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Technological Innovation and Regional Development: The Case of Organic Light-Emitting Diode Valley Project in Yamagata Prefecture

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1. Introduction

There has been considerable interest in regional innovation among not only scholars but also local authorities. Many of the regional innovation initiatives have been intended as forms of endogenous development based on the utilization of the local university's knowledge, which is expected to create a knowledge-based high-technology cluster. Moreover, many scholars (Lundvall 1992, Maskell and Malmgerg 1999, Morgan 1997) point out the importance of interaction among local actors in encouraging innovation in a particular region.

Recently, since many assembly plants have migrated from developed countries to newly industrialized countries, many regions in the developed countries have been deteriorated. These regions compete with each other to establish strong local economies. To this end, they have been actively promoting industrial policies that aim to create knowledge-intensive industries rather than mass-product, low value-add industries. Experts (Lundvall 1992, Gibbons et al. 1994, Florida 1995, Nonaka and Takeuchi 1995, Etzkowitz and Leydesdorff 1997, Cooke 2002a) have started focusing on knowledge as an economic resource. Not only scholars but also government bodies (e.g. OECD 1996, DTI 1998) have shown interest in a knowledge-based economy. Knowledge has been utilised to revive the regional economy. To convert knowledge into economic profits, government bodies

have constructed institutional infrastructures for technology transfer.

In Japan, like other countries, various knowledge-based high-technology cluster initiatives have been promoted. The organic light-emitting diode (OLED) valley project in Yamagata Prefecture is one such initiative. The local authority has carried out endogenous development utilising a local university's technological seeds. As a result of the initiative, a venture firm began producing OLED light panels. Given that Yamagata's local economy has stagnated, the local authority has aspired to use high-technology OLED to revive the regional economy. Thus, this case study aims to reveal the characteristics of the OLED valley project by analysing the knowledge flow of the local university's technological seeds and to consider some issues in regional innovation and development, focussing on high-technology-oriented innovation and development.

2. Theoretical Framework

In the field of economic geography, numerous scholars (Gibbons et al. 1994, Cooke 2002a, Asheim and Isaksen 2002) insist that a proximate relationship is important to generate knowledge. The mechanism of knowledge production is not an individual but a collaborative activity (Keeble et al. 1998). Furthermore, because institutional interactions require propinquity, the system of a knowledge-based economy is a highly localised matter (Malmberg and Power 2004, Maskell and Malmberg 1999). In addition, Porter (1990) states that the competitive advantage of a nation's industries is determined by co-location or geographical proximity, which assists cross-firm interactions, spill over and synergies; therefore, regional conditions are critical to competitiveness among industries.

Following arguments can be made on the importance of spatial proximity. First, spatial proximity is important from an economical viewpoint. As the distance among learning actors increases, the transportation cost increases and so does the communication cost because frequent contact between actors is required during learning (Porter 1990, Antonelli and Quéré, 2002).

The second reason is the merits of cumulative knowledge and spill over of knowledge in a region (Jaffe et al. 1993, Porter 1999, Maskell et al. 1998). Experts insist that knowledge is accumulated and diffused easily within an industrial agglomeration. Some empirical studies suggest the importance of propinquity of agents. For example, Almeida and Kogut (1997) insist that geographical proximity assisted knowledge transfer in their case study of Silicon valley. Moreover, Zucker and Darby (1996) reveal the propinquity between star scientists and venture firms, which

heavily contribute to the successful commercialisation of new knowledge.

Third, spatial proximity is important because of the differences in the nature of knowledge. Nonaka and Takeuchi (1995) argue that knowledge can be distinguished into two types, codified and tacit knowledge. Economic geographers reveal that non-codified knowledge or know-how can be hardly conveyed beyond space because of its embeddedness and stickiness (Maskell et al. 1998, Maskell and Malmgerg 1999).

The fourth reason is described by an argument about different types of communication. Informal communication such as buzz contributes enormously to knowledge creation and inspiration (Bathelt et al. 2004). Therefore, spatial proximity such as face-to-face communication is important in that it can create knowledge through informal communication.

Finally, spatial proximity is important from a sociological viewpoint. The importance of trust is highly emphasised in regional development because trust assists in building relationships (Saxsenian 1995, Morgan 1997, Maskell et al. 1998). Cooke and Morgan (1998) and Putnam (1993) also focus on the significance of trust as a social capital that is based on locality.

As shown above, there are various reasons for the importance of spatial proximity in learning for innovation. In addition, proximity as a concept can be categorised into several types. Torre and Gilly (2002) identify two types of proximity, geographical and organisational. Boschma (2005) classifies it into five types: geographical, organisational, institutional, social and cognitive proximity. Nooteboom (2000) suggests the concept of cognitive distance related to absorptive capacity. He points out the importance of cognition or understanding in novel innovation.

Furthermore, Torre and Rallet (2005) and Torre (2008) put forward another argument on the nature of proximity, i.e. temporal proximity. They insist that a short or medium period of contact, i.e. temporal proximity, contributes more effectively to the transfer of knowledge than long periods or permanent proximity. The temporal relationship has been discussed not only with regards to proximity among learners but also in terms of organisation. That is, project-based learning as temporal organisational learning has been focused on (Asheim 2002, Asheim and Gertler 2005, Grabher 2002, Rutten and Oerlenens 2009). Project-based temporal learning organisation has following merits: It is flexible, easy to organise and suitable to integrate various knowledge types. Hence, project-based temporal organisation is advantageous for innovation activities. Therefore, proximity is indispensable in a knowledge-based economy.

3. Yamagata OLED Valley Project

1) Industrial Structure of Yonezawa City in Yamagata Prefecture

The core promotion area of the Yamagata OLED valley project is in Yonezawa City, located 350 km north of Tokyo. This city has a population of about 97,000. It is categorized as a peripheral area, although electronics and machinery manufacturing industries agglomerate there. In the 1970s, the central and local governments developed an industrial park in this city, and then, large external companies constructed assembly plants there. One feature of this city's local economy is the branch plant economy, which is highly dependent on the assembly plants owned by external prefecture firms. The local economy has been suffering from the migration and closing of these plants because of the strength of the yen and the rising East Asian countries.

The industrial structure of Yonezawa City was vertical like Fordism, dominated by seven large external companies' plants until the 1980s. When the oil crisis or the strong yen made it difficult for local subcontractors to export, some of them began to cooperate in order to survive, forming a horizontal network. They began to exchange information, to study marketing and new technologies and to develop new products. We can see this inter-firm network in Yonezawa City today.

In addition, the engineering faculty of Yamagata University is located in the city Traditionally, it has positively contributed to university–industry collaboration. Thus, Yonezawa City is rich in resources: the agglomeration of firms, enterprise networks and the engineering faculty of Yamagata University. In short, it is a quite wealthy area with good infrastructure and social capital for the manufacturing industry.

Given these resources, the regional development policy of Yamagata Prefecture has aimed at endogenous and innovation-oriented development. The local authority planned to regenerate the local industry by using the university's technological seeds as an indigenous resource. OLED was selected because of a prominent scholar at the university and an affinity with the local industry, the electronics industry agglomeration.

2) Activities of the OLED Valley Project

In Yonezawa City, rich resources are associated with OLED: the first is star professor Kido, who was the first to develop a white OLED panel. The second is Tohoku Pioneer (TP), a manufacturing subsidiary of Pioneer, which was the first company to successfully commercialize the OLED display panel in 1996. The third is the agglomeration of electronics and machinery industries.

The local authority has intended to implement endogenous development utilizing these indigenous resources, which has a comparative advantage. The OLED valley project began in 2002. Its intention was to transfer the university's advanced technology to local firms in order to create a new industry in the region. The main feature of the project was to establish the specific research and development (R&D) centre of OLED, Research Institute for Organic Electronics (RIOE) where was established in a closedown factory. The local authority invested 4.3 billion yen (approximately 373 million Euro) in the project over the course of seven years. Many advanced R&D programmes, which aimed to commercialise the OLED light panel, were conducted. The new R&D centre brought new knowledge, and venture firms began to produce OLED light panels. In 2006, there were 16 participant enterprises in RIOE, of which 10 were non-local firms and 6 were local. Thus, despite the electronics and machinery industries agglomeration in the region, more than half of the RIOE participants were large non-local companies. RIOE patented 44 products in seven years. Of them, 16 were joint patents with 9 companies, of which 1 firm was local and 8 were non-local.

RIOE closed in 2010 because it had been established as a temporal R&D laboratory for seven years and was judged to have completed the R&D stage of the OLED light panel. Next, the local authority established a promotion centre for commercializing OLED as a succeeding agency of RIOE.

3) University–Industry Collaboration with a Star Professor

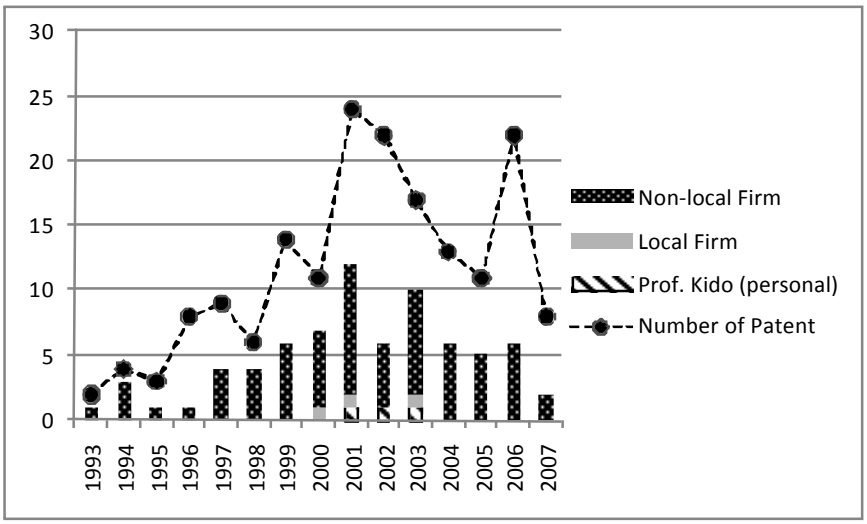
Professor Kido is a prominent scholar of OLED, who discovered the principle of white OLED device in 1993 and multi photon emission (MPE) OLED device in 2002. He is famous both domestically and internationally and was the former president of RIOE. Before the start of the OLED valley project, he carried out joint research R&D programmes with various firms, most of them being non-local ones. He has also been involved with several national R&D projects funded by the new energy and industrial technology development organisation (NEDO). Major partners of these national programmes were large non-local firms. To create a relationship between the professor and a company, the company first contacted the professor at a conference. Then, they started joint R&D programmes as a one-on-one relationship. In NEDO consortiums, the professor selected the member firms from among his related firms by judging the firm's R&D capability.

The professor has been strongly promoting joint R&D not only through RIOE but also through Yamagata University and national R&D consortiums such as NEDO. He has won several national

R&D projects and has simultaneously conducted several one-on-one joint R&D programmes. In general, fundamental R&D with chemicals has been carried out in the university lab, and the applied R&D related to process engineering has been conducted in RIOE. Because of the establishment of RIOE, various researchers from different companies started migrating to the city. Consequently, various element technologies—not only chemical material technologies (the professor's speciality) but also electric and manufacturing process engineering technologies—have been drawn in and integrated for commercialising OLED in the prefecture.

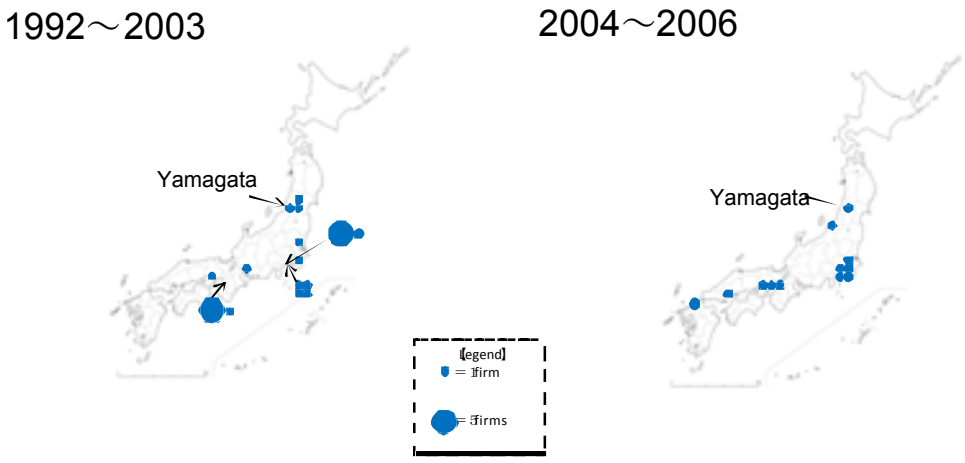
As a result of this joint R&D, Professor Kido has contributed to 161 patents in 15 years. Analysis of these patents by year shows that 2001 had the highest number, i.e. 24. In addition, the highest number of joint R&D partners was 11 in 2001 (Figure 1).

Figure 1: Transition of number of joint R&D firms with Prof. Kido



Source: Patent Office

Figure 2: Distribution of joint R&D firms with Prof. Kido



Source: Patent Office

Figure 2 shows distribution of partner firm of joint R&D with professor Kido. Before 2004, which was when RIOE began to bear fruits, the professor collaborated with 13 firms, of which 3 were local and 10 were non-local. After 2004, this number increased to 12, of which 1 was local and 11 were non-local. The establishment of the R&D centre has contributed less to local firms; rather, the joint research with the R&D centre avails R&D to large non-local firms.

Professor Kido has been recognized as a leading professor of OLED, strongly promoting university–industry collaboration. He has also gained funding for national projects. He is considered to be the hub of OLED R&D and has built up networks domestically as well as internationally. In 2008, the venture firm Lumiotec, which was financed by four large non-local firms and the professor, was established in the region. Thus, Professor Kido has significantly contributed to the creation of the OLED valley.

4. Technological Innovation and Regional Development

1) Characteristics of Regional Innovation

The OLED valley project has been carried out through collaboration among the university, the industry and government agents (Etzkowitz and Leydesdorff 1997). State-of-the-art R&D programmes have been conducted in Yonezawa City. Although the OLED valley project has mainly been promoted by local authorities, the R&D projects have been funded by both local authorities and the central government. The valley is constituted by both local and non-local resources such as

knowledge, human capital and finance. However, although some local firms participated in the R&D in RIOE, most of the patents were obtained by large non-local firms. The local university's resources contributed to fostering regional innovation; however, the state-of-the-art technology has been mainly transferred to large non-local firms. Large non-local firms, rather than local ones, have made great contributions to the R&D.

As seen in other characteristics of regional innovation initiatives, to create considerable new knowledge, which is a key element of the technology, various project-based joint R&Ds have been conducted. Many cooperate researchers come together in Yonezawa City. One-on-one collaborations between the professor and different companies or national consortiums have been conducted. Furthermore, for commercialisation of OLED, these various knowledge needed to be integrated. We might say that the valley project has been constructed with collecting various project-based joint R&Ds. For successful commercialisation of OLED, these project-based joint R&Ds have been sequentially connected, like a chain, according to phases. These knowledge chains are extended within and beyond the territory.

In addition, entrepreneurship in the area was very low. Only two venture firms were established as a result of the project. Lumiotec, which is one of the venture firms related with the project, decided to start small-scale production in its existing factory in the city. However, the company has not decided where or whether it will construct a mass production plant. The future regional development heavily depends on this decision.

Considering these situations, we cannot state that the project has succeeded in endogenous development (which would mean that local firms had converted into a high-technology, knowledge-intensive industry), despite utilizing the local university's technological seeds as an indigenous resource. Rather, we might say that one characteristic of the project is the indigenisation of the external capital. This indicates how much the venture firm that was established by non-local firms, invests in the local industry, and to what extent the venture established by external firms is involved with local firms.

2) Some issues of Innovation Activities

There are some issues of innovation activities in the case of Yamagata Prefecture. The first is weak spill over. Because there are many confidential matters in the joint R&D contracts between companies and the university, companies should protect their knowledge so that it is not leaked

around the area. In addition, the R&D capacity of local firms is also problematic. Because many branch plants are assembly facilities, they do not have R&D functions in their factories. Moreover, most local SMEs are subcontractors that are too small to largely invest in R&D for long periods. Furthermore, although these subcontractors have built a local horizontal network for mutual studies, their learning was catch-up-based; it was not state-of-the-art-based learning. Under these circumstances, it is not easy to transfer new knowledge to local companies.

The second issue is the difficulty of embeddedness of new knowledge in the local industry. Although the technological seeds of the local university are presumed to be an indigenous resource of the region, a characteristic of high-technology seeds is that they are footloose. The more prominent the technology is, the wider it becomes known. Although the project considered the local university's technological seeds as indigenous resources, as the reputation of the professor owing to these technology seeds has been growing, the technology seeds can no longer be held in possession by the region. Moreover, many of the participants in the joint research were non-local companies, and the relationships between the university and the companies were temporal and project-based. Therefore, it is difficult to retain high-technology seeds in the region.

Moreover, TP did not become an anchor company of the cluster It was a participant in RIOE but was only an inactive part of the project, because it was afraid of leaking its own advanced technology by participating in joint R&D. And, there was a technological mismatch between TP and RIOE (and Professor Kido). Although both parties had carried out OLED research, TP produced the OLED display panel; in contrast, the project aimed to develop the OLED light panel. At the beginning of the valley project, the local government intentionally selected OLED light panel to develop rather than display panel, because if the local government would aim commercialisation of OLED display panel, innovator might be involved in sever capital investment competition against East Asia counties, and such a less favoured region have no chance of winning. In addition, TP is an assembly plant of Pioneer, which has been concerned with process engineering. In contrast, Professor Kido specializes in chemical-based OLED materials. Moreover, the R&D centre of Pioneer is not located in Yamagata Prefecture but in Saitama Prefecture near Tokyo. There is no propinquity between them. Thus, Pioneer has constructed relationships with other universities rather than with Yamagata University in the field of OLED display panel R&D because of the geographical difference between them. However, in 2010, Pioneer obtained business cooperation with Mitsubishi Chemical Corp., which was a member of RIOE, in order to develop the OLED light panel. TP's

plant in Yonezawa City might become a trigger of OLED valley by using its facility.

3) Myths of Regional Innovation

Considering these issues, we can see some myths of regional innovation. First, many scholars say that spatial proximity is an important condition for regional innovation (for example, Asheim and Gertler 2005, Cooke 2002). However, spatial proximity does not guarantee technology transfer, especially under the advanced technology R&D. Large non-local firms tend to more masterly build relationships with universities than with local SMEs. They can tactically search new promising knowledge because of their cognitive capacity. To create relationships between companies and universities, not only trust but also finances are indispensable. Large firms are more affordable than SMEs. Thus, in the R&D of advanced technology, spatial proximity is less crucial for creating new knowledge (Boshma 2005).

As related with spatial proximity, there are several contradictions with the literature: First, as mentioned before, it is difficult to spill over within a region in the case of high-technology innovation. Participant firms are careful not to leak the state-of–the-art knowledge as a confidential matter. In addition, with regards to the argument on trust, joint R&D is conducted with contracts, which means that its relationship can be constructed without regional trust which is fermented locally. In other words, public trust, which is fermented by popularity including the factors of publicity of large companies, is probably superior to regional trust. Regarding the speed of establishing relationships, if both university and company are unknown to each other at the beginning, the period of establishing a relationship by regional trust takes likely longer than that by public trust. In addition, even if trust can be brought out in a region, large amounts of investment are required to construct relationships in R&D. Hence, trust-based spatial proximity is not a sufficient condition to create regional innovation.

In terms of transaction cost, firms, especially large firms, can pay any cost to accomplish innovation. Cost as a concept is not an absolute value but a relative one. This means that the value of payment, even the same price, is different for large companies and SMEs. Knowledge for innovation cannot be substituted as goods. Firms, in particular large firms, should construct a relationship with the best partner even if the transaction cost is greater than that with a local partner.

Given these conditions, although spatial proximity does not always assist innovation, we cannot deny its importance. Spatial proximity can facilitate innovation in a project-based R&D.

Time-limited and incessant proximity contact is required in project-based joint R&D, and it cannot be conducted without spatial proximity. The problem is that temporal proximity creates knowledge to such an extent that it is hard to be involved with locality. The goal ofregional innovation is not to complete knowledge creation but to construct a new industry. Hence, temporal entities should be embedded into the region in order to reap the benefits of regional innovation.

The second myth is that regional innovation seems to be created among the local network as a system (Cooke et al. 2004, Etzkowitz and Leydesdorff 1997). However, innovators, especially those involved in high-technology innovation, must connect with the very best partner anywhere rather than the second best in the same region. Therefore, innovators tend to build relationships with external partners because it is difficult to find specialized research partners in the same region. Especially, in a peripheral area, there are few resources for technological innovation. If innovation activities adjust the potential of the existing local stakeholders, regional innovation will become trivial. It might be better to stretch the network beyond locality rather than sticking to local relationships.

Third, it is said that regional innovation contributes to develop or regenerate the regional economy. However, regional innovation does not always directly lead to regional economic growth such as increasing employment or tax revenue because the merits of regional innovation easily move beyond the territory. Many studies related to regional innovation have so far focussed on regional agents as a system; however, we have to consider that innovation activities are carried out in a project-based temporal organisation. This means that many firms co-locate not permanently but temporally in the same region. Although many R&D researchers migrate to the region, they are time-limited single movers leaving their families in their hometown. Moreover, even if new knowledge or products are developed in a region, it is not guaranteed that the new product will be manufactured in the same region. Hence, knowledge creation is not a sufficient condition for regional economic development. In other words, regional innovation does not always bring out regional clusters. To benefit from innovation within the region, innovation must be converted into profit system in the region.

5. Conclusion

The OLED valley project has produced various positive results such as patents and venture firms. Large non-local firms, more so than local ones, have contributed to regional innovation. One of the

venture firms has started producing the OLED light panel. The success of the project depends on the decision of whether the investment of the venture firm should be in the region. In other words, regional innovation in Yamagata Prefecture depends on the indigenisation ofexternal resources.

As stated before, spatial proximity does not guarantee successful innovation, and the region faces difficulty in handling the regional innovation. The problem is territoriality of innovation. Thus, the OLED valley is still vulnerable. Moreover, although innovation has been facilitated in the region, it has not been enough to contribute to the growth of the regional economy.

Some implications for reviving the regional economy arise from the study: recent technological innovation initiatives have tended to place too much emphasis on the importance of knowledge creation. New knowledge alone cannot bring economic growth to a region. Business as well as technology development is indispensable to the maturation of innovation.

Moreover, the study discloses the importance of external factors for regional innovation. In regional renewal through high-technology innovation, it is best not to stick to endogenous development. Moreover, if regional innovation initiatives are carried out solely among the existing stakeholders, the influences of innovation become stunted. It is necessary to draw upon external resources to accelerate regional innovation. To revive a stagnating regional economy and construct a competitive local advantage, the policy tends to prioritize the interests of the existing stakeholders so far. However, if so, it becomes more difficult to bring out innovation because of limited capacity in the region, or in other words, innovation will become trivial. External factors have double sides that mean it can contribute up-grading as well as hollowing out cluster. Therefore, we have to manage to manoeuvre non-local actor mixing into local actors. To revive the old economy, we must not only promote innovation activities using only local agents, but should also consider how non-local agents are involved rather than how local firms make outlived.

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