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Dynamic Interactions between Assimilation Capacity, Technology Spillovers, Sales and R&D Intensity

- The Case of Electrical Machinery Industry in Japan

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Abstract

In light of the significant technology inducement of a dynamic game among leading high-tech firms, and also of the leading role of assimilation capacity (the ability to utilize technology) for this game, numerical analyses and empirical demonstrations are attempted taking Japan's 24 leading electrical machinery firms over the last two decades.

On the basis of the intensive analyses, specific techno-sales structure of the industry are identified including (i) explicit division of two groups according to firms size by sales in which smaller firms cannot manage to jump up to the bigger firms group, and (ii) continuous decrease in R&D intensity starting particularly from the middle of the 1980s.

In addition, sources compelling leading electrical machinery firms to such a techno-sales structure are identified in a context of dynamic interactions between assimilation capacity, technology spillovers, sales and R&D intensity.

1. Introduction

The dramatic advancement of information technology (IT) and economic globalization has accelerated the growth and spread of global technology spillovers [8]. Facing low or negative economic growth and consequent R&D stagnation, effective utilization of technology from the global marketplace has become an important competition strategy leading to greater concern for assimilation capacity [8].

Thus, dynamic interactions between assimilation capacity, technology spillovers, sales and R&D intensity have become a crucial issue particularly for high-tech firms. Under this circumstance while highly intensive R&D activities with huge investments are needed, these R&D resources being beyond the reach of smaller firms, and more effective and efficient utilization of technologies developed elsewhere which "spill over" into the market is necessary. Following Cohen and Levinthal (1985) [1] and Watanabe *et al.* (2000) [8], effective utilization of potential spillover pool largely depends upon assimilation capacity. Assimilation capacity is a function of the level of technology stock and the ability to maximize the benefits of a learning exercise (Watanabe *et al.*, 2001 [9]) and it depends on the level of R&D expenditures.

2. State of High-level R&D Intensity

2.1 Level of R&D Intensity in Electrical Machinery Industry

R&D intensity varies a great deal from industry to industry. The state of R&D intensity in different sectors of Japan's manufacturing industry in 1998 is shown in Fig. 1.

R&D intensity's positive contribution to sales increase provides multiplier impact on R&D expenditure inducement

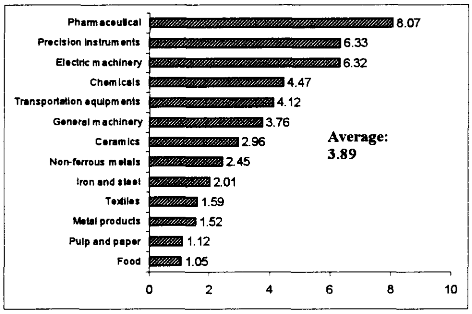

Fig. 1. R&D Intensity in the Japanese manufacturing Industry in 1998

leading to multiplier impact on the creation of technology stock (T). As traditional growth theory advises, technology stock generally provides significant contribution to sales increase.

2.2 State of Technology Structure in Electrical Machinery Industry

Table 1 summarizes the state of the interaction between R&D intensity, R&D expenditure, technology stock and sales in 24 leading R&D intensive firms in 1998.

Given the significant contribution of technology stock to sales in Japan's electrical machinery industry, our concern goes to the structure of the technology stock. As suggested by Cohen and Levinthal [1], and Watanabe *et al.* [8], technology stock consists of indigenous technology (T_i) and assimilated technology spillover (ZT_s; where Z: assimilation capacity; $T_s = \sum_{j(\neq i)} T_j$: potential technology spillover pool).

Therefore, contribution of technology stock to sales can be enumerated as follows:

$$S = AT^{\alpha} = A(T_i + zT_s)^{\alpha} \quad (1)$$

where A: scale factor; and α : elasticity of technology to sales. Since Z << 1, by taking logarithm, equation (1) can be approximated as follows:

$$\ln S = \ln A + \alpha \ln T_i + \alpha Z \frac{T_s}{T_i} \quad (2)$$

Therefore, Table 3 includes both T_i and Ti/Ts. Looking at the last column; we can classify these firms into two groups (Group 1 (G1): 1-7, and Group 2 (G2): 8-24) by their indigenous technology stock ratio $\frac{T_i}{T_s}$.

Table 1 State of Sales and R&D Structure of 24 R&D Intensive Japanese Electrical Machinery Firms in 1998: Yen bil. at 1990 fixed prices

No.	Firm	Sales	R&D Expenditure	R&D Intensity	Ti	Ti/Ts (%)
1	Matsushita Electric Industrial Co., Ltd.	6247.7	478.4	7.6	2539.0	17.56
2	Nippon Electric Industry Co., Ltd.	5065.5	316.5	6.2	2031.4	13.57
3	Hitachi, Ltd.	5161.4	362.4	7.0	2500.9	17.25
4	Toshiba Corp.	4659.8	281.6	6.0	1790.9	11.78
5	Fujitsu Ltd.	4284.9	318.3	7.4	1826.0	12.04
6	Mitsubishi Electric Corp.	3723.0	179.5	4.8	1140.5	7.19
7	Sony Corp.	3248.0	291.9	8.9	1384.5	8.87
8	Canon Inc.	2087.0	186.1	8.9	747.7	4.60
9	Sharp Corp.	1757.3	125.8	7.1	654.2	4.00
10	Sanyo Electric Co. Ltd.	1456.5	86.0	5.9	464.4	2.81
11	Matsushita Electric Works, Ltd.	1331.4	50.1	3.7	298.6	1.78
12	Victor Co. of Japan, Ltd.	793.3	38.1	4.8	257.4	1.54
13	Fuji Electric Co., Ltd.	733.2	32.8	4.4	214.2	1.28
14	Kyocera Corp.	620.0	24.9	4.0	117.0	0.69
15	Oki Electric Industry Co., Ltd.	674.4	33.8	5.0	250.1	1.49
16	Pioneer Electronic Corp.	459.2	26.5	5.7	158.1	0.94
17	Alps Electric Co., Ltd.	442.4	12.8	2.8	92.8	0.55
18	Casio Keisanki Co., Inc.	475.4	19.9	4.1	102.6	0.61
19	Rohm C., Ltd.	358.8	17.3	4.8	52.8	0.31
20	Aiwa Co., Ltd.	424.9	20.1	4.7	62.4	0.37
21	Yokogawa Electric Corp.	230.2	17.2	7.4	107.4	0.64
22	Japan Radio Co., Ltd.	233.3	14.0	6.0	79.6	0.47
23	Meidensha Corp.	231.8	8.0	3.4	62.7	0.37
24	Kokusai Electric Co., Ltd.	159.4	7.4	4.6	63.8	0.38
	Total 24 Firms	44858.8	2949.2	6.6	16997.9	
	Total Electric Machinery Industry	79604.7	3589.2	4.5	19980	

Fig. 2 analyzes the correlation between (S) and $\frac{T_i}{T_s}$ in the 24 Japanese electrical machinery firms over two periods from 1991-1994 and 1995-1998.

Fig. 2 demonstrates the structural difference between the two groups of firms depending on their size by sales (G1 and G2) indicating a higher indigenous technology stock ratio as firm size increases.

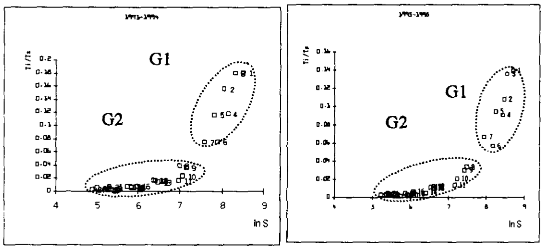

Fig. 2. Correlation between Sales and Indigenous Technology Dependency Ratio in 24 R&D Intensive Electrical Machinery Firms (1991-1998)

The ranks of the first 10 firms have been focused on and shown in Fig. 3. Looking at Fig. 3, we notice that since 1985, firms in group 2 (G2) can not manage to jump up to group 1 (G1). These observations support the foregoing analysis that the size of firms by sales is divided into two groups.

Previous analysis demonstrates that the size of firms is divided into two groups depending on technology structure. Technology structure is affected by two features: the level of technology stock and assimilation capacity.

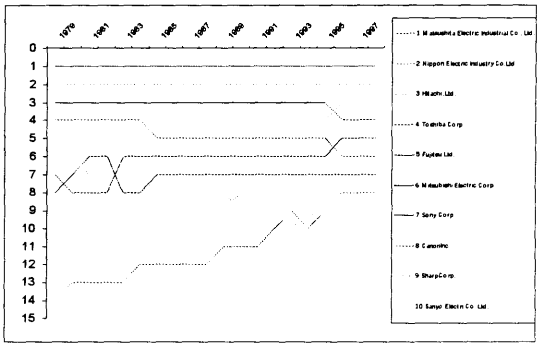

Fig. 3. Trends in Sales Rank of Top 10 Japanese Big Electrical Machinery Firms (1979-1998)

(i) Level of technology stock

R&D intensity is a decisive factor to the level of technology stock since, as we demonstrated before, it induces multiplier impact on the creation of technology stock. This stimulates us to review the trends in R&D intensity of 24 firms divided into two groups. Fig. 4 demonstrates that the trends in R&D intensity of almost all firms in both groups are continuously decreasing.

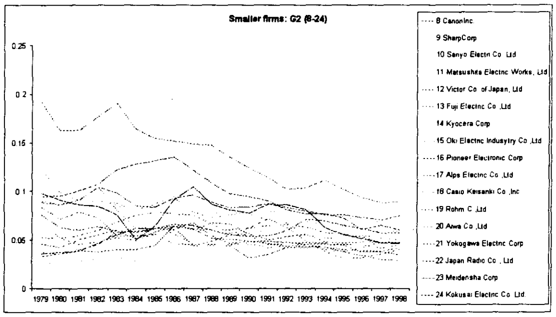

Fig. 4. Trends in R&D Intensity in 24 R&D Intensive Japanese Electrical Machinery Firms (1979-1998): 1990 fixed prices

(ii) Assimilation capacity

Fig. 2 suggests the following correlation between indigenous technology stock and sales:

$$\ln S = \ln A' + \alpha' \ln T_i \tag{3}$$

Comparing equation (3) with equation (2) and after simple algebraic computations the following correlation between sales and assimilation capacity can be obtained:

$$\ln S = \frac{-(a - b\frac{\ln A - \varepsilon \ln A}{1-\varepsilon} Z) + \sqrt{(a + b\frac{\ln A - \varepsilon \ln A}{1-\varepsilon})^2 + 4b(\frac{\alpha}{1-\varepsilon} + a\frac{\ln A - \varepsilon \ln A}{1-\varepsilon})}}{2b} \tag{4}$$

Equation (4) demonstrates our postulate that assimilation capacity is another source that causes the sales of firms to be divided into two groups.

The key findings obtained from the foregoing analyses can be highlighted as follows:

(i) Japan's leading electrical machinery firms can be divided into two groups (G1: 1-7, and G2: 8-24) according to their size in terms of sales.

(ii) Smaller firms belonging to G2 can not manage to jump up to G1.

(iii) Technology structure can be considered the major source to divide these firms into two groups, and this structure can be characterized by the level of technology stock and assimilation capacity.

(iv) R&D intensity induces with multiplier impact on technology stock and this intensity continues to decrease during and after the bubble economy.

3. Behaviour of Assimilation Capacity

Out of key factors such as R&D intensity, technology stock, and assimilation capacity, assimilation capacity particularly plays a significant role governing R&D intensity, technology stock and sales which stimulates us to analyze the behaviour of assimilation capacity in a context of a dynamic interaction between R&D intensity, technology stock and sales.

3.1 Mathematical Approach

The analyses of Fig. 2 suggests that the sales of the electrical machinery firms (S) can be enumerated as a function of the technology stock of the firm (T) as follows:

$$S = S(T) \tag{5}$$

Since high-tech industry as electrical machinery is spurred by strong competition, leading to **active interaction among firms**, and strong **dependency on technology** which result in such tendency as highly relying on spillover technology. Therefore, technology stock should include indigenous technology stock

(T_i) and assimilated spillover technology ($Z \cdot T_s$), which is generated by other firms (donor) and assimilated in the firm (host) as illustrated in Fig. 5. Where Z: assimilation capacity; and T_s: potential spillover pool.

Thus, technology stock in equation (5) can be enumerated as the following equation:

$$T = T_i + Z \cdot T_s \tag{6}$$

In line with the previous approaches (Watanabe *et al.*, 2001 [8]), assimilation capacity can be measured by the following equation using both indigenous technology stock and potential spillover pool:

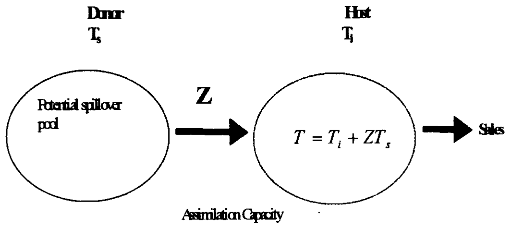

Fig. 5. Spillover and Assimilation Capacity Dynamics

$$Z = \frac{1}{1 + \frac{\Delta T_s}{T_s} / \frac{\Delta T_i}{T_i}} \cdot \frac{T_i}{T_s} \tag{7}$$

Equation (7) suggests that the assimilation capacity Z is proportional to the ratio of indigenous technology and potential spillovers pool. It is also governed by the ratio of the increasing rate of both technologies. Therefore, its trajectory is subject to the pace of increase between indigenous technology and the potential spillovers pool, which decreases as indigenous technology increases [12].

Fig. 6 suggests that all 24 firms depend on the similar ratio of assimilated spillover technology approximately 33%.

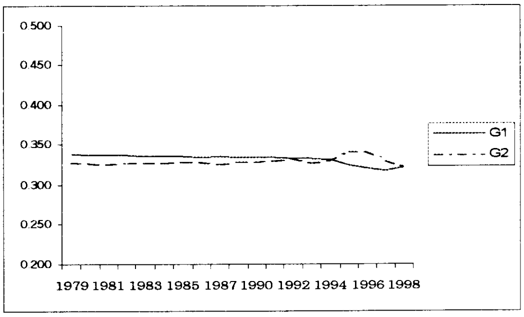

Fig. 6. Trends in the Dependency on Assimilated Spillover Technology

4. Interactions between Assimilation Capacity, R&D Intensity and Sales

4.1 Techno-sales Structure Decreasing R&D Intensity

Fig. 7 demonstrates a dynamic cycle among assimilation capacity, its impact on sales, their reaction to induce R&D intensity, and its contribution to assimilation capacity. Impact of assimilation capacity on sales can be traced by two routes: by means of increasing assimilated spillover technology and also through increasing technology elasticity to sales.

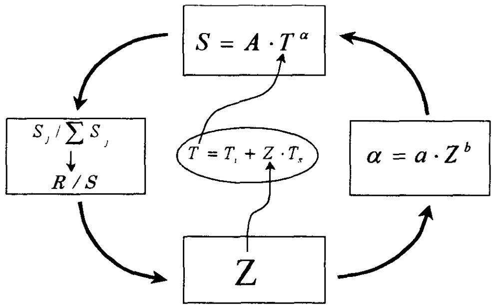

Fig. 7. Scheme of Dynamic Interactions between Assimilation Capacity, echnology Spillovers, Sales and R&D Intensity in the Japanese Electrical Machinery Industries

Based on these analyses regarding interactions between assimilation capacity, technology spillovers, sales and R&D intensity, the following noteworthy observations are obtained:

(i) Increase in assimilation capacity contributes to increase in sales in both bigger firms (firms with higher sales) and smaller firms through increase of total technology stock (Ti + Z Ts) and its elasticity to sales (α) as demonstrated in Table 9 and Fig. 11.

(ii) Increase in sales of each firm increases its share of all firms sales which in turn leads to increase in R&D intensity of each respective firm.

(iii) Increase in R&D intensity results in increase in assimilation capacity.

(iv) However, as demonstrated in Fig. 8, when R&D intensity exceeds a certain limit, assimilation capacity starts to decline.

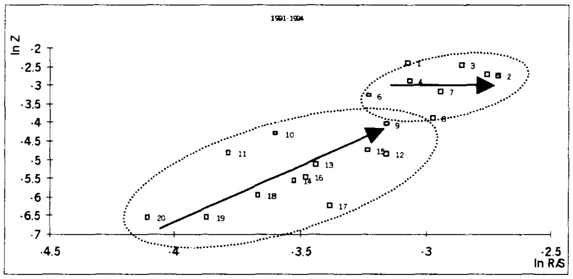

Fig. 8. Correlation between R&D Intensity and Assimilation

5. Implications

Noteworthy findings obtained through intensive theoretical analysis and empirical demonstration include:

(i) Technology structure is considered the major source to divide these firms into two groups, and this structure is characterized by the level of technology stock and assimilation capacity.

(ii) While R&D intensity induces with multiplier impact on technology stock and this intensity continues to decrease during and after the bubble economy, assimilation capacity has a significant impact on the sales trajectory leading to divide the firms into two groups.

(iii) All firms depend on the similar high ratio of assimilated spillover technology demonstrating the technology driven nature of the electrical machinery industry, which compels firms to maximize their utilization of spillover technology.

(iv) Level of sales of leading electrical machinery firms can be framed only by scale factors and technology elasticity to sales without depending on other efforts as R&D.

These findings suggest the significance of the identification of optimal dependency between indigenous technology and spillover technology in a global technology spillover context.

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