with past partners [1, 12] as mentioned in the theoretical section. There is also some evidence that in Japan old keiretsu relationships enable and constrain alliance formation [16], however, there is also evidence that recently these constraints are beginning to soften [17, 18] and keiretsu relations became more open and overlapping with the reorganization of Japanese industries and the entrance of foreign firms and managers (cf. the case of Carlos Ghosn and the Nissan-Renault relationship). We have also found support for this trend in our network and it seems that government consortia are also encouraging cross-boundary collaborations. Nonetheless, the clear tendency to leverage close ties between keiretsu group companies to form R&D alliances could be detected. Several alliances are clearly formed between affiliated companies and traditional buyers and suppliers. We have also looked at several keiretsu and manufacturing groups (Panasonic, Sumitomo, Hitachi, Mitsubishi), combined the group companies' ego networks and found that while existing ties do play a role in alliance formation, there are many cases where boundary spanning is achieved either by university and government mediation or active agency and individual research agendas.

The former takes us to the second major force within the network, which we call "top-down agency" or "legitimizing discourse" which attempts to influence industry participants and create a cohesive whole based on the image of 'government policy' and major academic vision (although perhaps academic vision is more significant in western Europe than in Japan). The high centrality of academia, as well as other governmental and non-profit public research organizations has been observed in the previous sections. A top-down policy is clearly exerting strong forces on the network. The literature on the Japanese innovation framework and alliance patterns reflects this fact. Today, government research consortia are the main drivers behind alliances in Japan [16]. In our patent data we can support this fact as most of the alliances include a governmental or academic actor that act as a coordinating force.

Agency (as defined by [10]) in network formation is a major topic in recent studies [1]. There is research on strategies to shape the alliance network by alliance management skills [19, 15]. In our sample, a company such as *Toyota Motor* or *Toray Industries* may be taken as a very powerful actor that consciously attempts to shape its network [9]. We propose that there is 'bottom-up agency' originating in the behavior of individual firms. This kind of agency is based on assumptions of alliance managers and research consideration. This kind of agency is the clearest form of emergent behavior displayed in a network. Here, we do not probe behind the veneer and just simply identify this type of force as our third type of force.

Last, regional clustering patterns could be observed as well. Collocation and geographic proximity enables firms to form new alliances more easily. In this case usually the regional partnering activity clustered around a powerful actor in the region, for example a university (Kansai area) or a local firm (*Toyota* in Aichi prefecture). In the first half of the 2000s the government designated some prefectures as potential industrial clusters and provided funding to these areas. It is possible to see some of these in the patterns of networking, especially Nagoya-Aichi and Nagano. However, we have to note that in Japan collocation seems to play a smaller role in alliance formation, as even closely located firms might refrain from any kind of interaction, especially if they used to be associated with separate keiretsu-s.

Next, our interest lied in looking at these four network shaping forces and answering the question of how they manifest in the actual nanotechnology network. We have performed two correspondence analyses in SPSS to find out 1) the relative distances of each group and the relative distances of the four forces, 2) the relative distances of industries and the relative distances of the four forces. The first test was carried out to see that what kind of groups within the network exhibit each feature. The result of the first test is shown in Figure 2. The positive side of the x-axis could be associated with existing ties and geography (past ties), while the negative values reflected agency. The interpretation of the y-axis was less straightforward but it reflected active bottom-up agency versus more top-down or predetermined more passive agency. We looked at the composition of each axis value for every group. The first force (1), existing ties, lied on the same axis as the large keiretsu and manufacturing group-based network clusters, such as Hitachi, Mitsubishi and Toyota. The second force (2) was mainly associated with the government research institute-led consortia-type network clusters (such as NAIST and JST groups). The third force (3) bottom-up agency is a more composite concept and most of the network groups cluster around it. After scrutiny, we identified some groups that are particularly representative of this local agency type behavior. These were newly formed 'Silicon Valley-inspired' venture companies and joint ventures specializing in nanotechnology. Some of these firms were clearly aiming to establish a diverse network and pursue a network embedded innovation strategy [25]. The last force (4), geography was not very influential (as predicted). Although many local groups were centered around regions, their attachment logic was not based on proximity, but on other considerations (such as existing ties, university leadership or conscious firm-level agency). The only major group clearly associated with force 4 on the correspondence analysis plot was Toyota Motors and a Nara-based group, both of which also display features of non-geographical attachment logics.

The second test looked at not the groups, but rather industries. We were interested in whether certain forces were more pronounced in a particular industry. In Figure 3, the distances between industries were combined with the distances of forces. We found that indeed there is a lot of variation between the distances. The interpretation of the axis showed a similar polarity of the concepts. Active agency versus passive agency and top-down action was visible.

The existing ties force (1) was closest in value composition to the chemicals industry and the automobile industry, which is quite easy to understand. These capital-intensive industries were the core of keiretsu groups and more traditional logics are probably still part of their institutional mindset. The chemicals industry, however, is also showing signs of bottom-up agency.

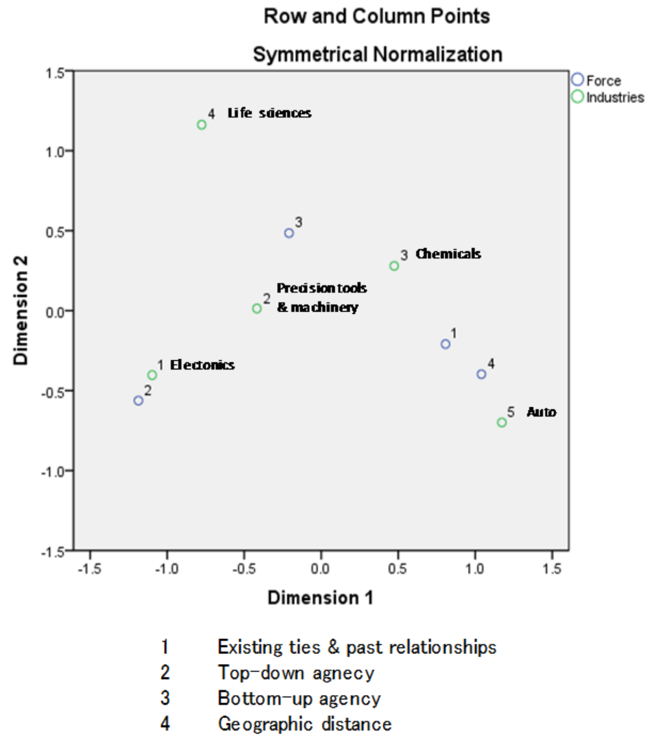


Figure 3 Correspondence analysis results for forces & industries

The top-down force (2) was strongest in the electronics and semiconductor industry and to a certain degree in the precision tools and devices industry. For example, government policy in nanotechnology (as mentioned above) concentrated on the electronics and semiconductor industry. The Japanese semiconductor industry used to be a major national champion. However, its decline in the 1990s and 2000s prompted action. In order to reinvigorate it, the government tried to invest in nanotechnology-based electronics and semiconductor technologies. This became the major target of nanotechnology policy. The precision tools and devices industry policies are still pushed today. For example, medical devices are the present major field for concentrated government policy.

The bottom-up agency force (3) was most prominent in the precision tools, chemicals and pharmaceutical industries. All of these industries contained younger firms (i.e. nanotechnology precision tools, new nanotechnology materials, and biotechnology firms) that are imbued with the logic of bottom-up conscious agency with both attempts at institutional work (e.g. by exploring new forms of business) and network engineering (e.g. by consciously developing alliance capabilities). Over time we expect a shift towards this type of agency.

Last, the geographical proximity force (4) seems to play no significant role in the network formation, although to a certain degree there is probably an overlap between geographical proximity and existing ties (as the close distance between force (1) and (4) shows). It would be interesting to pick up cases where despite geographic proximity the lack of existing relationship limit alliance formation. It seems plausible that geographic proximity is not as important as in the US, where informal networks easily connect actors within a local cluster.

V. DISCUSSION

At the beginning we were interested in the forces and underlying mechanisms of newly forming network. We have analyzed the Japanese nanotechnology industry and the institutional context it is embedded in. We have collected network data based on joint patenting to find out more about the structure of collaborative relationships among firms. Our analyses identified a certain number of main groups within the network, which helped us ascertain four types of forces that seemed to play a role in network formation. As expected, both existing relationships (such as keiretsu and established buyer-supplier relations) and government-academia coordinated relationships played a major role in network formation. We have found, however, that bottom-up agency of firms is an important feature of the network. Alliance management logics and decisions about technological research trajectories on the firm-level influence the development of the network. Last, we have found that geographical collocation is not as important a feature as with the case in US clusters, perhaps because of the more constraining nature of existing relationships and the risk-avoiding behavior of Japanese firms that holds back firms from partnering with local but low prestige firms.

There are certain limitations to our studies. First, we have only focused on R&D relationships, but there are many other networks that might constitute the underlying structure to the field, such as informal networks, supplier-buyer relationships, board interlocks, and professional networks, just to name a few. A more precise measure of multiplex networks would considerably improve the precision of the study. Second, we have limited ourselves to four forces that could be most readily discerned from the clustering patterns. Other forces that might be behind the formation remain unexplored (such as prestige consideration or homophily consideration). Last, we have assigned variable values to a group of firms that were represented as a cluster in the whole-network instead of each alliance (or dyad). This might lead to some imprecision in the correspondence analysis as some groups were somewhat ambiguous on whether they are based on existing ties or geographic proximity. In some cases, field interviews might be necessary to clearly ascertain the nature of the alliance. This might be the basis for further research.

VI. MANAGERIAL AND POLICY IMPLICATIONS

Managers have to be aware of the fact that their firm is embedded in a network of relationships. Their future trajectories are set not just by the manger's own decisions, but the surrounding environment and network partners. Thus, it is essential to be aware of the forces that shape the growth and dynamics of a network. Policy makers on the other hand have to be aware of the core forces operating in the target industry and look at ways to influence the right force.

In our study, we have only provided a simple overview of the network forces in one country, Japan's, inter-firm alliance network. While in large continent-wide countries, such as the United States, geographical clustering play a huge role in network formation, firms in Japan seems to care less about proximity as distances are smaller. This might apply to other countries with compact geography. This implies that it is less important to focus on local clusters in small countries. Existing ties have a very important role in "passive" agency, therefore clusters with preexisting industry might find it useful to try to invite other existing players or create new network connection instead of just simply trying to boost entrepreneurial activity too far. Government action, however, seems to be at odds with active agency at the firm level. Government can be seen as a form of passive agency. A force coming from the outside, therefore policy makes should not be content with just simply pumping money into building empty research facilities and entrepreneurial incubators. Managers on the other hand should actively seek out the forces that might benefit them.

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