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(出版者 / Publisher)
法政大学比較経済研究所 / Institute of Comparative Economic Studies, Hosei University
(雑誌名 / Journal or Publication Title)
Journal of International Economic Studies
(巻 / Volume)
30
(開始ページ / Start Page)
13
(終了ページ / End Page)
26
(発行年 / Year)
2016-03
(URL)
https://doi.org/10.15002/00012842

Journal of International Economic Studies (2016), No.30, 13-26

Industrial Dynamics and Locational Adjustment: Implications for Agglomeration Economies from the Case of Flat Panel Displays in Japan

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Abstract

Viewed globally, the production sites for the flat panel display (FPD) industry are concentrated in Eastern Asia. In particular, more than 90% of panels were produced in Japan, Korea and Taiwan. Also, in Japan, the geographical concentration was remarkable as was shown by Sharp, which produced liquid crystal panels in Kameyama, and Panasonic's manufacture of plasma display panels (PDP) in Ibaraki and Amagasaki in the 2000s. Taking these facts and the significant changes in the modern economic environment as starting points in this paper, I study the conditions surrounding the location of FPD factories and the factors that affect such conditions from the viewpoint of spatial and organizational decision-making that seeks global advantage by focusing on technological cycles and facilities investment. From the example of one of the largest FPD manufacturers, Panasonic, I observe the progress of large-scale production and the shortening of the technological cycle, which suggests that the "thickness" of an industrial agglomeration is very important if a company wishes to maintain competitiveness.

Keywords**:** locational adjustment, industrial agglomeration, technological cycle, facility investment, flat panel display, Panasonic

JEL Classification**:** L63, N65, O30, R11

1. Introduction: Acceleration of Locational Adjustment

The electronics industry in Japan "decentralized" after World War II. Especially from the second half of the 1960s, the factories in the large-city areas were decentralized, and a number of labor-oriented productions and processes were moved to local areas where linkages were created with hierarchies and networks in which work was shared among factories with affiliated companies, cooperating companies and subcontractors that supplied the factories located close by (Kondo 2007). According to the Census of Manufacturers, the percentage of offices and employees of electrical equipment and apparatus manufacturers located in local areas[1] was 15.7% and 21.1% in 1955, respectively, and this increased to 50.6% and 59.4% in 2000. This trend extended overseas. The ratio of production outside Japan was raised from a few percent in the period before the 1980s to

[1] Local areas are defined here as the areas in Japan outside three large-city areas: the Tokyo capital area (including Saitama prefecture, Chiba prefecture, the Tokyo metropolis and Kanagawa prefecture), the Chukyo area (including Gifu prefecture, Aichi prefecture and Mie prefecture) and the Hanshin area (including Kyoto prefecture, Osaka prefecture and Hyogo prefecture).

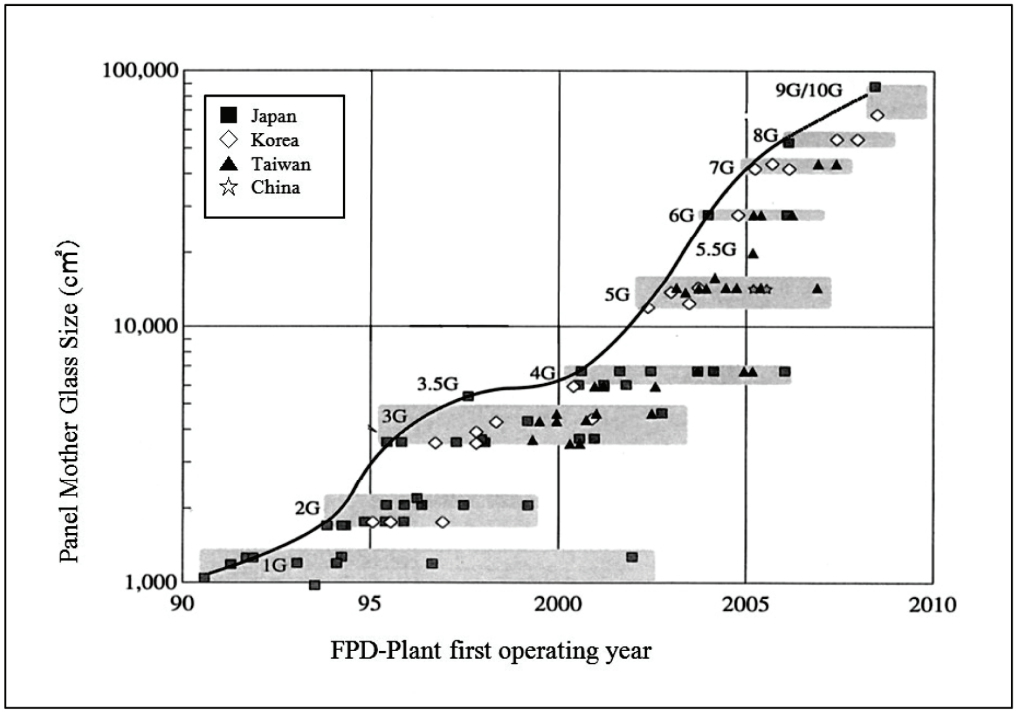
21.9% in 2000. This shows that, while the electronics industry was growing, companies moved their factories from Japan abroad.

This locational adjustment in the electronics industry has accelerated during the last dozen years or so. Due to a relative increase in production costs in Japan because of the yen's appreciation, together with the strategic participation in overseas markets after the 1990s, businesses restructured. Local production linkages were weakened because of the consolidation of domestic production sites and the development of international procurement. As a result, there was a temporary "hollowing out" in Japan. Since the 2000s, production has been "coming back to the country" because of the reinstatement of "monozukuri" (craftsmanship). Thus, changing locations has continued in the wider area that includes Japan and NE Asia.

There are rapid changes in the economic environment in the background that accompany these increasingly rapid changes in factory sites. First of all, globalization and being borderless have become part of the new economic environment. Not only the final product but also information, finance, human resources and raw and intermediate materials have become very mobile. The barrier of national borders has been lowered. Second, the technologies in the products have evolved. Concerning information technology and digitalization, it is said that electronic device technologies have become deeper and more complex, and that, as a result, the cost of research & development and facilities investment have sharply increased. In parallel, the interaction among production systems has become complex. Strategic coordination within a corporate organization and among firms has become important, requiring a review of the "boundaries of the firm", which concerns questions about which processes should be performed by the firm itself and which should be outsourced (Sako, 2006). Third, international competition has become fierce. While manufacturers in Korea and Taiwan have matured and the Chinese market has been developing more fully, Eastern Asia, including Japan, has become one of the biggest production sites in the global electronics industry and competition in this area has become increasingly severe. In this rapid change in the economic environment, relocation and locational adjustment have been developed in the whole of Asia, including Japan, and investment in factories in Japan has grown. In particular, domestic locations have been redefined as sites for the manufacture of high value-added products, therefore large-scale investment of more than 100 billion yen has continually been spent in such sectors as semi-conductors, flat panel displays and high-tech products. One of the reasons for the large-scale investment in production is to make the production site a "black box" inside a business model of vertical integration. This helps to prevent a leak of technologies outside the firm. In addition, recent large investment has been characterized by the fact that it has been carried out continually in specific production sites. For example, in the semi-conductor sector, a total of more than 500 billion yen has been invested in Toshiba's Yokkaichi plant since 2003. More than 600 billion yen has been invested in Hiroshima Elpida, which is Japan's only plant for DRAM memory chips. As for liquid crystal panels, the investment in IPS Alpha Technology, which is owned by Sharp, Hitachi, etc., and in Fujifilm's production of polarizing filter panel protection films has amounted to approximately 100 billion yen. These examples indicate that large-scale investment has come to areas devoted to materials and parts for "digital domestic appliances".

In this paper, I will take as an example the historical development of the flat panel display (FPD) industry against the background of the rapid changes in the economic environment mentioned above, and I will also study the structural factors behind the recent large-scale investment. We will specifically look at Panasonic's television production. Recently, technological innovation has been developed for television sets, and, in parallel with widespread high-vision broadcasting and digital broadcasting, televisions are undergoing a transition from CRT (Cathode Ray Tube), so-called "brown tube TV" models, to FPD (flat panel display), so-called "thin-type

TVs". FPD TVs, depending on the different image display devices that they adopt, consist of LCD (liquid crystal display) TVs, PDP (plasma display panel) TVs and rear-projection TVs. There is a large market for FPD TVs which lie in the category of "digital domestic appliances", this market has been growing globally. Therefore, production locational adjustment has accelerated by concentrating management resources and by investing strategically in facilities (Figure 1). In this paper, I will take up the process involved in the changes in Panasonic's TV products, and I will study the direction of the changes in the company's production sites from the viewpoint of technological cycles and facilities investment. Finally, based on these two examples of FPD, I will consider the relation between the locational adjustment and the resulting industrial agglomeration as well as the new trend in the rationale behind the choice of the factory sites.



Source: FPD Data Book by Electronic Journal, Inc.

Figure 1. FPD plant investment and technological development

2. The Case Study of Panasonic: Shifting from the CRT TV business to the PDP business

Panasonic's TV business started its full-scale operation in 1953, and it developed into one of Panasonic's core businesses. Looking at the change in Panasonic's mode of production in Japan, until the first half of the era of Japan's rapid economic growth, the main factories were located in Ibaraki and Moriguchi in Osaka. Factories were established in Fujisawa in Kanagawa in 1963 for the assembly of CRTs for black and white TVs and in Utsunomiya in Tochigi in 1967 for the assembly of color TVs. Thus, the production sites were diversified along with the expansion in demand for these products. In the middle of the 1970s, most TV production shifted from black and white to color, and after the restructuring of the business organization of TVs for export and black

and white TVs, the production since the late 1970s of color CRT TVs was carried out mainly in the Ibaraki plant in Osaka and the Utsunomiya plant in Tochigi. Outside Japan, factories were established in Mexico for the North American market and in Malaysia for the Asian market. Thus, international specialization was formed in such a way that new products were developed in Japan, and the production of matured products was transferred abroad. This constitutes the so-called "linear-model" type of production cycle. The production of color CRT TVs reached its peak in the mid-1980s, and the number of CRT TVs produced by Panasonic exceeded 10 million units.

Production in Japan decreased in the late 1980s since the market in Japan was saturated and competition with foreign manufacturers' products became fierce. Although domestic production specialized in high added-value products, such as flat CRT TVs, in the 1990s, production had to be restructured because it was less competitive in cost terms. Indeed, the entire group of Panasonic companies faced a management crisis between the late 1990s and early 2000s, and drastic management reform was conducted after the president of Panasonic, Yoichi Morishita, replaced Kunio Nakamura.[2] The TV business was then substantially restructured, and most products changed from being CRT TVs to PDP (plasma display panel) TVs.

After the second half of the 1990s, Panasonic restructured its TV business through the establishment of new businesses, the reduction of its CRT TV business and a substantial shift to the PDP business. The PDP business in Japan actually started in 1994 when the "Joint Development Committee of Plasma Display Panels for High-Vision Broadcasting"[3] was established. Panasonic kicked off its PDP business unit in 1998, when its competitors, i.e. Fujitsu, NEC and Hitachi, had entered into mass-production. Panasonic was the fourth participant in the PDP market in Japan. It was thus required to make a large investment to catch up with its advanced competitors. Panasonic established its PDP manufacturing subsidiary, "Matsushita Plasma Display Panel Company Ltd.", in July 2000, and it formed a coalition with Toray in October 2000, which resulted in the establishment of "Matsushita PDP Company Ltd." (MPDP) with 1.2 billion yen in capital (75% owned by Panasonic and 25% owned by Toray). The separate entity, engaging in the production of PDP and co-funded with Toray, was motivated by the goal to diversify investment risk and adopt a business model of vertical integration.

In the meantime, Panasonic invested continually in the liquid crystal panel business throughout the 1990s as well as in PDP, both of which were considered post-CRT products. However, as the decision to concentrate on "core competence" was made, the CRT business and the LCD business were restructured, and the PDP business was chosen for the concentrated investment in management resources. It was decided to sell the LCD business to Toshiba in 2002, which resulted in the formation of a manufacturing subsidiary, "Toshiba Matsushita Display Technology Co., Ltd.", which was 60% owned by Toshiba and 40% owned by Panasonic. At the end of October 2004, Hitachi took the initiative in establishing a production company for LCD panels for TVs by setting up "IPS Alpha Technology, Ltd.",[4] which was a joint investment with Toshiba and Panasonic. Thus, Panasonic's LCD business was restructured in such a way as to transfer its businesses to entities that were operated jointly with other companies. Its CRT business was also restructured and became a joint-venture with Toshiba, "Matsushita Toshiba Picture Display Co. Ltd.", established in 2003,

[2] In particular, the restructuring of business organizations involved the abolition of business units which were reorganized into 14 business domains, together with the delisting of subsidiary companies, which were merged into their parent company.

[3] This committee was established under the leadership of NHK for the purpose of commercializing PDP television receivers with 40 inch displays and developing PDP television receivers with 50 inch displays. 27 companies, institutions and associations participated.

[4] About 110 billion yen was invested in the Mobara plant in Chiba-prefecture in May 2006, which started operation with a production capacity of 1.6 million panels a year (32 inch panels) using the sixth generation glass base plate (with a size of 1,500 millimeters by 1,850 millimeters). The production capacity was increased to 2.5 million pieces per annum (32 inch panels) in April 2007.

which is a joint venture responsible for the development, production and sale of CRTs on a global basis.[5] As can be seen above, Panasonic reduced the importance of its CRT and LCD businesses through its alliance with other companies, and reformed its structure. This allowed it to invest intensively in its PDP business.

In this process of shifting to the PDP business, how was locational adjustment handled? According to Watts (1987), locational adjustment is defined as the process in which two or more production companies restructure their production facilities. It consists of the following phases: the establishment of a factory, adjustment within the factory (in situ adjustment), the closure of the factory, etc. If we regard locational adjustment and the restructuring of the TV business with reference to these phases, the factories of CRTs and TV parts were first closed. Panasonic's CRT production was carried out in the Takatsuki Utsunomiya (Hiraide) plants, both of which were located close to the final assembly factories in Ibaraki and Utsunomiya. The Utsunomiya plant was closed in August 2003 and the Takatsuki plant was reduced to being part of a trial production line, while its mass-production line was transferred overseas in September 2004. Along with these changes, many suppliers producing peripheral parts for CRT closed their domestic factories and transferred their production outside Japan.

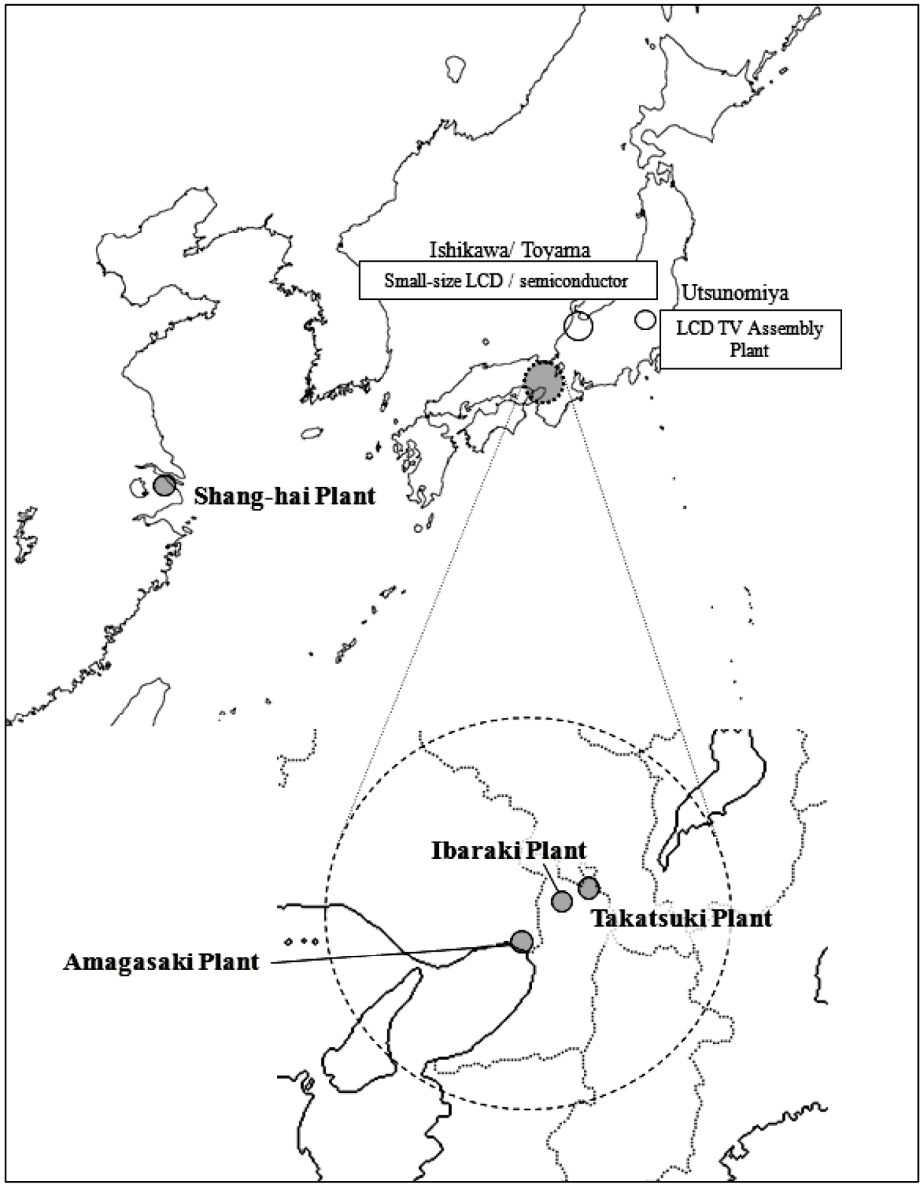
The next phase consists of changes within the existing factories. Here, the production facilities for CRT TVs changed into those for FPD panels. When the PDP business started in 1998, the only production facility for PDP was the trial production line in the Takatsuki plant. The First Factory was constructed in Ibaraki in June 2001, and full-scale production facilities for PDPs were launched in the Takatsuki and Ibaraki plants. The Second Factory in the Ibaraki plant started operation in April 2004. It was constructed in the empty space left after the production facilities for CRTs were removed. As for the relocation of the employees, about 700 employees were transferred from the parent company to the manufacturing subsidiary, "Matsushita Plasma Display Co., Ltd." when the latter was established. 700 employees was nearly equivalent to the total number of the subsidiary. The relocation of factory employees also proceeded in each of the other factories. In the development groups, about 400 employees at the Takatsuki plant were transferred to the Second Factory of the Ibaraki plant in 2004. In addition, the development groups, which had been divided into the Ibaraki plant for TV production and the Kadoma plant for the production of other AV products, were concentrated in the Kadoma plant, to which about 1,500 engineers in charge of the development of TV products were transferred. In other areas, the Utsunomiya plant, which had been the biggest domestic production site for CRT TVs, was transformed into the assembly base for LCD TVs,[6] and the Ishikawa plant, which had been the production base for LCD panels, was merged into the joint-venture company with Toshiba and it then specialized in the production of small to medium-size LCD panels. Thus, the adjustment of production resources was completed through the utilization of existing factories.

Finally, along with the transformation of the existing factories, new factories were established with a large investment. In the production of FPD panels, many types of alliance and cooperation and M & A were carried out among the companies. This may prove that specific image display devices require a huge investment. The factories established for the production of such devices are very big, and this requires such a large investment that it may affect the management of the company. As for Panasonic's factories, for PDP production, there are two factories in Takatsuki and Ibaraki, which reorganized their production facilities. In addition, the Shanghai Plant (2002), the

[5] At the end of March 2007, Panasonic bought all Toshiba's shares MTPD (35.5%), which made the company a wholly owned subsidiary of Panasonic. The corporate name was changed to "MT Picture Display Co., Ltd." It has capital of 10 billion yen and the employees of group companies number 9,077 (as of the end of 2006).

[6] While Panasonic sells LCD TVs, most of the LCD panels for the TVs are outsourced.

Third Factory (2005) and the Fourth Factory at the Amagasaki Plant (2007) were newly established in the years indicated. As a result, the production sites for panels in Panasonic's PDP business are, as seen in Figure 2, at four locations in Japan and one overseas. Viewed globally, panel production is concentrated in Japan and Shanghai, from which panels are exported to each of the factories near the market of final consumption. Assembly factories to complete the TV sets are located in Mexico for the North American market, Brazil for the South American market, the Czech Republic for the European market and Singapore for South East Asia and South Asia.



Source: Panasonic corporate profile

Figure 2. Panasonic PDP plant location in 2008

3. Industry Characteristics for PDP and their Production System

Along with the change from CRT to FPD, the characteristics of the TV (display) industry have changed significantly.[7] First, the industry has changed in terms of its product cycle. A product's life is very short, competition is fierce and the unit price of the product falls in a short period of time. The price per unit area of FPD panels for TVs has fallen about 25% every year since 2003. The company can secure a profit if it successfully launches products when there is an active demand for them. If the company loses out on the timing, it cannot earn sufficient money. As the pioneer has a bigger advantage (i.e. the first movers' advantage), it is very important to respond quickly to changes in market conditions. Investment needs to be more and more efficient, assuming that the same amount of money is invested, if the company starts production earlier. As each product has a short life cycle, it is not easy to differentiate one's own products from those of one's competitors and this tends to lead to severe price competition (Ogasawara and Matsumoto, 2006).

Second, there is a technical issue. As the production of CRT TVs consisted mainly of the assembly of parts and units, the production process was "visible".[8] The process of producing PDPs and LCDs is more invisible. In particular, the panel production process takes place in a clean room, which requires knowledge in the "device" field so that the yield ratio and the profit volume ratio can be assessed.[9] In addition, as the ratio of the panel components prices to the manufacturing cost is high, the source of added-value depends largely on the costs of the glass panel and the image processing circuit. Thus, the development of electronic parts, such as panel materials and semi-conductors and the management of procurement bear a considerable weight in the production system.

Third, there was a change in the competitive environment. Large-size FPD TVs, which were first commercialized by Sharp in 1999, have become popular internationally since 2002, and the number shipped exceeded that of CRT TVs in 2005. Until the late 1990s, the mainstream consisted of small and medium LCDs, which were only manufactured by Japanese companies. For the last few years, during which the market for FPD TVs has significantly expanded, producers in Korea and Taiwan have invested heavily, and Japanese manufacturers' relative market share in FPD panels on a shipment basis has gone down rapidly (see Figure 3). Also, there tends to be an oversupply in the market for FPD TVs not only because the companies in these three Asian countries are seriously competing with each other while Korean companies, such as Samsung Electronics and LG Electronics, and Taiwanese producers are becoming more powerful, but also because the different image display devices, such as LCD panels, PDPs and rear-projection systems are also in competition. Therefore, although the market has achieved real growth, the prices of the products are falling and profitability is rapidly declining except for a few of the top producers. In order for the manufacturers of FPD TVs to increase their profitability, a company has to achieve economies of scale to reduce procurement costs and gain enough financial strength to continue with its heavy investment in its facilities.

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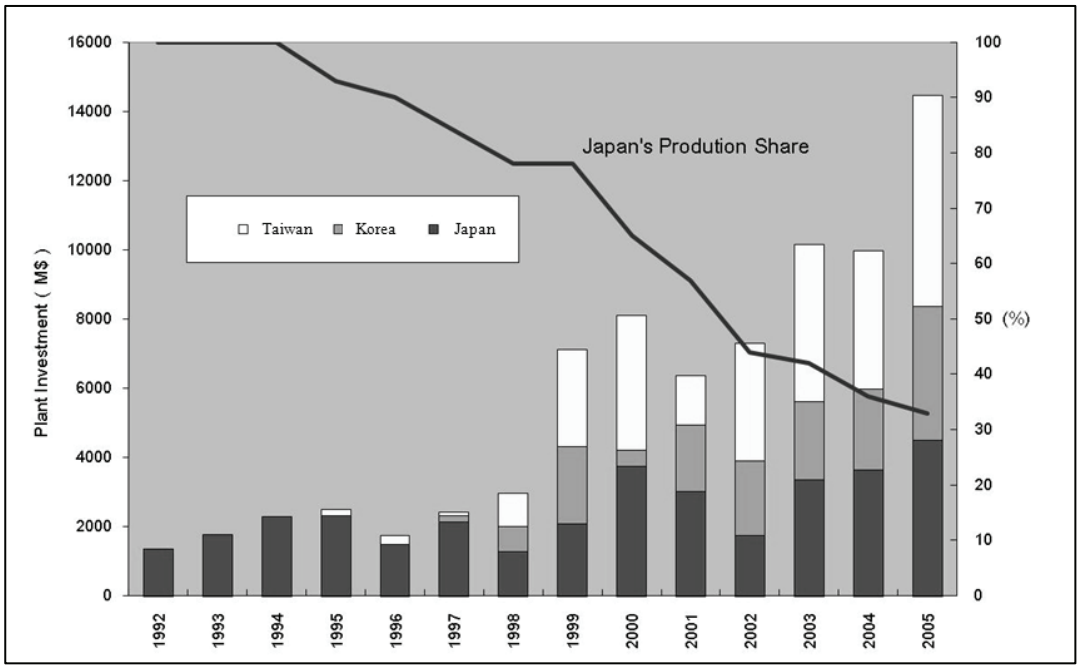
[7] Murtha, Lenway and Hart (2004) provides an overview of the history of the FPD industry from the beginning to the substantially developed phase.

[8] Hiramoto (1994) discusses the details of the manufacturing process and production system of CRT TVs.

[9] Mr. Ken Morita, who became Head of PDP business in 2000, is a specialist in the "semiconductor" field. His last position was Head of IC business at the Semiconductor Company, Matsushita Electric Industrial Co., Ltd. The fact that a person who was previously in the semiconductor business is assigned to be a leader in the PDP business proves that the TV business requires knowledge and know-how of the "devices" involved.



Source: Author's collected data

Figure 3. FPD plant investment in East Asian countries

After shifting its TV business to PDP, Panasonic divided its products into two categories, PDP with more than a 37 inch display and LCD with less than a 32 inch display.[10] Although all LCD panels of less than 32 inches were purchased from the Korean or Taiwanese manufacturers, the panels made in Japan have been partly used after IPS Alpha Technology's Mobara plant started full-scale operation. All Panasonic TVs over 37 inch have the PDP system. The business model for PDP is called "vertical integration." It has the production of panels and image processing circuits, which are the source of added-value, in a "black box" and actively increases the internalization of panel parts and related resources.

One characteristic of PDP's technology is that PDPs are not as dependent on manufacturing equipment as semi-conductors and LCD panels. Analog techniques form the core of the technology, such as know-how about calcination in the manufacturing process and the design of the circuit boards. Panasonic has two unique technologies. One is the production process developed by Toray with "small rooms" with fluorescent devices that are formed on a glass base plate in a reticular pattern by means of a photosensitive paste system that mainly perform the functions of exposure and development. This system is more productive than the sandblasting system that is generally adopted in the industry. The other technology is the design of the circuit drive. TV systems incorporate an image quality circuit (which is relevant to image quality) and a circuit drive as well as many peripheral parts, such as decoders, graphics circuits, demodulating circuits, modems, and interfaces. The parts relating to the image quality are crucial for differentiating one's products from

[10] Panasonic has started selling LCD TVs with more than 37 inch displays since the first half of 2007. LCD panels are outsourced from a Taiwanese manufacturer. The fact that PDP TVs and LCD TVs, both of which have 37 inch displays, are sold by Panasonic indicates that the competition among the different image display devices mentioned above has become fiercer.

other brands as consumers require high quality images from high-end TVs. Panasonic has developed the universal platform system LSI called "Uniphier", which provides a common circuit design with the system LSIs used in digital domestic appliances. This gives Panasonic a competitive advantage in the design of system LSI, through features such as an image quality circuit and the circuit drive.[11] Thus, Panasonic has adopted its strategy to differentiate its products through the integrated power of its panel technology and its image processing circuit technology as well as its vertical integration business model.

PDP's production system consists of the following processes: a rear panel process, in which electrodes and dielectrics are formed on a glass board, a front panel process, panel assembly and the final assembly. In the First Factory in Ibaraki, the first and second floors are allocated to the front panel process, there is a canteen on the third floor, the process of sealing the front panel and rear panel is performed on the fourth floor and the fifth floor is allocated to the set's assembly (after a driver LSI is affixed). The rear panel process is located separately in the Takatsuki plant, which thus has a share in the total process with Ibaraki.[12] The Shanghai plant, which is the only panel production site overseas, was constructed in October 2001, and it started operation in December 2001, copying the production line at the First Factory.[13] In the beginning, it imported panels from Japan and carried out assembly. In April 2003, it started to build facilities for panel production, then it started to manufacture and ship PDP in August 2003. The PDP business pushed locational adjustment toward a process that used existing factories and gradually developed a vertical integration model.

Integrated production began when the Second Plant in Ibaraki started. Cost reduction in PDP requires three elements: (1) standardized processes, (2) energy-saving, a reduction in materials and parts, and (3) improved productivity. As a precondition of these efforts, the crucial factor is the size of the glass base plate. The bigger the plate, the more panels you can take from it. In FPD production, the number of panels taken from the material is an important parameter because production costs can be halved if twice the number of panels are taken from one plate. For this reason, the factory building, the production facilities and so forth should be bigger to make larger glass base plates so that costs can be reduced.

Table 1 shows Panasonics' PDP production bases. In the production line of the First Factory at Ibaraki, only one panel can be taken from the glass base plate where 42 inch panels are concerned. In the Second Factory, three panels can be taken. Six panels can be taken in the Third Factory in Amagasaki, and the Fourth Factory, which started production in June 2007, can produce eight. The number of panels taken from one glass base plate is directly linked to productivity. As for investment productivity which is defined as the ratio of the number of panels produced in a factory to the amount of investment made in that factory, this amounts to 5.3 per invested amount for the Fourth Factory in Amagasaki if that of the First Factory is counted as 1 for the same investment. As a result, investment per factory has rapidly increased, and investment in the Fourth Factory in Amagasaki was boosted to about 180 billion yen. Furthermore, in the planned Fifth Factory in Amagasaki, which will be the world's largest PDP production base, about 280 billion yen will be

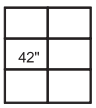
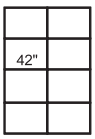
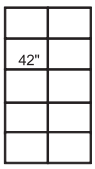
[11] The system LSI "PEAKS", which is a common engine of the products named "VIERA", is a concrete example of system LSI developed on the basis of Uniphier.

[12] Panasonic explains that the production was not integrated in one location at the First Factory because "it prioritizes early start-up and the utilization of existing facilities." (Panasonic's corporate materials)

[13] The corporate entity of Shanghai Plant was established in January 2001 as Shanghai Matsushita Plasma Display Co., Ltd. a joint venture by Panasonic, Shanghai Ko-Den Electronic Co., Ltd. (SVA), Shanghai Industry Investment (Group) Ltd. and Shanghai Ko-Den (Group) Ltd. It is designated as "the first project of domestic PDP production" by the National Development Committee of the Peoples Republic of China. Registered capital is 70 million dollars, 51% of which is held by Panasonic, 41.9% by Shanghai Ko-Den Electronic and the rest of about 8% being held by other investors.

invested. It will be an enormous plant, with a total floor size about nine times that of the First Factory.

Table 1. Panasonic PDP plants in Japan and China

	Ibaraki Plant		Amagasaki Plant			Shang-hai Plant
	No.1 fab	No.2	No.3	No.4	No.5	
Plant site size	122,000㎡		147,000㎡		?	47,000㎡
Plant building size	30,000㎡	75,000㎡	147,000㎡	192,000㎡	284,000㎡	17,000㎡
start year to operate	2001	2004	2005	2007	2009	2002
number of building floors	5th floors	4th floors	4th floors	6th floors	6th floors	-
Investment cost (million YEN)	35,000	60,000	95,000	180,000	280,000	20,000
Production Units per month	30,000	100,000	250,000	500,000	1,000,000?	25,000
Productivity for investment	1	2.4	4.3	5.3	-	1～1.5
Labor Productivity	1	2.3	4.2	-	-	-
Mother Glass Size (per 42 inch)	1	3	6	8	10	1
						

Source: IRC (2003, 2006) and author's data collected from interviews with companies

The total investment Panasonic made in its PDP business during the period between 2001, when it started making substantial investments, and the end of the first half of 2007 exceeded 700 billion yen. With its cumulative and continual facilities investment, Panasonic gained the world's top share in 2006 in terms of PDP TVs (as a complete set) and PDP panels.[14] This is the largest investment in a single product ever made by Matsushita Electric Industrial Co., Ltd., whose entire business focus has shifted significantly to PDPs. Sales in the PDP business are growing rapidly in proportion to facilities investment, and more than 20% of the company's total facilities' investment is devoted to the PDP business. However, a difficulty the company faces is the requirement to invest within the limit of the funds it has to hand, as cash-flow management is important for it to maintain its financial rating in the market. There may be a risk of excessive debt, if it fails to pay off its huge investment, and it may be exposed to the risk of a negative spiral in which its debts increase, its market rating declines, and its investment has to be reduced. Strategic action becomes more important for making decisions regarding both timing and which production systems should be invested in. As a result of the technological character mentioned above and the strategic investment in facilities, factory investment has become large-scale and concentrated.

[14] According to the "World's Market Share of 26 Items" for 2007 issued by the Nikkei financial newspaper, for PDP TVs, Panasonic has 29.5% of the total market share, LG Electronics (Korea) has 15.8% and Samsung Electronics (Korea) has 14.1%. As for PDP panels, Panasonic has 31.5%, LG Electronics (Korea) has 28.2% and Samsung SDI (Korea) has 22.1% (both market shares for PDP TVs and PDP panels are calculated on the basis of shipment value).

4. Concentrated Locations and Industrial Agglomeration

Regarded globally, the production sites of the FPD industry are concentrated in Eastern Asia. In particular, more than 90% of all panels are produced in Japan, Korea and Taiwan. While the production of cathode-ray tubes was diversified into the United States, Europe and Asia, the production of FPDs shows an excessive concentration in Eastern Asia. Therefore, there appears to be a sort of "phenomenon of market occupation by a specific winner (Winner-Takes-All)" in which the winner of the competition in Eastern Asia will be the winner in the global market. In the intensified competition in Eastern Asia, the management of cost reductions, the protection of intellectual properties[15] and speed have become important.

In this competitive environment, FPD panel manufacturers are trying to concentrate their locations for various reasons, such as the need to focus investment at the production site, proximity to their suppliers of components and related materials, preferential treatment under national or municipal policies (such as industrial parks), and the use of local resources. Examples are, for LCD panels, Sharp's Kameyama Factories, in which concentrated investment continues, and Samsung Electronics' factories in Cheonan and Tangjeong, and, for PDPs, Panasonic's Ibaraki and Amagasaki factories. To analyze the concentration of these locations, a cross-sectional view of geographical proximity and industrial clusters may be useful.[16]

If we look at the locational adjustment of Panasonic's PDP business, geographical proximity is one of the key points in the expansion of factories from Takatsuki and Ibaraki to Amagasaki. A similar example, which is very suggestive, is Intel, an American semiconductor manufacturer, which experiments with "co-location" (Sakakibara 2005: 152-154). Co-location means to conduct R&D and production in the same place. The semiconductor industry has a distinctive product cycle called the "silicon cycle". In this cycle, the frontrunner's benefit is larger if the product cycle becomes shorter, and the speed of technological transfer from the research group to the development and production bases and other production sites is of great importance. Co-location may accelerate both the establishment of the production process and the startup of mass-production, and improve yield ratios. Furthermore, Intel has successfully speeded up its startup of mass-production at a global level by using "copy exactly", a method where all processes developed and completed in the mass-production development facility, including the logistics systems, are copied exactly in other mass-production facilities (McDonald, 1998). These examples from Intel suggest that close information exchange and information sharing among each group in R&D and production have become more and more necessary in order to accelerate mass-production using "vertical startups" and cooperation among these groups. Like Intel's method that maximizes the merit of proximity, Panasonic is also successful in setting up mass-production smoothly in Takatsuki, Ibaraki and Amagasaki.[17]

Since material costs represent 40 to 65% of the total cost of an FPD panel, the proximity to the

[15] Although this report does not go into detail on intellectual property management, it should be pointed out that patent disputes over PDPs occur from time to time between the manufacturers of Japan, Korea and Taiwan, and that the importance of the protection of intellectual property is increasing. In Japan, the Advanced PDP Development Center Corporation (APDC) was established in July 2003 by the five Japanese PDP manufacturers (Panasonic, Hitachi, Pioneer, Fujitsu and NEC Plasma Display) for the purpose of engaging in the joint development of the fundamental technologies of the next generation of PDPs. Hitachi and Panasonic formed a comprehensive alliance in the PDP business in February 2005 by establishing the patent management company "Hitachi Plasma Patent Licensing Co., Ltd". Thus, Japan has been moving to strengthen the protection of intellectual property.

[16] According to Porter, an industrial cluster is defined as "the status of associated companies, suppliers, service providers, related institutions etc. in the specific sector being geographically concentrated and cooperating with each other while competing with each other." (Porter 1998)

[17] In the assembly process of the Ibaraki Factory, efforts are made to implement the cell production system under the direction of the Deputy Head of Production Innovation Headquarters who formerly worked for Toyota. The production system at the Ibaraki Factory is horizontally spread over Panasonic's other factories throughout the world. In this sense, the production system of the Ibaraki Factory is designated the "mother factory".

panel component manufacturers and the manufacturing equipment producers and the co-location of R&D and production are important. Cooperation with components manufacturers and equipment producers is indispensable for starting up mass-production quickly. Therefore, not only the engineers in Panasonic's R&D groups but also the engineers at the components manufacturers and the equipment producers work in Panasonic's PDP production factories. Furthermore, the different timing for the design of various elements in the production line, such as panels, which are designed in two-year cycles, semiconductors, which are newly designed every year, and the circuits and mechanisms of the equipment, which are designed afresh every six months, causes the engineers in charge of these elements to make frequent adjustments in the factory. So, the proximity of the location of these component manufacturers and the equipment producers is one of the requirements to increase the cumulative effect of gathering many engineers from different groups and companies in the factory.

Another reason for the increased importance of proximity is transportation. Along with the glass base plate becoming larger, the equipment, components and materials are all becoming bigger as well. So, the issue of transportation becomes serious. In this respect, the cluster brings advantages by gathering the equipment producers and component manufacturers near to the FPD panel production site. In the past, when the sites were spread out, labor costs were a more important condition for deciding on the sites, and transportation costs were not so important because they were reduced by the development of motorway networks. However, the production of most of the "digital domestic appliances", such as FPD TVs, exhibits all the characteristics of an "apparatus industry" requiring a huge amount of facilities investment. In such a situation, the weight of fixed costs becomes higher than variable costs such as labor costs. For this reason, as well as for the other reason of requiring close cooperation with the groups within the company and with the components and equipment manufacturers and their associated suppliers, the importance of transportation costs has come up again. As for Panasonic's PDP business, the industrial cluster in the Hanshin large-cities area where the factories of Takatsuki, Ibaraki and Amagasaki are located is a huge advantage for Panasonic, and the cluster that extends east and west in Osaka, Nara and Mie provides Sharp's LCD business with a large advantage.

5. Concluding Remarks

As a summary of this paper, the interrelation between locational adjustment and the industrial cluster is mentioned below. Recently, the issues of proximity and the cluster have been actively discussed, and industrial accumulation has renewed people's awareness of its role as a cradle of economic growth and innovation.[18] Its importance has also increased in view of the company's competition strategy and policy.[19] The discussions on industrial accumulation are broadly divided into two categories. One concerns the benefits of accumulation which help to reduce transportation

[18] In the context of economic geography, industrial agglomerations and industrial clusters have almost the same meaning. However, the concept of cluster involves a partly non-geographical concept. For example, competitive relations and conditions regarding the demands involved in the concept of the cluster are not necessarily geographical matters. As for industrial agglomerations, there is an enormous amount of research on this subject. As they involve many points of discussion, such as what the benefits of accumulation are, and how the accumulation effect can be measured, the geographical concentration of industry cannot simply be called agglomeration. Recognizing the abovementioned points, a more neutral concept of industrial agglomeration is used in this paper.

[19] Japan's regional policy, "Law concerning Regional Industrial Agglomeration and Activation," was implemented in 1997, and since 2001, the "Industrial Cluster Plan" has been developed by the Ministry of Economy, Trade and Industry as has the "Knowledge Cluster Project" by the Ministry of Education, Culture, Sports, Science and Technology. There are some reports, such as Ishikura 2003, that discuss the subject of policy comprehensively from the viewpoint of industrial clusters.

costs and transactional expenses, and improve the social infrastructure. For companies choosing their locations in industrial clusters, the benefits are connected to economies of scale or economies of scope. The other point of discussion about industry accumulation is the benefit from the viewpoint of "intellectual activities" such as R&D and technological development; the spillover brought about by the stock of knowledge as well as communication through face-to-face contact play an important role. The existence of external economies related to non-market interaction is also thought to be important.[20] In this light, it is suggested that in the PDP business the external economies are as important a factor as the conditions when it comes to enjoying economies of scale.

In the FPD industry, such as PDP or LCD, one feature is competition in facilities investment, and another is the concentration of knowledge and know-how. In traditional discussions on geographical proximity, the effect of reduced transportation costs and transactional expenses and the spillover effect of knowledge are identified. However, how to reinterpret the dynamism of locational adjustments from the viewpoint of proximity is still open to discussion. In the FPD industry, where the market is changing drastically, a variety of collaborations and alliances have become important so that companies can quickly recover their huge investment, therefore locational adjustments are developing in a dynamic way, too. From case studies of the PDP industry, the increasing importance of the "thickness" of the industrial cluster is observed as an environmental factor that enables the acceleration of locational adjustment and influences the maintenance and improvement of competitiveness.

Finally, I would like to mention a new trend in factory locations, which can be observed in FPD. It is worth noting that large-scale factories are located in bay areas, such as Panasonic's Amagasaki Plant and Sharp's Sakai Complex, which is to be built soon. Traditionally, in the bay areas, there were a lot of heavy industrial complexes, but the amount of unused land has increased. Land for industrial use in a bay area has a lot of advantages. For example, supply of electricity and gas is located in the vicinity, a logistics infrastructure, such as airports and seaports, is provided, and large areas can be secured. On the one hand, it is remarkable that in the production of leading-edge and technology-oriented products such as FPDs that is taken up in this report facilities investment has become significant and that the facilities have concentrated more and more in the main bases. Therefore, we may notice in the near future that factory locations will be concentrated in bay areas along with strengthened hub functions in logistics. In the domestic production of FPDs, the importance of the Hanshin Industrial Zone has been growing. This illustrates one aspect of the "panel bay".

Acknowledgement: This study was supported by JSPS KAKENHI Grant Numbers 21720308, 26284133

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[20] As for external economies being related to non-market interaction, Yamamoto (2005) organizes the subject in a comprehensive collection of relevant works. Mizuno (2005) also arranges the subject in the context of innovation and industrial agglomeration. Fujita and Thisse (2003) and others study the theory on the accumulation effect concerning intellectual activities. However, as Fujita and Thisse (2003) pointed out, there is substantial room for future study both in theory and facts to deal with the subject of the accumulation effect concerning intellectual activities.

2006, Issue 1, 72-79.

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