2E12 Intra-Firm Technology Spillovers Leveraging Co-Evolution between Digital Technologies and their Application to Global Warming Mitigation

—Toward Eco-Friendly Digital Business in a Service Oriented Economy

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1. Introduction

In the age of Information Technology with growing CO2 emission concerns, firms are under high pressure of global competition. This inevitably forces firms to a way to eco-friendly digital business in a service-oriented economy for their survival strategy. In fact, innovation through interaction with end-users in digital economy has achieved high in energy efficiency and pushed rather small firms into the top stage of the market. Typical examples are Cannon Inc. in digital camera and Sharp Corp. in liquid crystal display. Another noteworthy trend is a dramatic increase in Japan's photovoltaic cell (PV) production, which in 2004 amounted to a 50.4% share of the world market, which Sharp has taken grate lead to its competitors.

These observations suggest the hypothetical view that Sharp has succeeded in accomplishing a co-evolution between technologies for liquid crystal and PV by means of intra-firm technology spillover. Technology spillover is key factor to establish the "Virtuous Cycle" of R&D through direct and indirect information exchange (Watanabe (1999), Watanabe (2003)). This paper, on the basis of an empirical analysis of Sharp's PV technology development, demonstrates the firm-level technology spillover and its effect on innovation process.

2. Different Innovation Path Among Manufactures

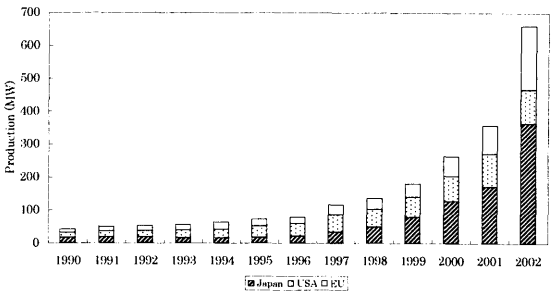


Figure 1 Solar Cell Production (*1990-2002*).

World's PV production recorded nearly 1,200MW in 2004 with dramatic increase in the late 1990's. This

coincidentally matches with Japanese sudden rise in the PV production, with the fact that now Japan is leading the world PV industry (fig. 1). Among the Japanese PV manufactures, it is outstanding that Sharp by sudden went ahead of all its competitors since 1999 (fig. 2).

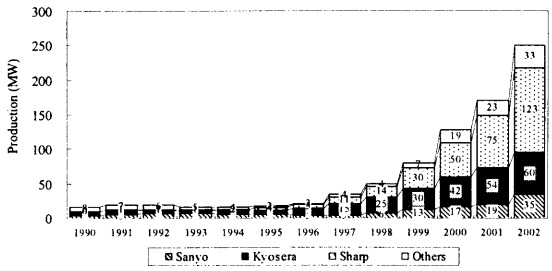


Figure 2 Solar Cell Production Share in Japan (*1990-2002*).

This sheer fact suggests the leading role of Sharp in Japanese PV production and, as a result, the leading role of Japanese PV manufactures influenced by Sharp in the world PV industry. With close look on the chronological trend in PV production share in Japan, interesting finding is the dramatic shift of the leading role among major players, which suggests the difference in each firm's innovation path and utilization rate of internal technology knowledge, in other words, the spillover effect (fig. 3).

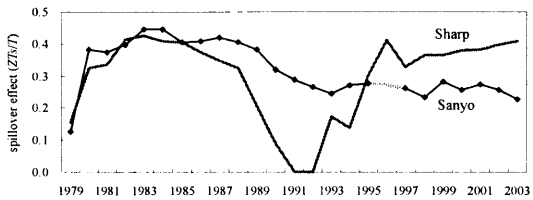


Figure 3 Technology spillover effect on total technology stock; Sharp and Sanyo (*1979-2003*).

3. Key Assumptions and Approach

From the observations on Japanese PV manufactures, key assumptions to explain Sharp's success in PV development in the late 1990's are set as follows.

(i) Sharp achieved a "virtuous cycle" of its entire operation, which enabled Sharp to increase in R&D spending. (See detailed logic of this concept in Watanabe et. Al. 2000)

(ii) Efficient PV R&D of Sharp resulted from experience sharing from liquid crystal technology R&D, which can be defined as inner-firm technology spillover.

To examine these assumptions, an empirical analysis is conducted by (a) showing typical performances asa consequence from the established "Virtuous Cycle" in Sharp's corporate data, and (b) demonstrating information flow between Liquid Crystal and PV in a form of researchers' shift in research topics.

Because of wide variety of research topics relating to Photovoltaics manufacturing and use, patent data in the category of the optical "thin-film formation" (F term of 5F051) is selected. Analysis on selected patent data is justified because it is well known fact that LC's thin-film formation technique is easily applicable to that for PV. Thus, the selection of patent data only eliminates insignificant data for the purpose of this paper.

Table 1 Classification of Thin-film by Function.

Function	Generic term of application
Electric& Electronic	Integrated Circuit
	Packaging
	Ultra Conductivity
Optic	Optical thin-film element
	Photoelectric transducer
	Optical memory element
Magnetic	Magnetic memory element

Sharp's patent data is obtained at Japanese patent database by selecting date from 1989 and by setting "F term" and "FI" as 5F051, H01L31/, respectively. For each researcher involved in the selected research topic, all the involved patent are collected regardless of the year of submission nor of technology category for obtaining complete collection of each researcher's activity. The year of patent data is set as the date of patent release.

4. Hypothesis Testing

4.1 Presence of a "virtuous cycle" for technology development

By observing the Sharp's

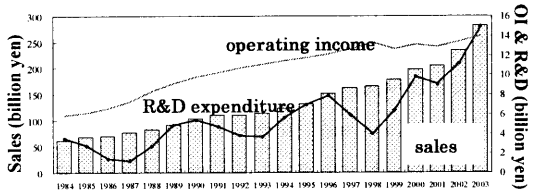


Figure 4 Trends in Sales, Operating Income and R&D Expenditure in Sharp (*1984-2003*): billion yen at 2000 fixed prices.

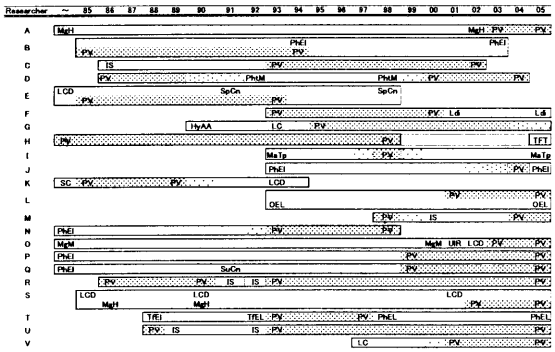
The "virtuous cycle" in Sharp's technology development as a whole can be confirmed by key figures from the 2004 Annual Report of Sharp and publicly available data. With increase trend in sales, decrease in R&D expenditure ratio to sales suggests the decrease trend in change rate of R&D expenditure itself. It implies the increase in R&D performance and efficiency, and eventually the decrease in cost of production. Notably, such evidence of the "virtuous cycle" can be seen just after the Liquid crystal display (LCD) hit the market.

4.2 Technology development strategy

In December 1998, Sharp developed clearer and stronger environmental strategy on its R&D activity, called "3G-1R (*Green Product, Green Factory, Green Mind, and Recycling*)." Under the Green Product strategy, high-energy-efficiency product and decreasing environmental impact from product use are the most prioritized concepts at the design stage. Thus, it led the increased production of PV for energy generation and LCD for less energy consumption are the two pillars in Sharp's production line.

4.3 Presence of inner-firm technology spillover

For examining the presence of technology spillover between Liquid Crystal and PV, it is the most appropriate to examine the chronological patent data of Sharp.

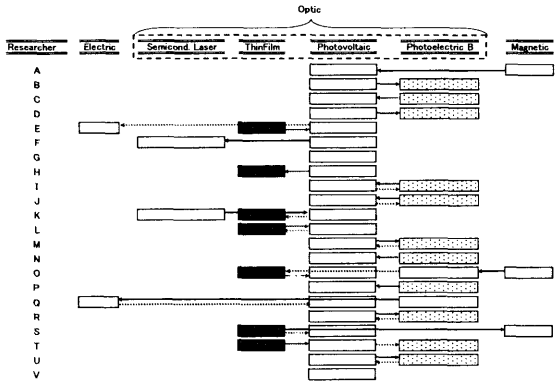


PV: photovoltaic, PhEl: photoelectrics, IS: Image sensor, PhtM: Photo-magnetics, LCD: Liquid crystal display, SpCon: Super conductive, Ldi, Lazar diode, HyAA: Hydrogen alloy, absorbing, SC: semiconductor, MaTp: Magnetopic disk, OEL: Organic EL, MgM: Magnetic memory, UlR: Ultrared ray, MgH: Magnetic head, TFT: thin-film transistor, TfEL: thin-film EL.

Figure 5 Sharp's Patent Applications Relating to Optical Thin-film Formation Topics Initiated by Researchers (*1985-2005*).

Figure 5 and 6 show the transitions of research topics of major researches from 1985 to 2005. Interestingly, all but two researchers (researcher G and V) have worked and stay in the area of thin-film technologies. In figure 6, the shift between PV and LCD are counted 7, whereas the shift between PV and other photoelectric

technologies ("Photoelectric B") are 11. Considering the technology distance, the similarity of technologies, it seems to be natural occurrence.



Solid line: first shift, Dotted line: second shift, Chain line: third shift

: shift between LCD and PV,

: shift between other photoelectric tech. and PV.

Figure 6 Chronological Trends in Sharp's Patent Applications Relating to Optical Thin-film Formation Topics Initiated by Researchers *(1985-2005)*.

5. Conclusion

From the empirical analysis, the "Virtuous Cycle" of Sharp as a whole corporation can be found, which differentiates Sharp from its Japanese competitors in both LCD and PV market. This provides Sharp with strong technology knowledge stock inside the organization. With further look on the Sharp's cooperate performance, it can be concluded that the establishment of the "Virtuous Cycle" is based on the LCD technology. this result suggests the presence of inter-firm knowledge spillover, generally presented as black-boxed mechanism, between LCD and PV.

The Sharp's patent data in PV technology, optical thin film formation, explicitly shows the evidence of intra-firm technology spillover between PV and LCD, and between PV and other photoelectronic technologies. This information flow can be confirmed as a form of researchers' shift in research topics. This is the clear evidence of inter-firm technology spillover through the direct contact of researchers and technologies, such as meetings, discussions, and products.

It is interesting findings to observe that the establishment of the "Virtuous Cycle" is in fact the result of conspicuous R&D strategy of Sharp with environmental consciousness. This is the grate encouragement to other firms to achieve successful and efficient R&D strategy in high competitive era of industry. Also, the excellence in Sharp's innovation strategy can be seen in the overlap among the different technology development in a form of amplified functions and strengthens Sharp's product line-up. Thus, Sharp's success story can be concluded as the multiplied application of similar technology through inter-firm spillover, which, again, is the grate hint to the others trying to establish better R&D performance in near future.

6. Reference

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