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# Resilience as a source of survival stategy for high-technology firms experiencing megacompetition

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**Abstract**

A dramatic surge in information technology (IT) around the world and an evolving global economy are subjecting firms to megacompetition, thereby compelling them to develop a resilient structure for survival. The construction of a co-evolutional structure between enhancement of core competences and agile correspondence to dynamically changing external circumstances, including dynamic change in customer preferences and competitive conditions, is thus essential. While technological innovation for developing new functionality is a strategic option, given the huge risks and uncertainty indigenous to technological innovation, a high level of dependence on this process can lead to a vulnerable structure. The fluctuating nature of external circumstances can also have the same result. Thus, sustainable firm development can only be expected using systems resilience incorporating a stable innovation orbit. Prompted by this postulate, this paper attempts to identify a resilience structure for high-technology firms that are experiencing megacompetition through a comparative empirical analysis of factors governing operating income to sales for R&D intensive Japanese pharmaceutical and electrical machinery firms over the last two decades.


*Keywords:* Resilient structure; Co-evolution; Megacompetition; Operating income to sales; Japan's pharmaceutical and electrical machinery firms

## 1. Introduction

Stimulated by a dramatic surge in information technology (IT) around the world and an evolving global economy, firms are now in the midst of megacompetition, which inevitably urges them to construct a co-evolutional structure between enhancement of core competences and agile correspondence to dramatically changing external circumstances.

In order to enhance core competences, convergence to certain innovation is important while divergence is essential for agile correspondence to dynamically changing external circumstances including dynamic change in customer preferences and competitive conditions. Thus, co-evolutional approach is indispensable for a simultaneous solution to these contradictory requirements (Watanabe and Nagamatsu, 2002).

An orbit control of this co-evolution requires an extremely subtle management as it sustains a simultaneous solution of contradictory issues. Under a long lasting economic stagnation in Japan while facing a megacompetition, not a few firm strays from an orbit. This is clearly observed in a contrast between two major Japanese high-technology industries, pharmaceutical and electrical machinery industries. If we compare the balance of estimated ordinary profit or loss in leading firms of these industries, we are surprised to see that while the majority of pharmaceutical firms are counted among profitable firms, many electrical machinery firms are counted among non-profitable firms.

This clear contrast in leading high-technology industries can be attributed to the different orbit of operating income to sales of these industries. While the pharmaceutical industry generally maintains its increasing trend in operating income to sales, the electrical machinery industry displays a decreasing trend after the bubble economy started from 1987.

It is generally assumed that an orbit of operating income to sales is subject to technological innovation

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and external circumstances of firms (Watanabe and Wakabayashi, 1996). However, since these factors contain uncertainty and subsequent fluctuation, a high level of dependence on them can lead to a vulnerable structure. Thus, sustainable firm development can only be expected using systems resilience[1] incorporating a stable innovation orbit.

Prompted by this postulate, this paper attempts to identity a resilience structure for high-technology firms that are experiencing megacompetition. To date, a number of studies have evaluated high-technology firms profits structure and sources supporting such profits by measuring internal rate of return to R&D investment.

Mansfield (1977) attempted pioneer work and calculated social and private returns and found that the social return (return to spillover R&D) was twice as big as the private (own) return. Bernstein and Nadiri (1991) also obtained similar conclusions. Recently Watanabe et al. (2001) computed their own and spillover return using assimilation capacity method, stimulated by Jaffe's (1986) attempt to measure technology spillover based on proximity approach. Griliches and Lichtenberg (1984) as well as Mohnen and Lepine (1988) attempted to analyze such returns by using patent flows while Terleckyj (1974) and Sveikauskas (1981) I-O flows analysis, and Bernstein and Nadiri (1988, 1989, 1991) initiated cost function approach. Mohnen (1996) attempted to identify R&D externalities and their impacts on productivity growth in OECD countries based on cost function approach. All these works correspond to the analysis aiming at identifying firms or industries profits and factors contributing to such profits.

However, these works focus on the identification of respective factors contributing to firms profits, and none have taken the perspective of systems resilience. Therefore, this paper aims at identifying a resilience structure for high-technology firms that are experiencing megacompetition by conducting a comparative empirical analysis of Japanese pharmaceutical and electrical machinery industries over the last two decades taking intensive R&D (thirty firms and twenty four firms, respectively).

Section 2 reviews states of R&D and revenue in high-technology industries. Section 3 is devoted to model synthesis. Empirical analysis and its interpretation are presented in Section 4. Section 5 briefly summarises new findings and implications for firms survival strategy in a mega-competition.

[1] The word "resilience" here means "the capability of strained body to recover from or adjust smoothly to external changes, shocks or crises".

## 2. States of Japan's high-technology industries: R&D and revenue

Triggered by a shift from heavy and chemical industrial structure in the 1960s to knowledge intensified industrial structure in the 1970s, the electrical machinery industry took a leading role in the advancement of Japan's industrial structure and made a significant contribution to its "high-technology miracle" in the 1980s. This can be demonstrated by electrical machinery's extremely big amount of R&D expenditure as 35.2% of industry total R&D expenditure in 2000 as demonstrated in Table 1.

In addition to such an extremely large amount of R&D expenditure, electrical machinery maintains a high level of R&D intensity (ratio of R&D expenditures and sales) as demonstrated in Fig. 1. Fig. 1 illustrates trends in R&D intensity at 1990 fixed prices in major sectors in Japan's manufacturing industry over the period 1979–2000.

Looking at the Fig. 1 we note that R&D intensity of electrical machinery, together with pharmaceutical which substituted for electrical machinery's highest position in 1987, demonstrates an extremely high-level and leads Japanese manufacturing industry's R&D over the whole period examined.

As demonstrated above, electrical machinery played a leading role in Japan for its economic development in the 1970s and the 1980s by shifting from heavy and chemical industrial structure to knowledge intensified industrial structure. It is the biggest sector in Japan's manufacturing industry with respect to GDP by sharing 16% of manufacturing total, and shares one third of industry's total R&D investment. However, notwith-

Table 1
R&D expenditure share in the Japan Industry in 2000 (%)[a]

| | |
|---|---|
| Agriculture | 0.1 |
| Mining | 0.2 |
| Construction | 1.7 |
| Manufacturing | 90.4 |
| ***Electrical machinery*** | ***35.2*** |
| *Chemicals* | *15.0* |
| (***Pharmaceutical***)[a] | **( *6.9* )** |
| *Transport machinery* | *14.3* |
| *General machinery* | *8.1* |
| *Precision instruments* | *4.5* |
| *Food* | *2.1* |
| *Other manufacturing* | *1.5* |
| Transport, telecommunication, public utility | 5.6 |
| Software industry | 1.9 |
| Industry total | 100.0 |

Source: Report on the Survey of Research and Development (Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT), 2001).

[a] Pharmaceutical is encompassed in chemicals.

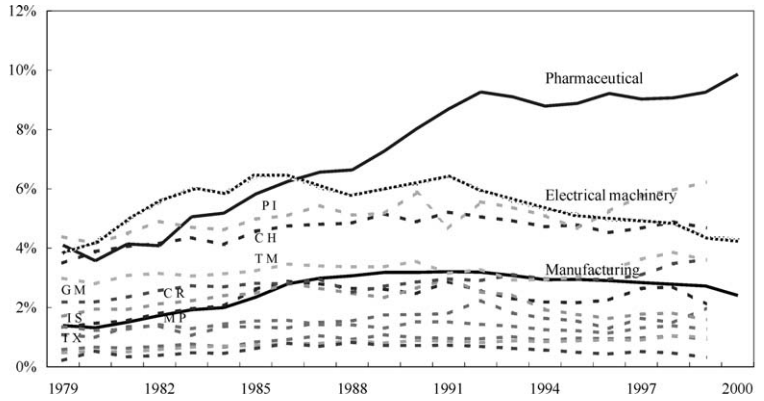


Fig. 1. Trends in R&D Intensity in Japan's Manufacturing Industry (1979–2000): *1990 fixed prices*. (a) Ratio of R&D expenditure and sales by 1990 fixed prices using R&D deflator and WPI (wholesale price index), respectively. (b) The notation of Japan's manufacturing industry is as follows: PI: precision instruments; CH: chemicals; TM: transportation machinery; GM: general machinery; CR: ceramics; IS: iron and steel; MP: metal products; and TX: textiles. Sources: Report on the Survey of Research and Development (1980–2000, Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT)), and Economic Statistics Annual (Bank of Japan, annual issues).

standing increasing expectations, its R&D investment has stagnated in the 1990s. Looking at Fig. 1 carefully, we note that the trend in electrical machinery changed to a decreasing trend in the 1990's while the trend in pharmaceutical remains a slightly increasing trend.

R&D intensity represents firms R&D strategy for their sustainable development and its level is affected by internal and external circumstances surrounding firms business activities including the level of sales, the degree of competition, the state of the external crises (e.g. exchange rate and energy prices) and R&D investment condition such as rate of return to R&D investment (Watanabe et al., 2000). This implies that such a decrease in R&D intensity in electrical machinery affects firm's returns structure.

Fig. 2 illustrates trends in operating income to sales in 54 firms in pharmaceutical and electrical machinery over the period 1979–1998 by dividing them into bigger and smaller firms categories.[2]

Looking at Fig. 2 we note that these trends demonstrate oscillating trend influenced by changing economic cycle (particularly silicon cycle in the case of electrical machinery) with a clear contrast between pharmaceutical and electrical machinery. While operating income to sales of electrical machinery changed to a decreasing trend from the middle of the 1980s due to the appreci-

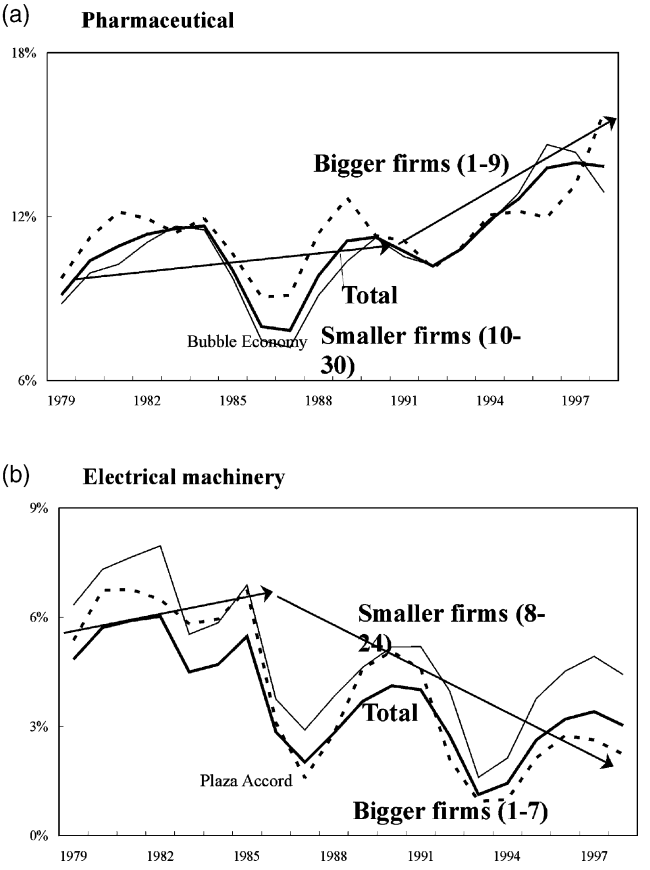


Fig. 2. Trends in Operating Income to Sales in Japan's R&D Intensive 30 Pharmaceutical and 24 Electrical Machinery Firms (1979–1998) %. Sources: Quarterly Japan Company Handbook (Toyo Keizai Inc., Tokyo, quarterly issues) and Toyo Keizai Monthly Statistics (Toyo Keizai Inc., Tokyo, monthly issues).

[2] Bigger firms in pharmaceutical include: Takeda, Sankyo, Yamanouchi, Daiichi, Eisai, Shionogi, Fujisawa, Tanabe, and Chugai; while smaller firms include: Banyu, Dainippon, Ono, Yoshitomi (presently Mitsubishi Pharma Corporation), Tsumura, Santen, Green Cross, Kaken, Mochida, Nikken, Kissei, Nippon Shinyaku, Fuso, Tokyo Tanabe, Toyama, Torii, Fujirebio, Teikoku, Seikagaku, Nippon Chemipha, and Hokuriku. Bigger firms in electrical machinery include: Matsushita, NEC, Hitachi, Toshiba, Fujitsu, Mitsubishi Elec., and Sony; while smaller firms include Canon, Sharp, Sanyo, MEW, JVC, Fuji Elec., Kyocera, Oki, Pioneer, Alps, Casio, Rohm, Aiwa, Yokogawa, JRC, Meidensha, and Kokusai Elec.

ation of Japanese Yen triggered by the Plaza Accord in 1985 and consequent bubble economy started from 1997, and continued to decrease, this operating income to sales of pharmaceutical maintained increasing trend with small oscillation influenced primarily by drug price (NHI price: new health insurance) adjustment trend,[3] and demonstrated higher increase in the 1990s.[4]

Given that an orbit of operating income to sales is subject to technological innovation and external circumstances of firms, the foregoing contrast between pharmaceutical and electrical machinery with respect to R&D structure and profits demonstrated by operating income to sales under dynamically changing circumstances, prompts us to the structural differences of the two industries, particularly of resilience structure to dramatic change in external circumstances as well as uncertainty inherent to technological innovation.

## 3. Model synthesis

### 3.1. General function

Operating income to sales (OIS) in high-technology firms are subject to their external circumstances as well as innovation. External circumstances are typically represented by an economic cycle such as silicon cycle for electrical machinery and drug price adjustment trend for pharmaceutical, while innovation can be traced by the trend in functionality development (Watanabe et al., 2001). In addition to these factors, OIS in Japan's high-technology industries are sensitive to the exchange rate of the Yen and also the state of competitiveness of the industry. Furthermore, OIS is subject to certain time trends inherent to the respective industry in a respective era.

Taking these factors into account, a function depicting governing factors on OIS can be expressed as follows:

$$OIS = F(EC, YR, FD, SV, t) \quad (1)$$

where $EC$ is economic cycle; $YR$ is exchange rate of Yen; $FD$ is functionality development; $SV$ is state of versatility; and $t$ is time trend.

Eq. (1) incorporates economic cycle and state of versatility as proxies of external circumstances and state of competitiveness of the industry, respectively.

### 3.2. Measurement of economic cycle

Among factors governing OIS taken in Eq. (1), measurement of the economic cycle in an objective way is considered essential for objective analysis of the governing factors of OIS and also for identifying the mechanism of dynamic change. In light of these understandings, further effort in identifying a dynamic behavior of economic cycle is first attempted.

The economic cycle can generally be traced by composite index (CI)[5] of business indices and this index for Japan's economy over the period (1979–1998) can be represented by the following sine curve:

$$CI = a + b_i \sin(c_i * t_i + d_i) + gD_{1994} \quad (2)$$

where $i$ indicates five periods, (1) 1979–1982; (2) 1983–1986; (3) 1987–1990; (4) 1991–1994; and (5) 1995–1998.

The year 1994 was the year of Japanese economy's termination from the damage of the bursting of the bubble economy in 1991, which lasted up until 1994 before the change to recovery.[6]

In order to demonstrate the representability of Eq. (2) depicted by sine curve, a correlation analysis between estimated model by means of sine curve and composite index of business indices is conducted.

Looking at Table 2 we note that all parameters estimated demonstrate statistical significance over the whole periods examined with high representability as illustrated in Fig. 3. This high representability is supported by such a high adj. $R^2$ ratio as 0.992.

Thus, we concluded that the state of economic cycle can be represented by sine curve model enumerated by Eq. (2).

## 4. Analysis and its interpretation

By using Eqs. (1) and (2) an empirical analysis is conducted taking R&D intensive Japanese firms, 30 pharmaceutical and 24 electrical machinery firms (see names of these 54 firms in footnote 2) over the period 1979–1998.

[3] Drug prices are generally adjusted to lower prices in the period of economic boom and higher in the period of economic recession.

[4] The period 1979–1998 can be divided into the following five periods depending on their structural back ground of the economy: 1979–1982 (after the second energy crisis and before the fall of international oil prices); 1983–1986 (after the fall of international oil prices and before the "bubble economy"); 1987–1990 (during the period of the "bubble economy"); 1991–1994 (after the burst of the "bubble economy"); and 1995–1998 (during the further stagnation of economy). General trends of OIS in pharmaceutical firms demonstrated structural difference between the first two periods (1979–1986: before the "bubble economy") and the latter three periods (1987–1998: during and after the bursting of the "bubble economy"), while similar trends in electrical machinery firms demonstrated structural difference between the first three periods (1979–1990: before the bursting of the "bubble economy") and the latter two periods (1991–1998: after the bursting of the "bubble economy").

[5] CI was developed by the US NBER and deployed for practical use by the DOC in 1968.

[6] Trend in Japan's GDP growth rate (fixed prices base) suggests the following termination indication with respect to the year 1994: 1990=5.5, 1991=2.9, 1992=0.4, 1993=0.5, 1994=0.6, 1995=3.0, 1996=4.4 (%p.a.)

Table 2
Correlation between composite index (CI) and sine curve in Japan's economy (1979–1998)

| $a$ | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $d_1$ | $d_2$ | $d_3$ | $d_4$ | $d_5$ | $g$ | adj. $R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45.29 | 5.29 | 4.40 | 88.32 | 20.83 | 12.65 | 2.82 | -1.87 | 0.22 | 3.92 | -2.78 | 0.76 | 2.99 | 0.76 | 3.42 | -0.19 | -33.10 | 0.992 | 1.64 |
| (5.68) | (5.07) | (7.85) | (6.91) | (20.14) | (8.88) | (455.94) | (-337.57) | (767.75) | (3931.80) | (-1822.80) | (1.51) | (7.19) | (12.43) | (39.75) | (-1.36) | (-20.39) | | |

*i* indicates five periods, 1: 1979-1982=1, other years=0; 2: 1983-1986=1, other years=0; 3: 1987-1990=1, other years=0; 4: 1991-1994=1, other years=0; and 5: 1995-1998=1, other years=0.

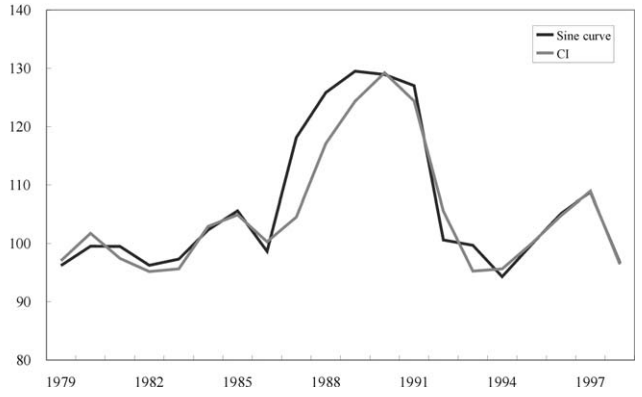


Fig. 3. Trends in Japan's economic cycle measured by CI and sine curve (1979–1998).

These firms share 65.6% of sales and 78.5% of R&D expenditure of total pharmaceutical industry and 56.4% of sales and 82.2% of R&D expenditure of total electrical machinery industry in 1998.

### 4.1. Comparison of resilience structure

Eq. (1) can be represented by the following simple Cobb–Douglas type function:

$$OIS = A(EC)^b(YR)^g(FD)^h(SV)^k e^{\lambda t} \quad (3)$$

where $b$, $g$, $h$, and k indicate elasticities, and $\lambda$ indicates time trend coefficient.

Taking logarithm and correlation analyses are conducted. Results are summarized in Table 3 (pharmaceutical) and 4 (electrical machinery). Tables 3 and 4 summarize not only the results of the analysis of whole firms but also those classified by bigger and smaller firms.

Tables 3 and 4 provide the following interpretations with respect to factors governing operating income to sales in R&D intensive pharmaceutical and electrical machinery firms:

(i) Elasticity of economic cycle to operating income to sale in pharmaceutical (= 0.56) is much smaller than that of electrical machinery (= 1.38) which demonstrates that operating income to sales of pharmaceuticals is not so sensitive to decline in the economic cycle as electrical machinery. This propensity can be observed more clearly by classifying bigger and smaller firms: 0.25 vs 2.24 in bigger firms, and 0.04 vs 1.08 in smaller firms.

(ii) Both industries demonstrate that the operating income to sales decreases as the Yen rate increases (strong Yen). This is because both industries are export oriented industries. In pharmaceuticals, smaller firms are more sensitive than bigger firms, while bigger firms are more sensitive in electrical machinery.

(iii) Elasticity of functionality in pharmaceutical (4.57 for 1979–1990 and 2.81 for 1991–1998) is more stable (less elastic) than that of electrical machinery (5.50 for 1979–1986 and 5.73 for 1987–1998) which implies that the possibility of failing to capture economic fluctuations can be minimized even in the case of decrease of functionality development.

(iv) Increase of sales entropy contributes to increase in OIS in pharmaceutical with high elasticity (12.60–14.10) while it is the reverse in electrical machinery (−2.75–−4.91). This is due to the structural difference between the two industries with respect to homogeneity (pharmaceutical firms are relatively more heterogeneous than electrical machinery). Increase in sales entropy implies stimulation of competition leading to an increase in OIS in pharmaceutical while there is a decrease in OIS in electrical machinery.

(v) Pharmaceuticals maintain a relatively higher positive coefficients with respect to time trend (0.24) than electrical machinery (0.04). This is considered due to self-propagating structure of pharmaceutical industry regarding new functionality development.

These findings demonstrate that the structural sources of the degree of operating income to sales in electrical machinery can be attributed to its sensitive structure to change in economic cycle and functionality development, which suffered from a significant decreasing trend. Contrary to such a structure in electrical machinery, pharmaceuticals maintains more resilient structure against fluctuations of the economic cycle and uncertainty inherent to functionality development by diversifying the dependency on them and supported by self-propagating structure.

Similar trends can also be observed in each respective firm in the two industries as illustrated in Figs. 4 and 5.

Tables 5 and 6 summarize the results of similar correlation analysis as demonstrated in Tables 3 and 4 taking five representative firms in each respective industry.

Tables 5 and 6 provide the following implications with respect to factors governing operating income to sales in representative R&D intensive pharmaceutical and electrical machinery firms:

(1) Pharmaceutical firms

(i) Elasticities of economic cycle to OIS of Daiichi (1.19), Takeda (0.78) and Yamanouchi (0.73) are bigger than that of the whole pharmaceutical (0.56) which demonstrate that OIS of these firms are more sensitive to the economic cycle than whole pharmaceutical. On the other hand, that of Eisai (0.33) is smaller than the whole pharmaceutical which indicates that OIS of Eisai is less sensitive to economic cycle than whole pharmaceutical supported by its unique innovation.

Table 3
Factors governing operating income to sales (OIS) in R&D Intensive Japanese Pharmaceutical Firms (1979-1998)[a–d]

$$\ln OIS = a + b\ln(a' + b'\sin(ct + d) + \gamma D_{1994}) + g\ln YR + D_i h_i \ln FD + D_i k_i \ln SV + \lambda t$$

**30 firms**

| $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|
| -45.40 (-6.98) | 0.56 (3.49) | -0.16 (-2.01) | 4.57 (5.94) | 2.81 (3.88) | 12.60 (5.50) | 14.10 (5.80) | 0.24 (5.19) | 0.937 | 1.82 |

$D_1$: 1979-1990; $D_2$: 1991-1998 (see footnote 4).

**Bigger firms (No. 1-9)**

| $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|
| -11.17 (-4.71) | 0.25 (1.56) | -0.50 (-5.53) | 0.42 (3.21) | 1.13 (1.71) | 2.56 (1.04) | 2.44 (1.03) | 0.02 (1.64) | 0.821 | 2.35 |

$D_1$: 1979-1990; $D_2$: 1991-1998.

**Smaller firms (No. 10-30)**

| $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|
| -11.87 (-2.92) | 0.04 (0.14) | -0.82 (-5.03) | 0.26 (1.12) | -2.66 (-2.36) | 1.97 (0.48) | 2.98 (0.69) | 0.03 (1.27) | 0.837 | 2.23 |

$D_1$: 1979-1990; $D_2$: 1991-1998.
[a] $a' + b'\sin(ct + d) + \gamma D_{1994}$ represents trend in composite index (CI).
[b] *YR*: exchange rate of Yen (US$/Yen); *FD*: functionality development; $\epsilon$:sales entropy; and *t*: time trend.
[c] FD is represented by the ratio of actual to carrying capacity ($RAC_{t-1}$) and technology elasticity to sales.
[d] SV is represented by sales entropy ($\epsilon$).

(ii) Elasticities of Yen rate to OIS of Takeda (−0.75), Eisai (−0.81), Tanabe (−0.80) and Yamanouchi (−0.21) are bigger in negative direction than that of whole pharmaceutical (−0.16) which demonstrate that OIS of these firms are more sensitive to Yen rate than whole pharmaceutical. Those results are considered due to high exportation rate (the rate of exportation to sales) of these firms as Takeda (22.4%), Eisai (10.8%), Tanabe (13.7%) and Yamanouchi (10.1%) in 1998 while the average rate of whole pharmaceutical was 4.2%.

(iii) Elasticities of functionality of all five firms examined (0.66–3.61) in 1979–1990 are more stable (less elastic) than that of whole pharmaceutical (4.57) which imply that these firms are robust to an uncertainty inherent to innovation and consequent decrease in functionality development. However, the elasticities except Takeda increased over the whole period after 1991 which provide a warning that the robustness decreased after 1991.

(iv) Elasticities of entropy are positive for Tekeda, Daiichi, Eisai and Tanabe as is observed in the whole pharmaceutical industry which implies that these companies are strong in the competitive business environment and stimulated by competitive circumstance. An exception is Yamanouchi which demonstrates a fragile structure against severe competition.

(v) Coefficient of time trend indicates other governing factors of OIS including such factors relevant to self-propagating structure as economies of scale, management restructuring, learning effect etc. The values for five firms examined are 0.06 to 0.10.

While the general tendency on the contribution of the governing factors to OIS is almost common to all pharmaceutical firms examined, there are some differences between each firm depending on its business strategy and core competences as mentioned above.

(2) Electrical machinery firms

(i) Elasticities of economic cycle to OIS of the firms (2.06 to 4.77) except Sharp are bigger than that of thewhole electrical machinery (1.38) which imply that these four firms tend to be influenced stronger than the whole electrical machinery. On the other hand, Sharp (1.22) is supposed to be more robust to

Table 4
Factors governing operating income to sales (OIS) in R&D Intensive Japanese Electrical Machinery Firms (1979–1998)[a–d]

$$\ln OIS = a + b\ln(a' + b'\sin(ct + d) + \gamma D_{1994}) + g\ln YR + D_i h_i \ln FD + D_i k_i \ln SV + \lambda t + lD_{1981}$$

**24 firms**

| $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $l$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|---|
| −8.65 | 1.38 | −1.55 | 5.50 | 5.73 | −2.75 | −4.91 | 0.04 | 0.35 | 0.800 | 1.13 |
| (−5.37) | (2.36) | (−2.89) | (5.41) | (5.21) | (−2.72) | (−4.26) | (2.10) | (1.68) | | |

$D_1$: 1979-1986; $D_2$: 1987-1998 (see footnote 4).

**Bigger firms (No. 1–7)**

| $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|
| −12.67 | 2.24 | −1.96 | 6.70 | 6.87 | −5.34 | −6.34 | 0.05 | 0.974 | 1.41 |
| (−6.16) | (2.66) | (−2.74) | (5.76) | (5.78) | (−4.45) | (−4.95) | (1.95) | | |

$D_1$: 1979-1986; $D_2$: 1987-1998.

**Smaller firms (No. 8–24)**

| $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|
| −8.95 | 1.08 | −1.52 | 4.21 | 3.02 | −3.21 | −4.74 | 0.04 | 0.857 | 2.48 |
| (−4.60) | (1.86) | (−3.48) | (4.52) | (1.78) | (−3.45) | (−2.70) | (1.62) | | |

$D_1$: 1979–1986; $D_2$: 1987–1998.

[a] $a' + b'\sin(ct + d) + \gamma D_{1994}$represents trend in composite index (CI).

[b] *YR*: exchange rate of Yen (US$/Yen); *FD*: functionality development; $\epsilon$:sales entropy; and *t*: time trend.

[c] FD is represented by the ratio of actual to carrying capacity ($RAC_{t-1}$) and technology elasticity to sales.

[d] SV is represented by sales entropy ($\epsilon$).

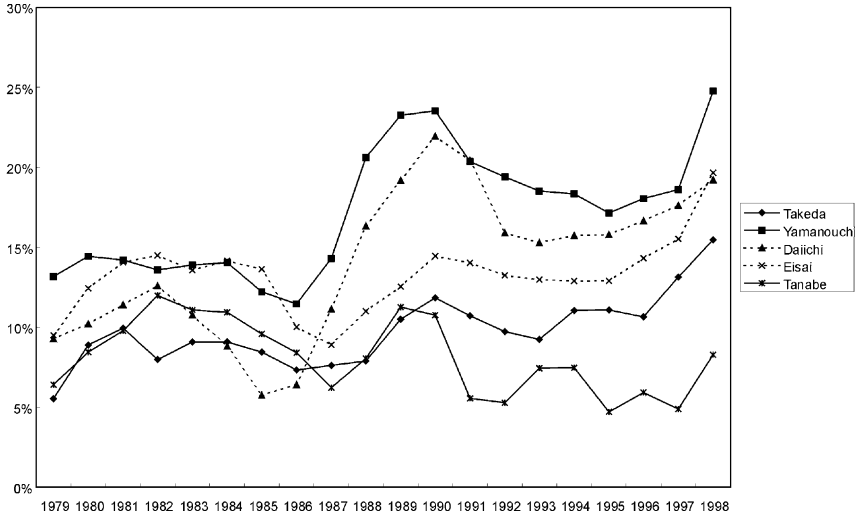


Fig. 4. Trends in operating income to sales in selected Japanese pharmaceutical firms (1979–1998).

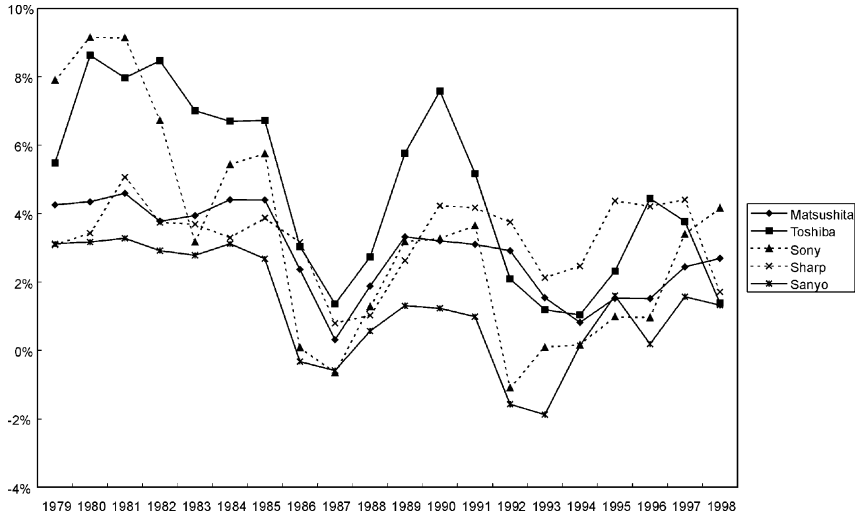


Fig. 5. Trends in operating income to sales in selected Japanese electrical machinery firms (1979-1998).

Table 5
Factors governing operating income to sales (OIS) in selected Japanese pharmaceutical firms (1979-1998)[a,b]

$$\ln OIS = a + b\ln(a' + b'\sin(ct + d) + \gamma D_{1994}) + g\ln YR + D_i h_i \ln FD + D_i k_i \ln SV + \lambda t$$

| | $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Takeda | −27.29 | 0.78 | −0.75 | 3.61 | 3.53 | 14.82 | 14.88 | 0.08 | 0.742 | 1.98 |
| | (−3.33) | (2.12)∗∗ | (−3.62) | (3.29) | (0.38)# | (2.31)∗ | (2.18)∗∗ | (3.04)∗ | | |
| Yamanouchi | 1.66 | 0.73 | −0.21 | 0.66 | 11.16 | −8.39 | 10.41 | 0.10 | 0.871 | 2.68 |
| | (0.36)# | (2.80)∗ | (−1.44)∗∗∗ | (1.80)∗∗ | (3.23) | (−2.28)∗ | (-2.57)∗ | (5.25) | | |
| Daiichi | −13.58 | 1.19 | −0.12 | 0.90 | 6.14 | 4.30 | 3.25 | 0.06 | 0.971 | 2.13 |
| | (−3.82) | (5.56) | (−1.08)∗∗∗∗ | (2.77)∗ | (2.28)∗ | (1.52)∗∗∗ | (1.04)# | (4.14) | | |
| Eisai | −12.58 | 0.33 | −0.81 | 1.83 | 2.28 | 3.47 | 3.42 | 0.07 | 0.945 | 2.13 |
| | (−5.31) | (2.47)∗ | (−11.2) | (6.42) | (1.67)∗∗∗ | (1.85)∗∗ | (1.71)∗∗∗ | (7.68) | | |
| Tanabe | −17.38 | −0.47 | −0.80 | 2.18 | 59.06 | 11.11 | 5.38 | 0.09 | 0.717 | 2.17 |
| | (−1.98)∗∗ | (−0.95)# | (−2.99)∗ | (2.07)∗∗ | (2.19)∗ | (1.60)∗∗∗ | (0.64)# | (2.53)∗ | | |

[a] $D_1$:1979-1990; $D_2$:1991-1998.
[b] Figures in parentheses indicate t-statistics, all indicate significance at 1% level except ∗: 5%; ∗∗: 10%; ∗∗∗: 20%; ∗∗∗∗: 30% significance; and #: non significance.

economic fluctuations with its unique corporate strategy and products.

(ii) Elasticities of Yen rate to OIS of the firms (−2.38 to −8.73) except Sharp (−1.18) are higher in negative direction than that of whole electrical machinery (−1.55). Those results are due to higher exportation rate of these firms as Matsushita: 50.7%; Toshiba: 39.9%; Sony: 71.8%; and Sanyo: 46.9% in 1998.

(iii) Over the period 1979–1986, elasticities of functionality to OIS of Matsushita (24.17) and Sanyo (9.82) are higher than those of whole electrical machinery (5.50), Toshiba (5.30) and Sharp (3.25). These results suggest that Matsushita and Sanyo might have been less stable (higher dependence on functionality) than other electrical machinery firms. After 1987, the elasticities of Toshiba (−13.45), Sony (−13.85), Sharp (−10.91) and Sanyo (−16.30) turned out to be negative values. These results suggest the possibility that the relation between profits and functionality of these firms made a dramatic change due to long lasting economic stagnation.

(iv) Contrary to a general trend in the whole electrical machinery industry, elasticities of entropy to OIS are positive for Toshiba, Sony and Sharp while those for Matsushita and Sanyo are negative. These results indicate that the former three firms maintain a competitive nature that market competition leads to increase OIS while reverse for the latter two firms similar to whole electrical machinery which takes rather homogeneous behavior.

Table 6
Factors governing operating income to sales (OIS) in selected Japanese electrical machinery firms (1979-1998)[a,b]

$$\ln OIS = a + b\ln(a' + b'\sin(ct + d) + \gamma D_{1994}) + g\ln YR + D_i h_i \ln FD + D_i k_i \ln SV + \lambda t$$

| | $a$ | $b$ | $g$ | $h_1$ | $h_2$ | $k_1$ | $k_2$ | $\lambda$ | $adj.R^2$ | $DW$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Matsushita | 48.63 | 4.77 | −2.66 | 24.17 | 7.03 | −102.81 | −98.31 | 0.50 | 0.838 | 2.31 |
| | (1.24)∗∗∗∗ | (4.09) | (−3.25) | (4.14) | (0.99)# | (−2.52)∗ | (−2.37)∗ | (4.37) | | |
| Toshiba | −91.18 | 2.92 | −2.38 | 5.36 | −13.45 | 60.49 | 71.25 | −0.06 | 0.958 | 2.59 |
| | (−3.88) | (3.58) | (−5.25) | (2.15)∗∗ | (−3.89) | (2.49)∗ | (2.78)∗ | (−1.16)∗∗∗∗ | | |
| Sony | −121.07 | 2.06 | −8.73 | 36.70 | −13.85 | 96.40 | 54.68 | −0.27 | 0.927 | 2.51 |
| | (−1.98)∗∗ | (1.08)∗∗∗∗ | (−8.59) | (0.87)# | (−4.28) | (1.56)∗∗∗ | (0.91)# | (−2.17)∗ | | |
| Sharp | −95.59 | 1.22 | −1.18 | 3.25 | −10.91 | 80.96 | 86.56 | −0.07 | 0.831 | 2.58 |
| | (−3.45) | (1.25)∗∗∗ | (−2.00)∗∗ | (1.25)∗∗∗ | (−2.45)∗ | (2.96)∗ | (3.07)∗ | (−1.08)∗∗∗∗ | | |
| Sanyo | −9.12 | 3.77 | -3.70 | 9.82 | −16.30 | −46.47 | −12.49 | 0.10 | 0.962 | 2.03 |
| | (−0.29)# | (3.51) | (−3.98) | (1.33)∗∗∗ | (−2.02)∗ | (−1.36)∗∗ | (-0.34)# | (0.98)# | | |

[a] $D_1$:1979-1986; $D_2$:1987-1998.
[b] Figures in parentheses indicate t-statistics, all indicate significance at 1% level except ∗:5%; ∗∗:10%; ∗∗∗:20%; ∗∗∗∗:30% significance; and #: non significance.

(v) Coefficient of time trend which include other factors governing OIS varies from −0.27 (Sony) to 0.50 (Matsushita).

Similar to pharmaceutical firms, while the general tendency on the contribution of the governing factors to OIS is almost common to all electrical machinery firms examined, there are some differences between each firm depending on its business strategy and core competence as mentioned above.

All these analysis support the results obtained in the analysis by means of aggregate level as summarized in Tables 3 and 4.

### 4.2. Comparison of factors contributing to OIS

In order to identity structural characteristics of resilience of pharmaceutical and electrical machinery firms, a comparative analysis of factors contributing to change in OIS of firms in two industries over the period 1991–1998 is conducted. Results of the analysis is summarized in Table 7.

Looking at Table 7 we note that the average change rate of OIS in pharmaceutical firms recorded was 2.53%, which was contributed primarily by their self-propagating structure represented by the time trend followed by stimulation of competition in the industry, while negative impacts due to decrease in economic cycle and functionality development is relatively small. Contrary to pharmaceuticals, electrical machinery firms experienced a 2.36% decrease in their OIS which was derived primarily from a dramatic decrease in functionality development followed by a decrease in economic cycle. Appreciation of Yen as well as an increase in competition in the industry also reacted to decrease in OIS. Although factors represented by time trend contributed to increase in OIS, its contribution was extremely small in comparison to the significant contribution observed in pharmaceutical firms.

This analysis demonstrates clear contrast of resilience structure between the pharmaceutical and electrical machinery industries. A stable OIS increase in the pharmaceutical industry can be attributed to its resilience structure characterized by less dependency on the economic cycle with fluctuating nature and functionality development with inherent uncertainty while incorporat-

Table 7
Comparison of factors contributing to change in OIS in R&D intensive Japanese pharmaceutical and electrical machinery firms (1991–1998)

| | | Contribution of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Economic cycle | Yen rate | Functionality development | State of versatility | Time trend | Other factors |
| Pharmaceutical | 2.53% | −2.02% | −0.20% | −3.74% | 1.19% | 24.00% | −16.70% |
| Electrical machinery | −2.36% | −3.06% | −1.18% | −22.04% | −0.28% | 4.00% | 14.81% |

ing stable innovation orbit supported by its self-propagating structure.

### 4.3. Comparison of impacts of OIS change on deviation of firms OIS

As demonstrated in the analysis in section 4.1, the state of competitiveness of the industry provides a significant impact on the operating income to sales of each respective firm in the industry. This observation suggests that there exists certain cyclic correlation between state of the operating income to sales of the industry and state of deviation of firms in the industry which reacts to the governing state of competitiveness of the industry leading to a significant impact on the operating income to sales of each respective firm in the industry as illustrated in Fig. 6.

Under a long lasting economic stagnation, a few Japanese industries currently suffer from decreasing OIS, which results in an increasing number of firms "dropping out of the race". Those firms who drop out lose their credit standing leading to a difficult position in securing funding in a capital market, and result in falling into a vicious cycle between business recovery and OIS increase. "Bipolar phenomena" dividing winner and defeater observed in a few industries in Japan in the latter half of the 1990s can be attributed to this vicious cycle.

In light of these structural problems, a comparative analysis of impacts of OIS change on deviation of firms OIS is attempted. Figs. 7 and 8 analyze trends in standard deviation of OIS in 30 pharmaceutical firms and 24 electrical machinery firms over the period 1979–1998 by dividing bigger and smaller firms.

Looking at the Figs. 7 and 8 we note that while standard deviation in smaller firms of pharmaceutical fluctuates demonstrating an increasing trend in the first half of the 1990s changing to a decreasing trend in the later part of the 1990s, standard deviation of bigger firms demonstrate slightly increasing trends in the latter half of the 1990s.

Contrary to these trends in pharmaceuticals, the standard deviation in smaller firms of electrical machinery demonstrate sharp increases in the latter half of the 1990s, while a similar trend in bigger firms remains stable after decreases in the early part of 1990s.

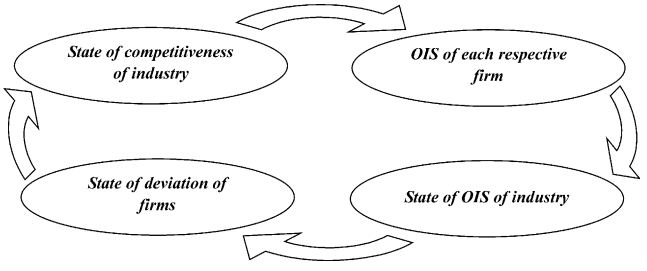


Fig. 6. Cyclic correlation between state of OIS of industry and state of deviation of firms in the industry.

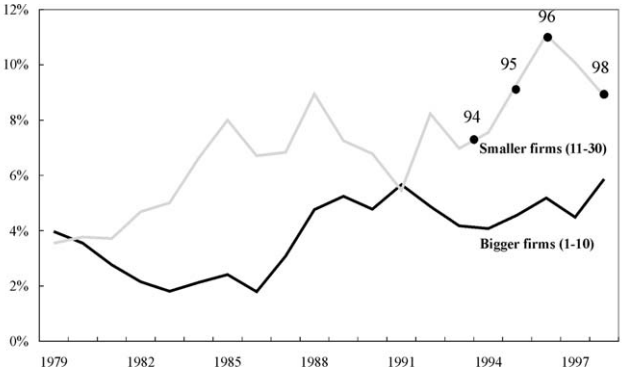


Fig. 7. Trends in standard deviation of OIS in R&D intensive Japanese pharmaceutical firms (1979–1998).

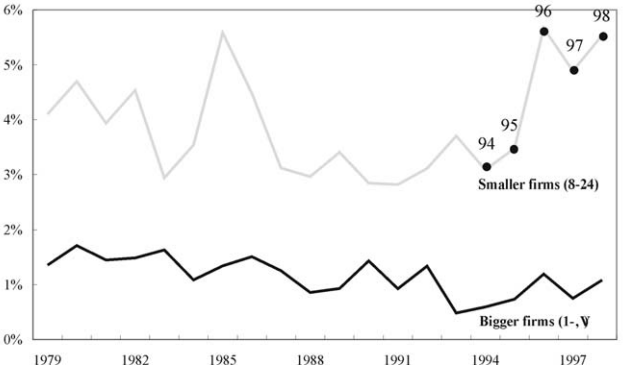


Fig. 8. Trends in standard deviation of OIS in R&D intensive Japanese electrical machinery firms (1979–1998).

In order to identify the impact of OIS on deviation of these two industries, Tables 8 and 9 analyze the correlation between operating income to sales and standard deviation of OIS in pharmaceutical and electrical machinery firms over the period 1979–1998 by dividing bigger and smaller firms and also five periods.

Tables 8 and 9 demonstrate that an increase in OIS reacts to increasing standard deviation in bigger firms of both industries while it is the reverse in smaller firms of both industries. This observation suggests that under the increasing circumstances of OIS, deviation increases (diverge) while decrease in OIS reacts to a decrease (converge) in deviation in bigger firms in both industries. Contrary to these behaviors in both industries, while an increase in OIS reacts to a decrease in deviation under the decreasing circumstances of OIS, deviation increases in smaller firms in both industries.

Synchronizing the results obtained by Tables 3 and 8 (for pharmaceutical) and Tables 4 and 9 (for electrical

Table 8
Correlation between operating income to sales (OIS) and standard deviation of OIS in R&D intensive Japanese pharmaceutical firms (1979-1998)

$\ln SD = a + b_i D_i \ln OIS$

| **30 firms** | | | | | | | |
|---|---|---|---|---|---|---|---|
| *a* | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | *adj.* $R^2$ | *DW* |
| −3.23 (−7.48) | 0.02 (0.11) | −0.18 (−0.93) | −0.26 (−1.37) | −0.24 (−1.26) | −0.40 (−1.82) | 0.916 | 2.68 |
| **Bigger firms (1–10)** | | | | | | | |
| *a* | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | *adj.* $R^2$ | *DW* |
| -1.66 (-6.27) | 0.21 (2.70) | 0.20 (2.88) | 0.22 (2.61) | 0.23 (2.60) | 0.17 (1.92) | 0.777 | 2.52 |
| **Smaller firms (11–30)** | | | | | | | |
| *a* | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | *adj.* $R^2$ | *DW* |
| −2.75 (−10.01) | −0.13 (−1.55) | −0.19 (−1.93) | −0.16 (−1.59) | −0.19 (−1.81) | −0.31 (2.65) | 0.906 | 2.31 |

Table 9
Correlation between operating income to sales (OIS) and standard deviation of OIS in R&D intensive Japanese electrical machinery firms (1979-1998)

$\ln SD = a + b_i D_i \ln OIS$

| **24 firms** | | | | | | | |
|---|---|---|---|---|---|---|---|
| *a* | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | *adj.* $R^2$ | *DW* |
| −3.96 (−4.10) | −0.25 (−1.98) | −0.17 (−1.53) | −0.10 (−1.01) | −0.10 (−1.11) | −0.18 (−1.77) | 0.724 | 2.32 |
| **Bigger firms (1-10)** | | | | | | | |
| *a* | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | *adj.* $R^2$ | *DW* |
| 0.12 (0.08) | 0.69 (2.05) | 0.66 (2.05) | 0.74 (2.40) | 0.86 (3.00) | 0.82 (2.74) | 0.763 | 2.31 |
| **Smaller firms (11-30)** | | | | | | | |
| *a* | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | *adj.* $R^2$ | *DW* |
| −4.59 (−4.71) | −0.63 (−2.01) | −0.46 (−1.55) | −0.40 (−1.41) | −0.20 (−0.72) | −0.48 (−1.49) | 0.759 | 1.54 |

machinery)[7] Table 10 summarizes institutional behavior of pharmaceutical and electrical machinery firms experiencing megacompetition in the 1990s.

Looking at Table 10 we note that the following noteworthy observations with respect to institutional behavior of pharmaceutical and trical machinery firms in the 1990s under megacompettion:

(i) Bigger firms of pharmaceuticals under increasing

[7] Although Table 10 attempts to link (i) state of versatility measured by sales entropy ($\epsilon$), (ii) OIS, and (iii) standard deviation of OIS (not sales), the general relationship between entropy ($\epsilon$) and standard deviation of the same factor ($\phi$) can be depicted as follows:

$$\varepsilon = \sum \frac{x_i}{\sum_n x_i} \ln \frac{\sum^n x_i}{x_i} \text{ and } \phi = \sqrt{\frac{1}{n}\sum^n x_i^2 - \left(\frac{\sum^n x_i}{n}\right)^2}$$

where $x_i$ is state of firm $i$ (eg. sales of firm $i$); and $n$ is number of firms in the same group. Let

$$\frac{\sum^n x_i}{n} = z,$$

then

$$\phi^2 = n\sum^n \left(\frac{x_i}{n}\right)^2 - z^2,\ z^2 = n\sum^n \left(\frac{x_i}{n}\right)^2 - \phi^2$$

Table 10
Institutional behavior of high-technology firms experiencing megacompetition in the 1990s

| Industry | Firm size | Change rate of OIS | $SV_{sales}$[a]→ OIS (State of competition) | OIS → $SD_{OIS}$[a] | Firms institutional behavior |
|---|---|---|---|---|---|
| Pharmaceutical | Bigger | + | + (Severe competition) | + (Diverge) | Clear distinction between winner and defeated |
| | Smaller | + | + (Severe competition) | − (Converge) | Shift to cartel behavior |
| Electrical machinery | Bigger | − | − (Weak competition) | + (Converge) | Acceleration of standardized behavior |
| | Smaller | − | − (Weak competition) | − (Diverge) | Increase of dropouts |

[a] $SV_{sales}$: state of versatility measured by sales entropy; and $SD_{OIS}$: standard deviation of OIS.

trend in OIS display divergence demonstrating a clear distinction between winner and defeated, while smaller firms display convergence demonstrating shifting to cartel behavior.

(ii) Contrary to those behaviors in pharmaceuticals, bigger firms of electrical machinery under a decreasing trend in OIS display convergence demonstrating acceleration of standardized behavior, while smaller firms display divergence demonstrating an increase of dropout firms.

## 5. Conclusion

Prompted by a postulate that sustainable development of firms under the megacompetition can be expected by systems resilient with sustainable innovation function, this paper attempts to identify a resilience structure for high-technology firms that are experiencing megacompetition.

Firstly, based on an intensive review of states of Japan's high-technology industries focusing on R&D and profits, a general function depicting governing factors on operating income to sales (OIS) incorporating economic cycle orbit depicted by sine curve function was developed.

Secondly, using this model, a comparative empirical analysis of Japanese pharmaceutical (30) and electrical machinery (24) industries taking R&D intensive firms in the respective industry over the period 1979–1998 was conducted.

On the basis of the empirical analysis following findings suggesting a resilient structure for sustaining OIS were obtained:

(i) Elasticity of economic cycle operating income to sale in pharmaceutical is much smaller than that of electrical machinery which demonstrates that operating income to sales of pharmaceutical is not so sensitive to decline in economic cycle as electrical machinery. This propensity can be observed more clearly by classifying bigger and smaller firms.

(ii) Both industries demonstrate that operating income to sales decreases as Yen rate increases (strong Yen). This is because both industries are export oriented industries. In pharmaceuticals, smaller firms are more sensitive than bigger firms, while bigger firms are more sensitive in electrical machinery.

(iii) Elasticity of functionality in pharmaceuticals is more stable (less elastic) than that of electrical machinery which implies that the possibility of failing to capture economic fluctuations can be minimized even in cases of decrease of functionality development.

(iv) An increase of sales entropy contributes to an increase in OIS in pharmaceuticals with high elasticity while it is the reverse in electrical machinery. This is due to the structural difference between the two industries with respect to homogeneity. An increase in sales entropy implies stimulation of competition leading to an increase in OIS in pharmaceuticals while it decreases in OIS in electrical machinery.

(v) Pharmaceuticals maintain relatively higher positive coefficients with respect to time trend than electrical machinery supported by its self-propagating structure regarding new functionality development.

These findings demonstrate that the structural sources of the degree of operating income to sales in electrical machinery can be attributed to its sensitive structure to change in economic cycle and functionality development which suffered from a significant decreasing trend. Contrary to such a structure in electrical machinery, pharmaceuticals maintain a more resilient structure against fluctuations of the economic cycle and uncertainty inherent

$$\varepsilon = \sum^{n} \frac{\frac{x_i}{n}}{\frac{z}{x_i}} \ln \frac{z}{\frac{x_i}{n}} = \sum^{n} \frac{\frac{x_i}{n}}{\sqrt{\sum^{n} \left(\frac{x_i}{n}\right)^2 - \phi^2}} \ln \frac{\sqrt{n \sum^{n} \left(\frac{x_i}{n}\right)^2 - \phi^2}}{\frac{x_i}{n}}$$

Therefore, entropy is subject to standard deviation and state of firms depicted by $x_i/n$.

to functionality development by diversifying the dependency on them.

These suggestions, with respect to a resilient structure, were demonstrated by further comparative analysis on factors contributing to OIS leading to an identification of a resilient structure that well balanced structure with less dependency on economic cycle and functionality development and incorporating stable innovation function supported by self-propagating structure.

Stimulated by a finding that state of versatility provides significant impact on OIS, a cyclical relation between state of OIS of industry and state of deviation of firms in the industry was identified leading to a correlation analysis between them. On the basis of this analysis it was identified that state of deviation of firms has a positive correlation with state of OIS in bigger firms in both pharmaceuticals and electrical machinery industries, while it was the opposite correlation in the case of smaller firms in both industries.

These findings provide reasonable interpretation on "dropping out of the race" phenomena observed in a few industries in Japan in the later half of the 1990s.

More specifically, the following noteworthy observations with respect to institutional behavior of pharmaceutical and electrical machinery firms in the 1990s under megacompetiton were observed:

(i) Bigger firms of pharmaceuticals under an increasing trend in OIS display divergence demonstrating a clear distinction between winner and defeated, while smaller firms display a convergence demonstrating shifting to cartel behavior.
(ii) Contrary to this behavior in pharmaceuticals, bigger firms of electrical machinery under a decreasing trend in OIS display convergence demonstrated an acceleration of standardized behavior, while smaller firms display divergence demonstrating an increase of dropout firms.

All provide constructive insight suggestive to survival strategy for high-technology firms that are experiencing in a megacompetition by means of restructuring to a resilient structure.

Future works should be focused on further elucidation of system interaction in an OIS orbit function including elucidation of twisted correlation of state of versatility and deviation of firms between bigger firms and smaller firms. In addition, application of developed approach to broader industries would provide further insight not only supportive to survival strategy for these industries but also suggestive to the above elucidation.

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