The Role of Universities and Governmental Organizations in Organizational Fields
— The Case of the Japanese Nanotechnology Industry —

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Abstract

The paper investigates the role of universities and governmental organizations in the formation and maintenance of the Japanese nanotechnology organizational field. The results suggest that both universities and governmental organizations occupy a central position within the field. The formation of network ties mostly operates on a top-down basis facilitated by government policy. Despite their highly central positions in the networks, it is also evident that universities failed to facilitate the formation of an independent network where for-profit firms would take over some of the hub functions. As such, they are only partially achieved to become anchor tenants in their respective regions. Universities often remain internally fragmented and fail to fully leverage the brokerage advantages that stem from their network positions. However, building a more cohesive internal function has the potential to boost their ability to broker within the network. This finding has a further implication for network theory in that brokerage for complex organizational networks might be more complicated than originally conceived.

1. Introduction

The paper is a case study of the Japanese nanotechnology organization field focusing on universities and public research organizations and their role in the formation and maintenance of the field. It has long been held that both government organizations and universities are key facilitators of organizational field formation and maintenance. Evidence was found for this in cases of the American computer industry (Saxenian, 1994), biotechnology (Powell, Packalen & Whittington, 2012), and others (Berman, 2012).

Government policy has played a critical role in transforming universities into engines for the economy, making them more entrepreneurial. Universities are seen as playing a crucial role in transferring technology to industry and participating in joint development (Berman, 2012; Kaiser, 2010; Gillmor, 2004). As key targets of government funding, universities in the United States have become central to organizational fields and, in the end, to the national innovation system. Likewise, government policy has also played an important role in Japan (Johnson, 1982).

Chaminade, Lundvall, & Haneef's (2018) national innovational system concept highlights the importance of relationships among organizations. Following in their footsteps, the present paper mapped relationships among organizations as a network of relationships in an organizational field. In the organizational field studied, universities were connected to both governmental organizations and for-profit firms, occupying central positions. Network theory predicts that these central positions play a quintessential role in field formation and maintenance. What these roles are and why universities sometimes cannot leverage their central positions are questions this paper seeks answers to.

It will be shown that universities play multiple roles: building connections to other organizations, facilitating connections among third parties by being local hubs, and ideally acting as anchor tenants, as well as network hubs or brokers.

The data shows that universities and government organizations are both central in the networks and can potentially serve as network hubs. However, while the government and its generous funds often back public research organizations, universities can be more fragmented as they comprise individual-led research initiatives. When internal departments are siloed within universities, research can be fragmented, and universities might be unable to leverage their brokerage positions in the network.

This has implications both for network theory and innovation policy. The internal cohesion of university research becomes important to avoid fragmented networks. It will also be shown that the top-down government-led field maintenance identified in the paper faces difficulties when it tries to switch to a more diverse organization-led field maintenance.

2. Theory

Previous research has found that innovation no longer takes place simply within the limit of a large organization but enfolds in cooperative networks (Powell, Koput & Smith-Doerr, 1996). Thus, the focus has shifted to networks of organizations, collaboration among firms, and cooperation among universities, government organizations, and industry (Etzkowitz, 2018). Chaminade, Lundvall, & Haneef (2018) have emphasized cross-organizational relationships instead of simply university-government-industry collaboration, be it cross-industry or cross-university collaboration. Powell, Koput & Smith-Doerr (1996) conceptualized these relationships as a network of alliances that makes up an organizational field(1).

Powell, Packalen & Whittington (2012) have shown that the biotechnology industry has developed in geographic proximity to an anchor tenant, such as a university, or a public research organization. These anchor tenants facilitate the cross-pollination of ideas from different domains. Indeed, universities and public research organizations have been found to play important roles in innovation, and coordinating economic activity (Berman, 2012; Powell, Packalen & Whittington, 2012). While basic science and technology were seen as two distinct entities developing independently (Allen, 1984), there is now more evidence showing that the seeds of key technologies originate in universities and other publicly funded research initiatives (Berman, 2012; Mazzucato, 2018). However, basic research needs fertile ground in the form of for-profit organizations and capital-providing entities to develop into widely available products(2), and there is often a gap between basic discoveries and later applications.

As noted above, Powell, Packalen & Whittington (2012) gave a prominent role to universities in geographic biotechnology clusters (i.e., fields), calling them anchor tenants. Stanford University exemplifies such an anchor tenant (Powell, Packalen & Whittington, 2012). Its ties to industry in the Bay Area (Lowen, 1997; Gillmor, 2004; Shurkin, 2008) and its role in the formation of Silicon Valley are well documented (Saxenian, 1994; O'Mara, 2019). The Bay Area biotechnology cluster is also well-known (Hughes, 2011). As anchor tenants bring in more and more organizations in their orbits, they help local regions develop into industry clusters (Braunerhjelm & Feldman 2006).

This idea of a successful innovative cluster has become a template worldwide and served as a guidepost in policy-making around the world, albeit with mixed results (Casper, 2007; Breschi & Malerba, 2005; Braunerhjelm & Feldman, 2006).

This paper focuses only on universities and public research organizations in the larger organizational field. Universities facilitate field formation in multiple ways: they collaborate with other organizations, facilitate ties between third parties by being geographic hubs, and use their brokerage advantage to create strong positions within the network. One important feature of the field discussed here is that it comprises research and development collaboration ties. The field's main focus is innovation, and universities are therefore chiefly analyzed here from an R&D perspective (see Table 1 for the roles of universities in R&D). The

Table 1　What roles do universities play in the research and development of technology?

The role of universities in R&D
Spin-off venture firm creation and support
Venture capital and funding non-university ventures
Creation of research institutes with government or private funding
Collaboration with industry firms
Providing a location for research infrastructure
Conferences, events, symposia
Technology consulting
Education of engineers and workforce
Fluidity between faculty and industry

activities described in Table 1 also have a function in field formation and maintenance. Therefore, universities can be seen as major influencers of the field.

Powell, Whittington & Packalen (2012) emphasized that a central, lead organization is insufficient. An anchor tenant differs from a lead organization in several ways. Powell, Whittington & Packalen (2012) write that anchor tenants "occupy positions that provide them with access to diverse participants and the legitimacy to engage with and catalyze others in ways that facilitate the extension of collective resources." They contrast this with rigid organizations that try to impose their own rules. For them, the cross-pollination of ideas and community mobilization are key aspects of anchor tenants.

In successful clusters, ties beyond the anchor tenants begin to increase, and dense ties form among third parties, facilitating research within cooperation networks. As mentioned above, these networks of cooperation and clusters are often conceptualized in the literature as networks and organizational fields (Powell, White, Koput & Owen-Smith, 2005).

While both for-profit firms and universities are included in the organizational field, it is important to note that both in the case of universities and large multidivisional firms, it is not the whole organization that participates in the field, but only its constituent part, a department or a division. This makes analysis more cumbersome. While biotechnology venture firms, for example, are complete members of a larger biotechnology field, most large organizations in the Japanese nanotechnology field are not. Car makers such as Toyota use many technologies, and while it has built a prominent position within the Japanese nanotechnology industry (Fazekas, 2022), it is not simply a nanotechnology firm.

This has many implications. For one, organizations are part of multiple fields and may connect disparate fields within themselves, but they can also contain internal boundaries that block flows among internal departments. Universities are prime examples of this. Even in one department, professors might not communicate frequently enough. This silo effect within organizations questions whether universities can truly act as hubs. As will be shown, universities do multiple things to coordinate activities but sometimes can fall short of being anchor tenants.

Another idea behind the anchor tenant concept is network brokerage. DiMaggio and Powell (1983) have implied that organizational fields have a network structure. Certain positions within the network structure can provide advantages. According to this view, highly central firms or firms that connect different parts of the network can obtain both information and potential control benefits (Burt, 1992; Burt, 2021). Because they connect different parts of the network, they can also access unique information, which provides potential control benefits.

Lately, however, network research has shifted from static structural explanations toward acknowledging the importance of agency in networks (Tasselli & Kilduff, 2021) as well as the active role of brokers (Obstfeld, 2005; Halevy, Halali, & Zlatev, 2019). It is not only the position but also the agency of the organizations (or individuals) that establishes the advantages. Centrality alone does not make an organization a network hub or anchor tenant. Intra-organizational orchestration and, as Powell, Whittington & Packalen (2012) stated, legitimacy for acting on control benefits is necessary.

3. Data collection methodology

The present study is part of a larger case study of an organizational field, the Japanese nanotechnology field. In Fazekas & Wakabayashi (2014), we have previously focused on firms engaged in nanotechnology R&D. Fazekas & Wakabayashi (2014) explain the data collection method that forms the basis upon which the present extended analysis is built. The Japan Patent Office's online database was used to collect nanotechnology-related patents (based on a set of nanotechnology-related keywords). Data was collected for the formative years of nanotechnology from 2005 to 2010. We chose 2005 because universities became legal entities in the previous year, and thus patents could be registered for universities instead of only for individuals. Joint patents (958) were selected from a pool of around 5000 nanotechnology-related patents. Based on joint patents, I identified linkages among organizations (creating an actor-actor matrix with 1784 ties and 604 nodes and dividing it into three two-year periods). UCINet and NetDraw were used to analyze the network and compute network variables (Borgatti, Everett, & Freeman, 2002). Not all alliances can be mapped with this method. Those that did not produce patents are excluded, while some others might have been missed.

In Fazekas & Wakabayashi (2014), we created a database of the 464 companies in the matrix, excluding 85 universities and 55 research organizations. Fazekas & Wakabayashi (2014) focused on what forces drove the formation of the organizational field and identified some subfields. Fazekas (2022) has investigated the effect of this network on the most prominent industry participant, Toyota. In the present paper, I have focused on the remaining entities and compiled data for universities and research organizations.

The quantitative data was then complemented with other qualitative data, including archival records, magazine articles, government publications, and unstructured interviews with members of three university collaboration research initiatives as well as engineers who had participated in nanotechnology-related research collaborations (both industry-industry and industry-academia). I have collected qualitative data for both the 2005–2010 period and after.

4. Case background: Nanotechnology in Japan

Microelectronics and biotechnology were one of the great waves of industrial transformation, creating enormous economic value. Japan was able to capitalize on the microelectronics revolution but was a relative latecomer in biotechnology (Asakawa, 2006). Then, Japan lost its semiconductors leadership in the 1990s (Okada, 2006) and needed a new policy focus.

The government unveiled its First Science and Technology Basic Plan(3) in 1996, in which an emphasis was placed on university-industry technology transfer (Taguchi, 2009). This policy established the legal basis for technology licensing offices (TLOs) in 1998 and issued the Japanese version of the Bayh-Dole act in 1999 (Taguchi, 2009). This was also when countries began looking for new technologies to provide the basis for future country-level competitive advantage.

Japan emphasized developing the nanotechnology field from the beginning of the 2000s (Ikezawa, 2006). In the late 1990s, nanotechnology was first seen as a continuation of Japan's miniaturization trend and was therefore led by semiconductors-related nanotechnology research (Taguchi, 2005). However, other fields of nanotechnology, such as precision tools and nanomaterials, were soon identified as seeds for future industry development. Nanotechnology was featured in the First Science and Technology Basic Plan, and, in 2001, the government prioritized nanotechnology in its Second Science and Technology Basic Plan.

This plan was followed by the Third Science and Technology Basic Plan in 2006, which included nanotechnology as a key area of research. This plan also included plans for building local nanotechnology clusters and facilitating nanotechnology alliances among firms, universities, and government-affiliated organizations. In these clusters, universities and public research organizations were assigned important roles as hubs and physical locations for research infrastructure. This 2006–2010 period is covered in the quantitative data collection period (2005–2010), in order to capture the formation process of the organization field.

In order to understand government organizations and policies, it is important to give a brief overview of how the Japanese government built up its science and research policy after the war. During Japan's economic developmental phase after the war, MITI (the precursor of the Ministry of Economy Trade and Industry until its reorganization in 2001) was in charge of overseas technology transfer. Today, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) is the main ministry supporting basic research and science. At the same time, the Ministry of Economy, Trade, and Industry (METI) is more involved with technology and commercialization aspects.

An important agency that implements the policy of MEXT is the Japanese Science and Technology Agency (JST). Its history goes back to RIKEN, a division of which the Development Division was put in charge of university-industry technology transfer early in 1958. In 1961, it was separated into the Research Development Corporation of Japan (JRDC), which was created to develop Japanese domestic research by supporting universities and public research institutions and their industry connections to avoid dependence on overseas technology(4). JRDC could use government funds to support research that was too risky for companies to undertake and help with university-to-industry transfers. The JST was created out of the JRDC and another organization. Since 2003, JST has been a government-affiliated independent administrative institution(5) whose task is to develop R&D infrastructure in Japan and implement the Science and Technology Basic Plans.

The New Energy and Industrial Technology Development Organization (NEDO) is another important facilitator of the nanotechnology sector, though it is less prominent in the network that was drawn up in this paper. It is a government-affiliated organization close to METI, positioned as an innovation accelerator. NEDO is in charge of implementing METI policy and working with universities and for-profit firms. Its predecessor organization, the New Energy Development Organization, was founded in 1980, and the present name came into being in 1988(6). NEDO is not focused only on nanotechnology research but is in charge of diverse fields such as energy and industrial applications.

The National Institute of Advanced Industrial Science and Technology (AIST) is one of Japan's largest public research institutes, created by the merger of several research organizations. It has research bases across the country and is an important contributor to nanotechnology research. It is the most connected institution in the network presented here. Sato (2002) described it as the foremost research organization for nanotechnology in Japan at the beginning of the early 2000s. MITI (the predecessor of METI) started the Atom Technology Project with a predecessor institution of AIST and made it a central organization in university-government-industry collaboration (Sato, 2002). This project was the foundation for AIST's later nanotechnology capabilities.

Another key institution, the National Institute for Materials Science (NIMS), established in 2001, was created from the National Research Institute for Metals and the National Research Institute for Inorganic Materials(7) to focus on materials research. Both predecessor institutes were relocated to Tsukuba in the 1970s.

Table 2　ARIM and Nanoplatform participant institutions

Org.	ARIM	Nanoplatform
Univ Tohoku	148	characterization, fabrication
Univ Tokyo	105	characterization, fabrication
Univ Kyoto	104	characterization, fabrication
Univ Nagoya	92	characterization, fabrication, synthesis
NIMS	84	characterization, fabrication, synthesis
AIST	63	characterization, fabrication
Univ Hokkaido	56	characterization, fabrication
Univ Hiroshima	53	fabrication
Tokyo Institute of Technology	37	fabrication
Univ Osaka	37	characterization, fabrication, synthesis
Univ Kyushu	34	characterization, synthesis
Nara Advanced Insitute of Science and Technology	33	synthesis
Chitose Institute of Science and Technology	31	synthesis
Toyota Technological Institute	30	fabrication
Univ Waseda	29	fabrication
Univ Tsukuba	24	not in original nanoplatform
Nagoya Institute of Technology	23	synthesis
Univ Electro-Communications	20	not in original nanoplatform
Japan Advanced Institute of Science and Technology	18	synthesis
Univ Shinshu	12	synthesis
Univ Kagawa	11	fabrication
Univ Yamagata	9	not in original nanoplatform
QST National Institutes for Quantum S&T	6	not in original nanoplatform

Compiled by the author based on 2022 ARIM and nanoplatform data.
ARIM: shows the number of devices available in the ARIM platform for each organization (2022).
Nanoplatform: ARIM's predecessor platforms were characterization, nanofabrication and molecular and material synthesis

NIMS is important because it plays a key role in the operation of the Nanotechnology Platform Japan(8), now ARIM, a project run with the help of MEXT and JST. This platform provides the technological infrastructure for nanotechnology research with the collaboration of research centers and universities. Equipment can be rented by for-profit corporations and interested researchers for a fee. The original platform was made up of three platforms: advanced characterization (microscopy, spectroscopy, XDR, and other measurement capabilities), nanofabrication, and molecule and material synthesis platforms. Many of the top universities participated in more than one platform.

The Nanotechnology Platform, and its successor organization ARIM, is one of the key links between government, industry, and universities. Its main role is to broaden access to research infrastructure and shift it from AIST to more organizations. It also helps identify the most important universities active in nanotechnology research. Table 2 presents the list of the participating organizations and the number of devices they provide at their locations. They are not only important because they provide research infrastructure but also because the government has designated them as key institutions in nanotechnology, providing them further legitimacy.

Along with government- and university-based development, industry-centered orchestration has played a role too. In 2003, NBCI (Nanotechnology Business Creation Initiative) launched at the call of the Ministry of Economy, Trade and Industry (METI). It is a business network that joins member firms together. NBCI organizes symposia and is also an important facilitator of the annual 'nano tech' conference that attracts diverse participants from around the world. It is the largest nanotechnology trade show in Japan. While it plays an important role in the background, it is not visible in patents and does not appear in the network under study. Nevertheless, it needs to be mentioned as a facilitator of business-to-business relationships.

In the rest of this section, I will give a brief overview of the development of the nanotechnology organizational field in Japan in the 2005–2010 period and beyond. Data collection started in 2005 because this was the first year universities could be traced through patents. While patents cannot give a full picture of collaborative activities, they give a good overview of the organizational field and the key players present.

The field set off before the observation period (Taguchi, 2002), but the organizational field development picked up in the early developmental phase (2005–2006). This period saw a solidifying network where organizations sought collaboration in nanotechnology. In this phase, the network centered around some major universities and government research organizations (AIST, JST, NIMS).

In the next period (2007–2008), for-profit firms started to form hubs. Mainly electronics companies and companies related to the car industry were prominent. In this period, Toyota became a central player due to its need for nanotechnology in its fuel cell development project (Fazekas, 2022). However, it was less of an anchor tenant than a member of the field with weight and status that was able to create ties that it needed for gap-filling research. It did not assume leadership in the nanotechnology organizational network, however.

In 2009–2010, more fragmentation occurred. While nanotechnology made inroads into everyday technology, companies recognized that nanotechnology was just a subfield that can help other fields but might not be able to stand on its own feet. Instead of solidifying into a coherent nanotechnology industry, the organizational field remained fragmented. Many cross-industry alliances were gap-filling in nature or continuation of existing technologies, with features originating from nanotechnology research being added to existing products. Slowly, the government began to replace its focus on creating a nanotechnology industry with fostering diverse fields such as sustainability, renewable energy, and green technology. This reorientation first happened with the Fourth Science and Technology Basic Plan in 2011.

Unlike microtechnology or biotechnology, nanotechnology failed to materialize in the 2006–2010 period as a concrete industry-based field and instead remained a discipline of study and a tool that can be utilized in diverse applications. The quantitative data-collection period ended in 2010, but nanotechnology is still quietly developing, and most of its research infrastructure remains. Many of its institutions, such as university hubs and the annual nanotechnology conference 'nano tech,' are still functioning as of the time of writing in 2022.

Indeed, nanotechnology was not completely abandoned after 2010. In Tsukuba Science City, TIA-nano (Tsukuba Innovation Arena for Nanotechnology), a nanotechnology research and education center, was created in collaboration with government organizations (AIST, NIMS) and universities (the University of Tsukuba) in 2009. The University of Tokyo joined the group later in 2016 and is now a core member. In 2020, Tohoku University was added to TIA-nano.(9) Much of the funding came from the Ministry of Economy, Trade, and Industry (METI)(10). The Nanotechnology platform was reorganized as ARIM or Advanced Research Information for Materials and Nanotechnology in Japan.

5. Role of universities and public research organizations in the organizational field

The case revealed several important roles that universities play in the organizational field. Allen (1984), in his landmark study, found that science (i.e., basic research) and technology (development and applied science) are developing on their own trajectories, and technology does not simply emerge from basic research. This view has changed after the discoveries of biotechnology and information technology, where research in universities could be more readily developed into new technologies (Berman, 2012). However, it is probably true that it takes a long time, from basic research to marketable technologies. Nevertheless, it is important to note that universities are not only in charge of science and basic research but also undertake engineering tasks and technology development. Therefore, universities are known for their contribution to research and development.

Interviews with members of university research institutes have supported the view that gap-filling research (defined by Allen, 1984) is one of the most successful forms of university-industry collaboration. Universities can be seen as key partners in R&D and even originators of new technologies. University spin-off ventures have increased in number, not only in the US, but also in Japan.

However, apart from individual contributors to R&D in Japan, universities can also be seen as potential tools for government policy. It has been a long-held view that industrial policy is key for facilitating the development of new industries(11). The quantitative network study can attest to this. Government public organizations acted as hubs and key facilitators of both nanotechnology policy and alliance building. MEXT with JST, AIST, NEDO, and NIMS were the key facilitators of organizational field formation. The Second Science and Technology Basic Plan tried establishing industrial clusters across the country. For this, the government designated universities and public research organizations to become local hubs that facilitate cooperation in the regions, such as Shinshu University in the Nagano region. They have established the Nanotechnology Platform as a collaborative association of universities and research institutes to create the necessary infrastructure for nanofabrication and nanotechnology research.

However, universities are not just hubs in a geographic sense, but they can be seen as important hubs in the network holding together disparate for-profit firms and government organizations. This gives them potential advantages that stem from their central position in the network (Burt, 2021). However, it was unclear whether universities could easily exploit these benefits by forming industry linkages because there was considerable internal fragmentation within universities, and thus intra-institutional cross-pollination was limited.

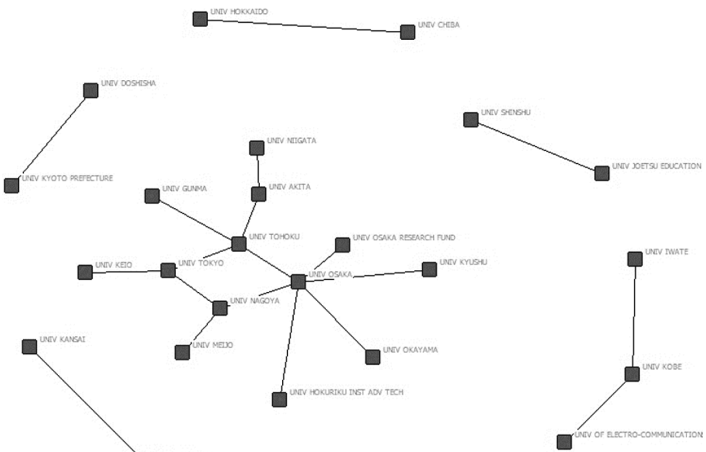

Figure 1　Network of the universities with only cross-university alliances

Furthermore, while universities are central within the network, key governmental institutions hold the university network together (AIST, NIMS, and JST), as shown in Figure 2. Cross-university linkages, as shown in Figure 1, are weak, and while university-industry alliances are numerous, they also form a fragmented network. Connections do not aggregate within the node and create a seamless network where information flows freely. Often for-profit organizations collaborate with departments, and in the early period, often with individual professors.

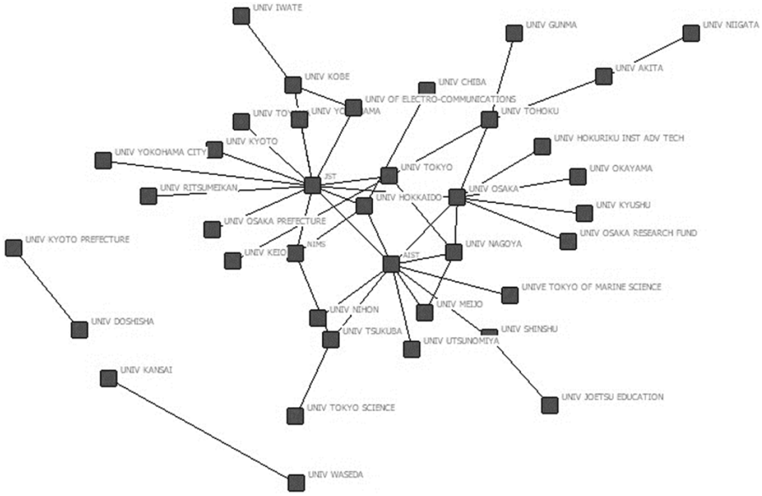

Figure 2 Universities with the three main government organizations (JST, AIST, NIMS) and their links among each other (other connections deleted)

While the government's cluster-building efforts encouraged the establishment of university-hosted nanotechnology hubs and research institutes, there were very few intra-university organizations that could aggregate the influence of ties, provide agency and offer a continuous organizational memory in the early period. This has implications for the expected results of network advantage theory. As universities occupy brokerage positions, they are expected to accrue benefits and engage in brokerage activity. To some degree, this is true, especially in the case of top universities. However, much of this brokerage activity stays fragmented within the universities. Burt (1992, 2021) predicts that structural hole spanning and brokerage bring both information and control benefits, but this paper has found that it might not be the case for complex organizations with low internal network connectedness.

Table 3 Connectedness by organizational type

Alliance statistics by organizational type		
Average	2.402083	Industry
Max	31	
Average	4.452381	Government organizations
Max	55	
Average	5.414634	Universities
Max	38	

Nevertheless, universities and governmental organizations are central in the measured networks. Table 3 shows that universities have the highest average connectedness (average number of alliances), while government organizations have their alliances concentrated in some central organizations (JST, AIST, NIMS). Average connectedness is the lowest for industry. While there are some highly connected firms, most have only one or just a few connections. There are some industrial hubs, such as Toyota Motor, but most key hubs are either universities or government organizations. University connectedness is further detailed in Table 4 below.

In Figure 3, first-degree ego network connections are added to the backbone of universities and government organizations previously shown in Figure 2. This almost completely reflects the core component of the network drawn in Figure 4, suggesting that the network and, thus, the organizational field is mainly orchestrated from above through government policy, relying on a top-down method(12).

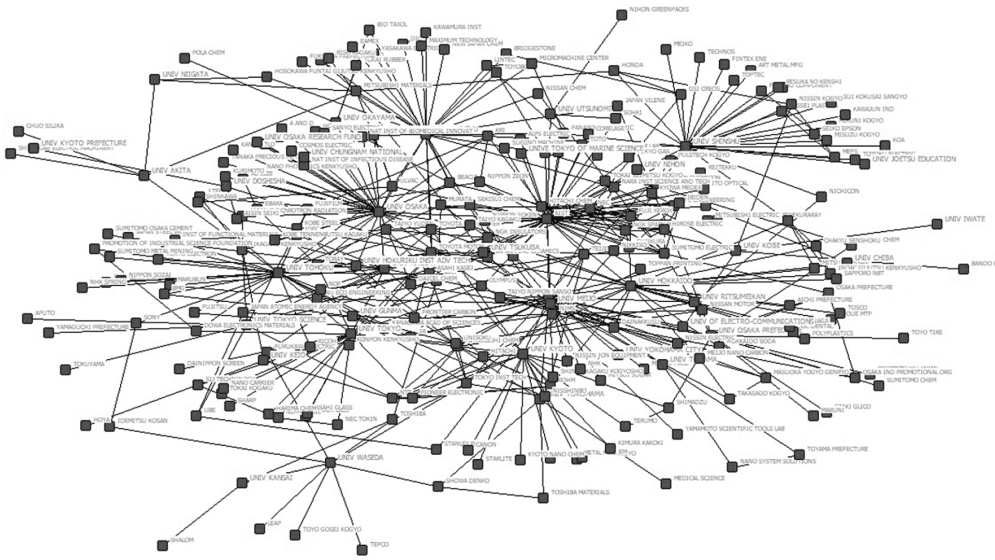

Figure 3 Universities, three government organizations, and their first-degree connections (industrial and other governmental)

This top-down organization has several implications for the maintenance of the organizational field. These organizations are essential for orchestrating the field and the maintenance of the network. However, these governmental organizations might not give universities and industrial firms enough legitimacy and leadership potential. Nanotechnology also necessitates new venture companies and an ecosystem that supports such ventures. Lately, the infrastructure for venture companies is being built out, and with it, there might be a shift towards a more bottom-up network. In the investigation period, however, it was clear that most collaboration initiatives came from the government, and the network could not have been sustained without universities and government organizations.

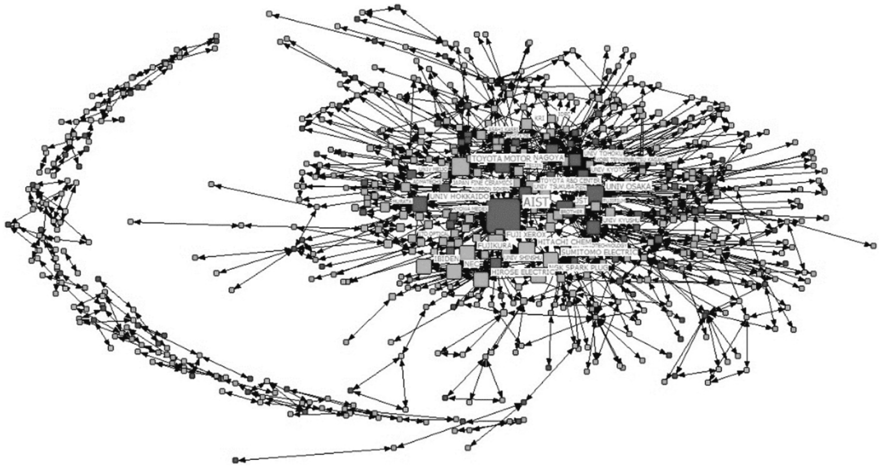

Figure 4　Whole network with universities and governmental organizations highlighted

Table 4　University network variables (top fifteen based on number of alliances)

Name of organization	Alliances (Degree Centrality)	Betweenness Centrality	Eigenvector Centrality	Structural Constraint
Osaka University	38	16588.334	0.221	0.060
Shinshu University	28	14347.277	0.102	0.054
Kyushu University	28	14179.339	0.140	0.069
Tohoku University	26	9159.392	0.128	0.072
Tokyo University	23	8769.99	0.119	0.084
Hokkaido University	24	8261.878	0.156	0.084
Nagoya University	17	8159.108	0.157	0.144
Kyoto University	19	5969.721	0.090	0.107
Osaka Prefectural University	15	4359.059	0.054	0.118
Tokyo University of Science	10	2060.697	0.034	0.100
Waseda University	9	2058.319	0.007	0.167
Kobe University	7	1772.006	0.030	0.314
Tsukuba University	7	1488.595	0.109	0.291
Hirosaki University	7	1469.76	0.012	0.245

Finally, it is interesting to see how the network becomes fragmented when universities and government organizations are deleted. Figure 5 shows an aggregated picture of the network in the period 2005–2010. Here, the main hubs are large chemicals, electronics, and car manufacturing companies. Nevertheless, a cursory look at the patents' content reveals that most large organizations cannot be perceived as anchor tenants for the organizational field. The main hub is Toyota, with its affiliated companies. Furthermore, although some nanotechnology-related venture companies built small niches with their alliances, they could not become large enough to form hubs in the network.

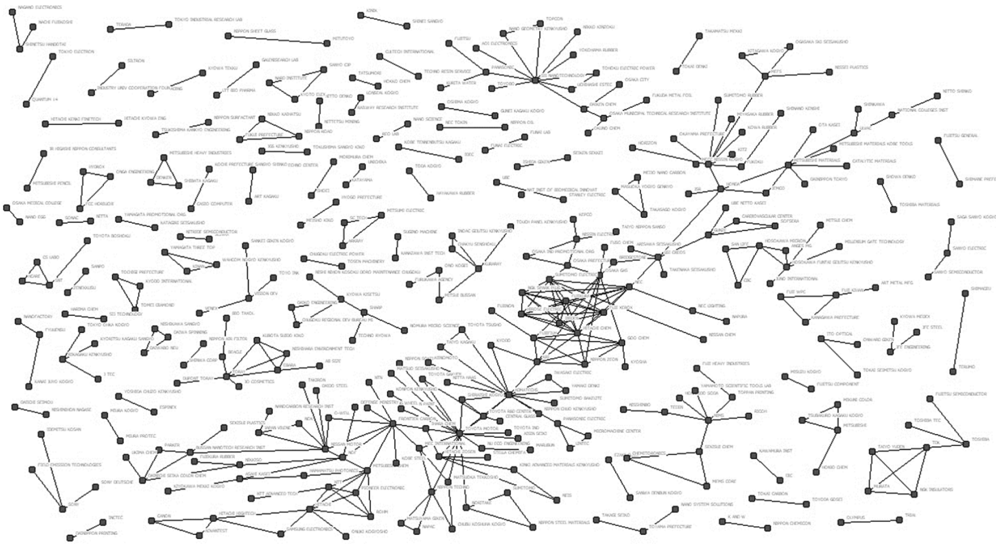

Figure 5 Network without universities and governmental organizations (with isolates deleted)

6. Conclusion

This paper has investigated the roles of universities and governmental institutions in the nascent Japanese nanotechnology organization field. These institutions played a key role in bringing forth the network and maintaining it. However, an independent nanotechnology field has failed to materialize. Industries remained fragmented, and new venture companies and smaller organizations could rarely become local hubs. Interviews have confirmed that universities have remained somewhat internally fragmented, with silos among internal departments and institutes, and that the industry often underutilizes some of its research hub status. This internal fragmentation led to the loss of some brokerage benefits that could have been captured in the network if the internal cohesion of the universities had been increased. It seems that universities could not completely become anchor tenants, and the organizational field remains heavily reliant on government policy and governmental institutions. However, with the establishment of better orchestration within universities, there is hope that some of these higher education institutions will be able to develop into full-fledged anchor tenants.

Notes

(1) Organizational fields are defined here along DiMaggio and Powell (1983: 148) as 'those organizations that, in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar

services and products.' DiMaggio and Powell (1983) emphasized that organizations in a field interact more with each other forming a network, that there are more powerful and less powerful organizations, and that there is a mutual awareness and shared meaning about belonging to a common field.

(2) There are arguments for a non-linear transmission of technology, where two-way interactions between university and industry are necessary for innovation (Maeda, 2000). Mere university-to-industry transmission of new research is not enough. This argument, too, suggests that innovation takes place in networks instead of simply within a dyadic relationship between two entities.

(3) The plan (which now is the 6th plan) is approved by the Council for Science, Technology and Innovation (CSTI), which formerly was called the Council for Science and Technology Policy (CSTP). It is made up of the Prime Minister, relevant Ministers, and experts. It is heavily influenced by MEXT and METI.

(4) JST governmental homepage: https://www.jst.go.jp/tt/EN/history.html

(5) It is also called an incorporated administrative agency (独立行政法人, dokuritsu gyōsei hōjin in Japanese). These agencies were created to sperate planning and operation functions, where the ministries are in charge of planning and the agencies are tasked with operations. While they are called independent, they are closely affiliated with the government.

(6) NEDO homepage: https://www.nedo.go.jp/english/introducing/ZZKH_100013.html

(7) NIMS organizational history: https://www.nims.go.jp/eng/nims/history.html

(8) It is now renamed to 'Advanced Research Infrastructure for Materials and Nanotechnology in Japan (ARIM) Program' as of 2022. Homepage: https://nanonet.mext.go.jp/page/dir000011.html Participants: NIMS, AIST, Tokyo University, Tohoku University, Nagoya University, Kyoto University, Kyushu University, Hokkaido University, Chitose Institute of Science and Technology, Yamagata University, Tsukuba University, Waseda University, Tokyo Institute of Technology, Hiroshima University, Toyota Tech, Kagawa University, JAIST, JAEA, QST, NAIST, and others.

(9) Zagar (2014) Nanotech cluster and industry landscape in Japan. EU-Japan Centre for industry cooperation report and the TIA-nano homepage: https://www.tia-nano.jp/.

(10) Same EU-Japan report from 2014.

(11) Johnson (1982).

(12) Fazekas & Wakabayashi (2014), building on insight from Powell, White, Koput & Owen-Smith (2005), theorized that collaboration ties form where ties previously existed or where the members were collocated in one geographic area. While we found evidence for the former, the latter was less typical in Japan where distances are shorter than in the U.S. We also found strong indications that subfields were called forth through top-down government initiatives and through the agency of individual firms. The focus in Fazekas & Wakabayashi (2014) was on firms and less on universities, so firm subfields received much attention. In this paper, more evidence is found that universities and government organizations are central to the Japanese nanotechnology industry and that top-down forces predominate. A similar top-down orientation was uncovered by Wakabayashi & Takai (2018) in another setting.

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