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Changes in the technology spillover structure due to economic paradigm shifts: A driver of the economic revival in Japan's material industry beyond the year 2000

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Abstract

Innovation is believed to be a driver of the economy in the 21st century. Above all, innovation in services and devices are essential to a post-information society. Importantly, materials continue to play a significant role in innovation, particularly in incorporating new functions in new devices. Now, Japan's economy is starting a significant recovery from the "lost decade". Therefore, it is an appropriate time to review and elucidate the dynamics of material innovation before, during and after this time in order to better understand the process of innovation throughout this economic paradigm shift. In the context of innovation and economic paradigm, compound semiconductor materials lend themselves to understanding the dynamics involved because they play a critical role in introducing new functions and subsequently innovation to information communication technology. In this paper, patent applications filed by Sumitomo Electric Industries, Ltd., the world's largest firm of compound semiconductor material were investigated. Its patent applications for compound semiconductor substrates from 1980 to 2004 were examined in detail. Through this analysis, the following relationship between technology spillover and economic paradigm shift can be observed. In an industrial society, intra-technology spillover successfully led innovation. In contrast, in an information society, opportunities for both intra- and inter-technology spillovers decreased, partly because of economic stagnation, but also because of organizational inertia in business strategy. However, in a post-information society, simultaneously with the renewal of national science and technology policy and reformation of business management, inter-technology spillover emerged across industries, and the economy revived.

Keywords: Material industry; Innovation; Institution; Paradigm shift; External resources; Technology spillover; Post-information society

1. Introduction

In a post-information society, "innovation" is one of the most commonly used words in science and technology. Above all, discussion of innovation seems to be a brand new trend for policy makers and business leaders who are considering sustainability in the 21st century (Palmisano, 2004). Innovation in service and devices is becoming more focused as indicated by successful cases such as Google and "i-mode". However, there has been another type of innovation which is equally important, but has received less emphasis than these new innovative phenomena. This is ongoing material innovation. In fact, material technology has supported service and device innovation in incorporating new functions into new devices. For example, the Internet and cellular phone systems work on optical fiber and wireless communication networks. Since the networks are supported by optoelectronics devices and performance of these devices are attributed to compound semiconductor materials, neither Google nor i-mode would

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have been created without material innovation. Needless to say, communication networks are the basis of a dynamic economy. Thus, in the post-information society, it is expected that material innovation as well as service and device innovation will play more important roles than before. Therefore, it is important to understand material innovation and elucidate its dynamics in the context of the economic paradigm shifts of the last three decades.

Japan's economy including material industry showed a significant recovery from the early 2000s. This revival can be attributed to the fusion of Japanese traditional business practice and that of Western countries (Smith, 2006; The Economist, 2007). Therefore, it is necessary to take of the transformation of business management into account in examining innovation and economic revitalization.

In analyzing innovation dynamics in material industry, Japan's nonferrous metal industry has been a subject for excellent case studies, because of a long history of its intense R&D compared with that of other material industries such as the iron and steel industry and fabricated metal industry. For example, Sumitomo Electric Industries, Ltd. (SEI), a leading firm in Japan's nonferrous metal industry, stated in its annual financial reports from 1987 to 1999 that R&D is the basis for sustainable growth of its corporate business (Sumitomo Electric Industries, Ltd., 1999a). This indicates that Japan's nonferrous metal industry has consistently made R&D efforts towards diversification by technological innovation. Since technological diversification could promote innovation (Lichtenhthaler, 2005; Garcia-Vega, 2006), this strategy taken by the industry has been favorable to innovation. In fact, supported by entrepreneurship and the intra-firm venture business system, the diversification strategy was successful in creating new businesses (Hirota, 1994, 1995). Actually, an ex R&D director of SEI said that R&D planning department-led business diversification of SEI (Matsushima and Odaka, 2004). SEI in fact consisted of 25 business units in 1992, and only 15 in 1972, thus increasing by 10. Furthermore, since maintaining originality in R&D activity was a constant concern in this industry, diversification inevitably enhanced technology spillovers within a firm.

In the 1990s, under the economic stagnation known as 'the lost decade', Japan's nonferrous metal industry suffered a continuous decline in the ratio of operating income to sales (OIS), following the decrease in marginal productivity of technology (MPT). From the perspective of technology spillover, this decrease in MPT can be attributed to the exhaustion of technology spillover sources in a firm (Nakagawa and Watanabe, 2007). Table 1 shows OIS for six major firms in Japan's nonferrous metal industry over the period of 1980–2005.

Surprisingly, Table 1 demonstrates that the trend in OIS for every firm except Showa Holdings Co. Ltd. (SHO) turned to an increase between 2002 and 2005: SEI in 2004, Furukawa Electric Industries Co. Ltd. (FUR) in 2005, Fujikura Ltd. (FUJ) in 2004, Hitachi Cable Ltd. (HIT) in 2003, and Mitsubishi Cable Industries, Ltd. (MIT) in 2002. These similar trajectories indicate that firms in Japan's nonferrous metal industry have revitalized their business performance in a post-information society. As technology stock, particularly that of new businesses, had increased OIS by boosting up MPT (Nakagawa and Watanabe, 2007), it can be safely said that the trend is tightly connected with OIS.

With an aim to demonstrate a contribution of innovation to OIS, a correlation of technology stock in new business sectors and OIS is analyzed in SEI, as shown in Table 2.[3]

The result of the regression is summarized as follows:

$$\ln OIS = \underset{(-3.34)}{-3.15} + \underset{(5.16)}{0.53} \ln T_4 - \underset{(-7.87)}{0.08}t - \underset{(-5.94)}{0.27}D$$

$$adj.\,R^2 = 0.89086, \quad DW = 1.74$$

where T_4 shows technology stock of new business sectors in SEI, $t = 0$ at 1980, dummy variables $D = 1$ at 1984, 1985, 1994, 1995, 2002 when OIS presents local minimum.

Thus, there is a strong correlation between OIS and technology stock in new business sectors.

Furthermore, as technology stock boosts MPT, and the marginal productivity increases OIS (Nakagawa and Watanabe, 2007). As MPT increases the productivity growth (Griliches, 1979; Watanabe and Wakabayashi, 1996; Watanabe and Tokumasu, 2003), this correlation is not just a coincidence, but does demonstrate causality.

This paper aims to identify the sources of innovation in Japan, and make several suggestions about innovation policy in a post-information society. Empirical analysis is undertaken in relation with technology spillovers presented in patent applications. Only the case study on SEI is discussed here, because it is a leading firm in Japan's material industry, particularly nonferrous metal industry with the longest history and the highest business performance.

Many studies demonstrated that technology spillover could play an important role in innovation. For example, technology spillover can impact on R&D strategy (Watanabe et al., 2001); firms with a well-developed assimilation capacity succeed in effectively utilizing technology spillover resulting in a very productive R&D structure (Watanabe et al., 2002); cross-functional spillover could be a survival strategy for ceramics industry (Ohmura et al., 2003; Ohmura and Watanabe, 2005); and the differences of firm's sizes are one of the important factors for technology spillovers (Ornaghi, 2006). Furthermore, other studies also demonstrated that technology developments could be attributed to technology spillover (Griliches and Lichtenberg, 1984; Jaffe, 1986; Bernstein and Nadiri, 1988, 1989; Goto and Suzuki, 1989; Kwang and Watanabe, 2001; Nakanishi, 2002; Watanabe and Ane, 2003; Watanabe and Tokumasu, 2003; Nieto and Quevedo, 2005). Most of

[3]An overview of SEI's business sectors is presented in Appendix A. An estimation of technology stock by SEI's business sector is demonstrated in Appendix B.