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Description	一般論文

1F16 インスティテューショナル技術経営学の確立へのアプローチ
―イノベーションとインスティテューションとの共進ダイナミズムの解明

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1. Introduction

The essence of innovation is highly dependent on the co-evolution with institution. Innovation evolves institution and the evolving institution causes a further innovation. This paper, on the basis of an empirical analysis, attempts to elucidate the co-evolutionary dynamism between innovation and institutional systems.

2. Japan's Co-evolutionary Development Cycle – Learning and Assimilation

2.1 Japan's Unique Learning Function

Japan's conspicuous X-efficiency can largely be attributed to its intensive cumulative learning efforts with the following unique function as (i) Motivated by xenophobia; (ii) Cumulative learning stimulates assimilation of spillover knowledge; and (iii) Rich in curiosity, smart in assimilation, thorough in learning and absorption.

2.2 Learning and Assimilation

Based on this unique function, Japan's system of MOT successfully achieved a co-evolutionary development by learning and assimilating advanced innovation from the US and Europe and advancement of own institutional systems as illustrated in **Fig. 1**.

US and Europe were inspired and improved their innovation and systems, then Japan learned there efforts and further developed its systems leading to a cycle.

Japan's cumulative learning minimized the impediments of the organizational inertia and it also accelerated assimilation of spillover technology.

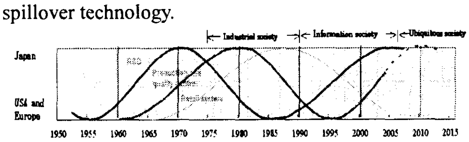


Fig. 1. Co-evolutionary Development Cycle of Japan's Systems of MOT.

2.3 Cumulative Learning Leads Japan's Surge to Recovery and New Functionality Development

While learning coefficients in Japan's leading electrical machinery firms continued to decrease in the1980s and the early 1990s, Canon changed to increasing trend from 1992, followed by Sharp in 1997.

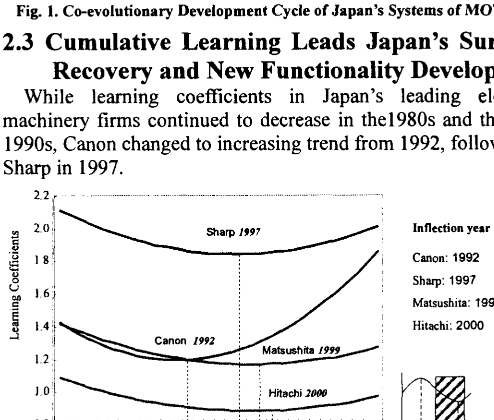


Fig. 2. Trend in Learning Coefficient in Japan's 4 High-technology Firms*(1980-2003).*

See also Cession 1A03(Kayamo Fukuda) and 1A19(Koji Moriyama).

Fig. 2 demonstrates that cumulative learning efforts during the course of the lost decade in the 1990s have born fruit in recovering Japan's indigenously well functioned learning dynamism.

The contribution of cumulative learning to new functionality development which represents the dynamic carrying capacity on some degree can be demonstrated in **Fig. 3**.

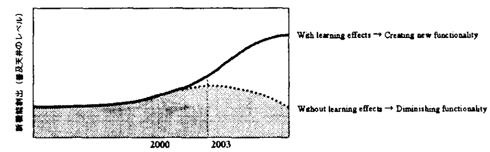
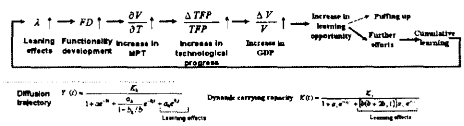


Fig. 3. Estimated Trajectory of Dynamic Carrying Capacity in Japan's Leading Electrical Machinery Firms.



The dynamism between learning, new functionality development, and sustainable co-evolution as illustrated in **Fig. 4** plays an important role in Japan's co-evolutionary development cycle.

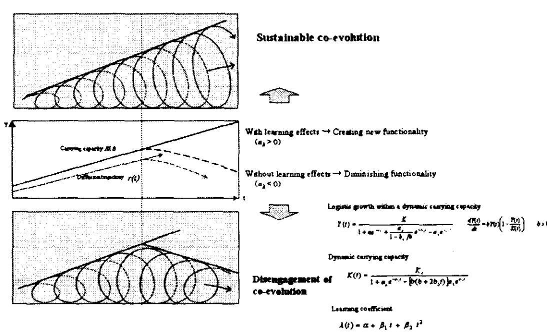


Fig. 4. Dynamism between Learning, New Functionality Development, and Sustainable Co-evolution.

2.4 Sustainable Co-evolution Initiated by Mobile Phones

Noteworthy co-evolutionary dynamism between innovation and institutional systems can be observed recently in Japan's mobile-phone driven co-evolutionary dynamism as illustrated in **Fig. 5**.

2.5 Reactivation of a Co-evolutional Function

It is noted that the reactivation of a co-evolutional function is indigenously incorporated in Japan's way of management of technology as demonstrated in **Fig. 6**.

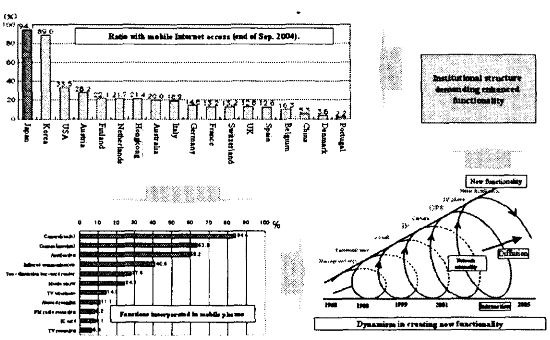


Fig. 5. Co-evolution of Innovation Initiated by Mobile Phones.

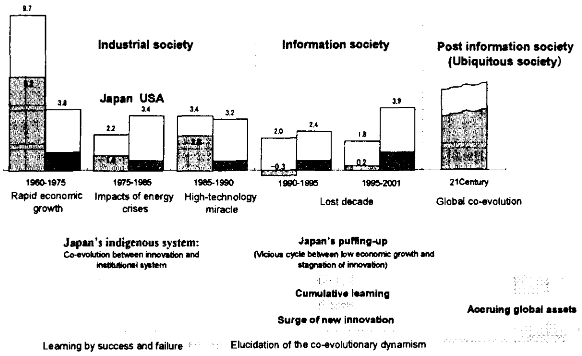


Fig. 6. Reactivetion of a Co-evolutiona Function.

2.6 Possibility for Reversal

From the statistics in different societies in **Fig. 7**, it is noted that Japan is reversing from the lost decade and increasing its competitiveness steadily and it is anticipated that "Japan flying again"(The Economist, Feb. 12, 2004).

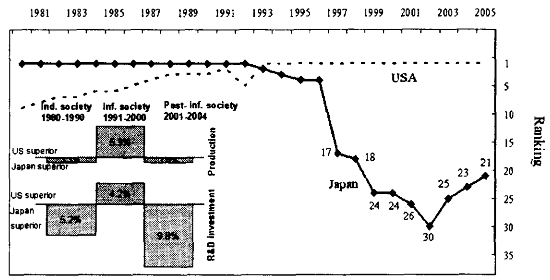
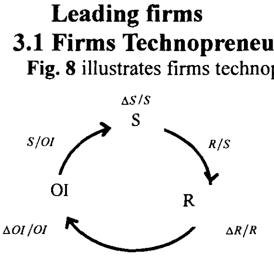


Fig. 7. Trend in the Competitiveness Ranking in Japan and US (1980-2005).

3. Transformation to Technopreneurship in Leading firms

3.1 Firms Technopreneur Dynamism

Fig. 8 illustrates firms technopreneur structure.



S : Sales; *R* : R&D investment;

OI : Operating income; *R/S*: R&D intensity;

OI/R : Operating income to R&D; and

S/OI: 1 /Operating income to sales

Fig. 8. Firms Technopreneur Structure.

Principal Component Analysis (PCA) is introduced to analyze the technopreneur dynamism in Japan's leading 60 electrical machinery firms (**Tables 1** and **2**).

Table 1 Descriptive Statistics of Principal Components (PCs)

PCs	Eigen value	Variance proportion	Cumulative variance proportion
1	1.657	27.62%	27.62%
2	1.466	24.44%	52.05%
3	1.042	17.37%	69.42%
4	0.799	13.31%	82.73%
5	0.586	9.77%	92.51%
6	0.450	7.49%	100.00%

Table 2 Standardized Weight of Valuables in Selected PCs

	Selected PCs		
	PC1	PC2	PC3
R/S	0.483	−0.182	0.445
OI/R	−0.622	0.267	−0.063
S/OI	0.373	0.538	−0.226
ΔS/S	−0.355	0.447	0.399
ΔR/R	0.139	0.369	0.660
ΔOI/OI	0.309	0.521	−0.389

The analytical process of co-evolution between technopreneur dynamism and market value of equity is as follows:

$$\underset{(-5.48)}{MVE = -0.366} \underset{(0.75)}{+0.035PC_1} \underset{(4.31)}{+1.112D_1PC_1} \underset{(0.83)}{+0.045PC_2} \underset{(-4.13)}{-0.618D_2PC_2} \underset{(1.26)}{+0.076PC_3} \underset{(3.72)}{+1.185D_3PC_3} \underset{(7.26)}{+2.134D_0}$$

$adj.\ R^2 = 0.791$

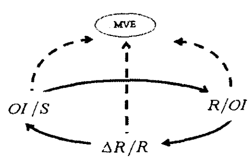
Stepwise screening approach

$$\underset{(-5.50)}{MVE = -0.358} \underset{(4.50)}{+1.122D_1PC_1} \underset{(-4.17)}{-0.573D_2PC_2} \underset{(1.28)}{+0.077PC_3} \underset{(3.70)}{+1.168D_3PC_3} \underset{(7.34)}{+2.141D_0} \qquad adj.\ R2 = 0.794$$

MVE: Market value of equity = Stock price × Number of stock issued
PC_1 : 1st PCs (*R/OI* : R&D directivity to OI initiated);
PC_2 : 2nd PCs (*S/OI* : 1 / OIS initiated);
PC_3 : (*Δ R/R* : Increase rate of R&D investment driven)
$D_1 \sim D_3$: Coefficient dummy variables
D_3 : 10 firms (Canon, Sharp, Sony, Sanyo, Ricoh, Rohm, Seiko Epson, Murata Manufacturing, Fanuc, TDK) **= 1, 50 firms = 0,**
D_1 D_2 : 10 firms in D_3 + 6 firms (Matsushita Electric, Hitachi, NEC, Toshiba, Fujitsu, Mitsubishi Electric) **= 1, 44 firms = 0.**
D_0 : Constant dummy variable (Canon, Sony, Matsushita Electric, Hitachi = 0, 46 firms = 0)

Based on the analysis, the co-evolutionary structure in Japan's leading 60 electrical machinery firms can be illustrated in **Fig. 9**.

	PC_1	PC_2	PC_3
10 firms	1.122	−0.573	1.246
6 firms	1.122	−0.573	0.077
44 firms	0	0	0.077
	(induced by *R/OI*)	(by *OI/S*)	(by *ΔR/R*)



MVE : Market Value of Equity;
OI/S : Operating income to sales;
R/OI : R&D directivity to OI;
ΔR/R : Increase rate of R&D investment.

Fig. 9. Co-evolutionary Structure between Technopreneur Dynamism and Market Value of Equity.

3.2 OIS-ROI Structure

Fig. 10 analyzes the correlation between OIR (1/ROI) and OIS in Japan's leading electrical machinery firms over the period 2001-2004. The Fig. demonstrates the significant correlation between them with the slope 0.048 which indicates R&D intensity (R/S). This demonstrates that leading electrical machinery firms share the similar R&D intensity.

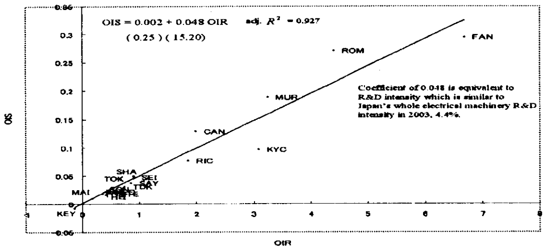


Fig. 10. OIS-ROI Structure in Japan's Leading 60 Electrical Machinery Firms *(2001-2004)*.

3.3 Change in Technopreneurial Features

Fig. 11 analyzes the correlation between coefficient of variant of OIR and OIS in 19 firms in 2001-2004 which demonstrates that 19 firms are divided into two groups, 8 higher coefficient of variant firms and 11 lower firms.

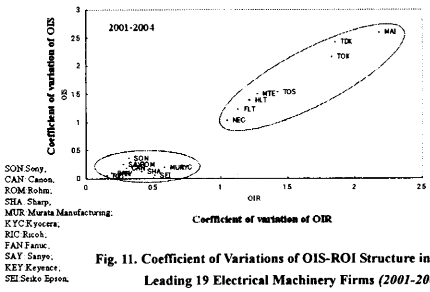


Fig. 11. Coefficient of Variations of OIS-ROI Structure in Japan's Leading 19 Electrical Machinery Firms *(2001-2004)*.

[a] Firms examined in 1984-1990 and 1991-2000 do not necessarily correspond to 19 firms examined in 2001-2004.

4. Cross-evaluation by TFP Regression

In order to demonstrate the results of the foregoing empirical analyses, cross evolution is conducted by means of TFP regression.

4.1 Analytical Framework

Governing factors to TFP growth

$$\frac{\Delta TFP}{TFP} = a' + b'\frac{R}{OI} + c'\frac{OI}{S} + d'\frac{\Delta R}{R}$$

R: R&D investment, OI: Operating income, S: Sales, ΔX: dX/dt

$$\frac{\Delta TFP}{TFP} = a' + b'\frac{R}{OI} + c'\frac{OI}{S} + d'\left(\frac{\Delta R/S}{R/S} + \frac{\Delta S}{S}\right)$$

$$S = F(X, T)$$

$$\frac{\Delta S}{S} = \sum\left(\frac{\partial S}{\partial X}\frac{X}{S}\right)\frac{\Delta X}{X} + \frac{\partial S}{\partial T}\frac{T}{S}\frac{\Delta T}{T}$$

$$\approx \sum\left(\frac{\partial S}{\partial X}\frac{X}{S}\right)\frac{\Delta X}{X} + \frac{\partial S}{\partial T}\frac{R}{S} \qquad \Delta T \approx R$$

$$= \sum\left(\frac{\partial S}{\partial X}\frac{X}{S}\right)\frac{\Delta X}{X} + \frac{\Delta TFP}{TFP}$$

Under the mature economy with aging and low birth rate, growth depends on technological progress,

$$\frac{\Delta S}{S} \approx \frac{\Delta TFP}{TFP}$$

When $\frac{\Delta R/S}{R/S} \ll 1$

$$(R/S)_t = (R/S)_0\left(1+\frac{\Delta R/S}{R/S}\right)^t \approx (R/S)_0\left(1+t\frac{\Delta R/S}{R/S}\right)$$

Given certain $t = n_0$

$$\frac{\Delta R/S}{R/S} \approx \left[\frac{(R/S)_t}{(R/S)_0} - 1\right]\Big/t = g(R/S)_t - h$$

where $g = 1/[(R/S)_0\, n_0]$, and $h = 1/n_0$.

Therefore,

$$\frac{\Delta TFP}{TFP} = a' + b'\frac{R}{OI} + c'\frac{OI}{S} + d'\left(g\frac{R}{S} - h + \frac{\Delta TFP}{TFP}\right)$$

$$(1-d')\frac{\Delta TFP}{TFP} = (a'-d'h) + b'\frac{R}{OI} + c'\frac{OI}{S} + d'g\frac{R}{S}$$

$$\frac{\Delta TFP}{TFP} = \left(\frac{a'-d'h}{1-d'}\right) + \left(\frac{b'}{1-d'}\right)\frac{R}{OI} + \left(\frac{c'}{1-d'}\right)\frac{OI}{S} + \left(\frac{d'g}{1-d'}\right)\frac{R}{S}$$

$$= a + b\frac{R}{OI} + c\frac{OI}{S} + d\frac{R}{S}$$

where $a = \frac{a'-d'h}{1-d'}$, $b = \frac{b'}{1-d'}$, $c = \frac{c'}{1-d'}$, $d = \frac{d'g}{1-d'}$.

$R/OI = x \quad OI/S = y \quad \partial S/\partial T = z \quad R/S = xy$

$$xyz = a + bx + cy + dxy$$

$$z = \frac{a+bx+cy}{xy} + d$$

$$xy = \frac{R}{S} = \left(\frac{R}{S}\right)_0(1+\varepsilon) \approx \left(\frac{R}{S}\right)_0$$

Given that $\varepsilon \ll 1$

$$z = \frac{a+bx+cy}{xy} + d = \frac{a}{(R/S)_0} + \frac{b}{(R/S)_0}\cdot\frac{(R/S)_0}{y} + \frac{c}{(R/S)_0}y + d$$

$$z = \alpha + \frac{\beta}{y} + \gamma y$$

where $\alpha = \frac{a}{(R/S)_0} + d$, $\beta = b$, $\gamma = \frac{c}{(R/S)_0}$.

$$\frac{dz}{dy} = -\frac{\beta}{y^2} + \gamma = 0; \quad y = \sqrt{\frac{\beta}{\gamma}} = \sqrt{\frac{b}{c}\left(\frac{R}{S}\right)_0} \quad \text{(minimum point)}$$

$$y = \sqrt{\frac{b}{c}\left(\frac{R}{S}\right)_0} = \frac{\left(\frac{R}{S}\right)_0}{x} = OI/S$$

$$x = \sqrt{\frac{c}{b}\left(\frac{R}{S}\right)_0} = R/OI \qquad OI/R = \sqrt{\frac{b}{c}\Big/\left(\frac{R}{S}\right)_0}$$

$y > \sqrt{\frac{b}{c}\left(\frac{R}{S}\right)_0}$, $x < \sqrt{\frac{c}{b}\left(\frac{R}{S}\right)_0}$ ⇨ $\frac{\partial z}{\partial y} > 0$ Group A

$y < \sqrt{\frac{b}{c}\left(\frac{R}{S}\right)_0}$, $x > \sqrt{\frac{c}{b}\left(\frac{R}{S}\right)_0}$ ⇨ $\frac{\partial z}{\partial y} < 0$ Group B

Necessary requirement to be a Group A firm

$y = \frac{OI}{S} > \sqrt{\frac{b}{c}\left(\frac{R}{S}\right)_0}$ ⇨ $\frac{1}{x} = \frac{OI}{R} > \sqrt{\frac{b}{c}\Big/\left(\frac{R}{S}\right)_0}$

$\frac{OI}{R}$ (Profitability of R&D intensity)

rather than R/S has become crucial.

4.2 Empirical Analysis

$$\frac{\Delta TFP}{TFP} = a + b_1\frac{R}{OI} + b_2 D\frac{R}{OI} + c_1\frac{OI}{S} + c_2 D\frac{OI}{S} + d_1\frac{R}{S} + d_2 D\frac{R}{S}$$

D: Coefficient dummy variable (13 firms including SON, CAN, MAI, HLT, SHA, FLT, NEC, TOS, RIC, FAN, MTE SAY, SEI = 1[1], other 6 firms including ROM, MUR, KYC, TOK, KEY, TDK = 0)

a	b_1	b_2	c_1	c_2	d_1	d_2	adj. R^2
-0.028	-0.001	0.019	-0.021	0.394	0.772	0.136	0.895
(-2.65)	(-0.974)	(2.40)	(-0.74)	(1.78)	(4.18)	(0.32)	

Backward elimination method

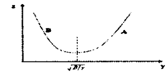
a	b_1	b_2	c_1	c_2	d_1	d_2	adj. R^2
-0.025		0.021		0.458	0.681		0.915
(-2.82)		(9.37)		(7.32)	(4.50)		

In case $\left(\frac{R}{S}\right)_0 = 0.048$ then $\alpha = \frac{-0.025}{0.048} + 0.681 = 0.160$, $\beta = 0.021$, $\gamma = \frac{0.458}{0.048} = 9.542$

$$y_{min} = \sqrt{\frac{\beta}{\gamma}} = \sqrt{\frac{b}{c/(R/S)_0}} = \sqrt{\frac{b}{c}\cdot\left(\frac{R}{S}\right)_0} = \sqrt{\frac{0.021}{0.458}\cdot 0.048} = \sqrt{0.00165} = 0.047$$

1) Similar to logistic dummy variable, TFP growth rate is considered in weighting variables as 0.1 for SON, MAI, HLT, FAN

(1) Development State of Firms



A: CAN, SHA, SON, SAY, RIC, ROM, FAN, MUR, KYC

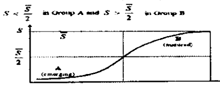
B: MAI, NEC, HLT, TOS, MTE, FLT, TDK, TOK

$z = \frac{\partial S}{\partial T}$, $y = OI/S$

$\frac{\partial z}{\partial y} > 0$ when $y > \sqrt{\beta/\gamma}$ (Group A) $\qquad \frac{\partial z}{\partial y} < 0$ when $y < \sqrt{\beta/\gamma}$ (Group B)

$z = \frac{\partial S}{\partial T} = aS\left(1 - \frac{S}{\bar{S}}\right) \qquad \frac{\partial z}{\partial y} = a\frac{\partial S}{\partial y}\left(1 - \frac{2S}{\bar{S}}\right) \qquad$ In general $\frac{\partial S}{\partial y} = \frac{\partial S}{\partial\, OI/S} > 0$

Then, $S < \frac{\bar{S}}{2}$ in Group A and $S > \frac{\bar{S}}{2}$ in Group B



(2) Effects of Learning Efforts

Learning efforts ⟶ increase FD (functionality development: $\bar{S}/S$)

$$\longrightarrow \text{increase } \frac{\partial S}{\partial T} = z \longrightarrow \begin{cases} \text{increase} & \text{OIS } (= y) \text{ in Group A} \\ \text{decrease} & \text{OIS } (= y) \text{ in Group B} \end{cases}$$

(3) Degree of Fluctuation (Coefficient of Variation)

$$z = \alpha + \frac{\beta}{y} + \gamma y$$

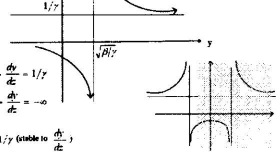
Differentiate by z

$$\frac{dz}{dz} = -\beta\frac{1}{y^2}\frac{dy}{dz} + \gamma\frac{dy}{dz}$$

$$\frac{dy}{dz} = \frac{1}{\gamma - \frac{\beta}{y^2}}$$

$y > \sqrt{\frac{\beta}{\gamma}} \longrightarrow \frac{dy}{dz} > 0 \quad \left(\sqrt{\frac{\beta}{\gamma}} \ll y\right) \longrightarrow \frac{dy}{dz} = 1/\gamma$

$y > \sqrt{\frac{\beta}{\gamma}} \longrightarrow \frac{dy}{dz} < 0 \quad \left(y \to \sqrt{\frac{\beta}{\gamma}}\right) \longrightarrow \frac{dy}{dz} = -\infty$



Group A firms ($y > \sqrt{\frac{\beta}{\gamma}}$) : OIS increase ⟶ $1/\gamma$ (stable to $\frac{dy}{dz}$)

Group B firms ($y > \sqrt{\frac{\beta}{\gamma}}$) : OIS increase ⟶ access to $\sqrt{\beta/\gamma} = -\infty$ (sensitive to $\frac{dy}{dz}$)

4.3 Technopreneurial Situation of Japan's Leading Electrical Machinery Firms

Fig. 12 illustrates the techno-preneurial situation in Japan's leading electrical machinery firms in 2001-2004 which demonstrates clearly the two groups: firms with coevolution between OIS and marginal productivity of technology and those with disengagement.

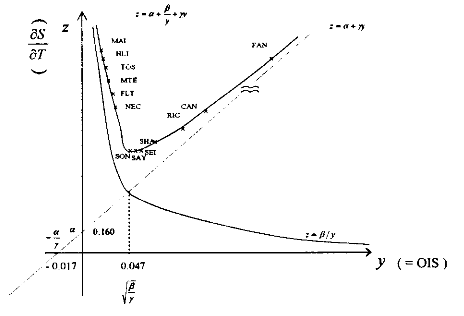


Fig. 12. Techno-preneurial Situation of Japan's Leading 13 Electrical Machinery Firms *(2001-2004)*.

[a] In order to avoid irregular OIS change after 2001, SON's OIS is base on the average between 1984 – 2004. Similarly, SAY's OIS is exclusive of 2002.

5. External Acquisition Dynamism.

5.1 Co-evolution between OIS and Marginal Productivity of Technology

These two groups firms can be classified as firms with (i) Operating income to R&D (OIR) substitutes for R&D intensity (R/S) and (ii) OIR complements R/S as compared in **Table 3.**

Table 3 Coefficient between R&D Intensity (R/S) and Operating Income to R&D (OIR) in Japan's Leading 10 Electrical Machinery Firms(1990-2004)

OIR = $a + b$ R/S

Group A	Coefficient b	adj. R^2	Group B	Coefficient b	adj. R^2
Canon	-24.51 (-4.12)	0.660	Hitachi	6.42 (7.41)	0.660
Sharp	-13.98 (-8.97)	0.860	Matsushita Electric	14.58 (3.37)	0.833
Ricoh	-53.57 (-8.95)	0.908	Toshiba	10.59 (4.77)	0.681
Fanuc	-123.00 (-8.00)	0.887	NEC	1.94 (1.82)	0.589
			Fujitsu	0.82 (1.45)	0.425
			Mitsubishi Electric	10.26 (6.14)	0.833
(OIR substitutes for R/S)			**(OIR complements R/S)**		

Figures in parentheses indicate t-value.
Dummy variables are used corresponding to identical circumstances in each respective firms.

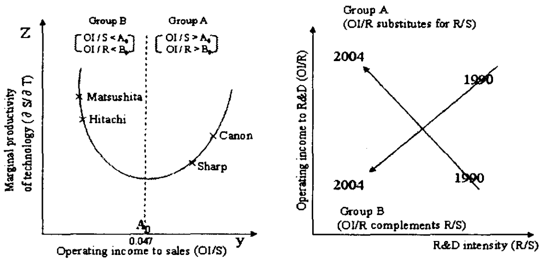


Fig. 13. Technopreneurial Situation toward a Co-evolution between OIS and Marginal Productivity of Technology Enabled by OIR Substitution for R&D Intensity.

5.2 Scheme of OIR Substitution for R/S

Fig. 14 demonstrates the mechanism shifting from R/S driven to OIR driven technopreneruship which suggests the significance of the shift from internal generation to external acquisition.

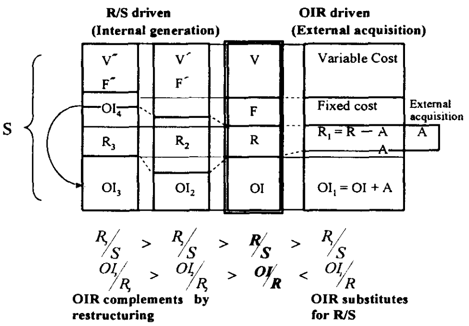
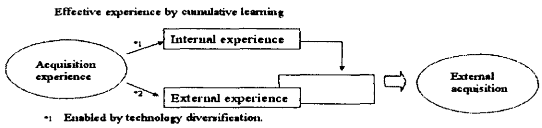


Fig. 14. Scheme of OIR Substitution for R/S by External Acquisition.

5.3 External Acquisition Dynamism

Fig. 15 shows the external acquisition dynamism according to effective experience depending on own internal experience enabled by technological diversification or external experience based on higher competitiveness.



*1 Enabled by technology diversification.
*2 Enabled by higher competitiveness.

Fig. 15. External Acquisition Dynamism.

Table 4 Learning External Acquisition and OIR Substitution for R/S in Japan's 4 Leading Electrical Machinery Firms

	Cumulative learning $\lambda_{2004}/\lambda_{1990}$	(Inflection year)[a]	Substitution coefficient[b]	Internal experience	External acquisition
Canon	1.25	(1992)	-24.51		
Sharp	1.01	(1997)	-13.98		
Hitachi	0.94	(2000)	6.42		
Matsushita	0.97	(1999)	14.58		

[a] See Fig. 2.
[b] Indicates coefficient b in the equation OIR = $a + b$ R/S.OIR substitutes for R/S when b is negative (see Table 3).

Table 5
Technopreneur Strategies Leading to Contrasting Development Trajectories

	Technopreneur strategy	Technopreneur situation $\left(\frac{dOIR}{dR/S}\right)$	Marginal productivity $\left(\frac{d\partial S/\partial T}{dOIR}\right)$	Contribution to TFP increase $\left(\frac{\Delta TFP}{TFP}=\frac{\partial S}{\partial T}\cdot\frac{R}{S}\right)$	Development trajectory
Group A firms	OIR driven (External acquisition)	− (Substitute)	+ (Co-evolution)	$\frac{\partial S}{\partial T}$	New functionality development model
Group B firms	R/S driven (Internal generation)	+ (Complement)	− (Disengagement)	$\frac{R}{S}$	Economic growth dependent model

Summarizing these analyses, **Table 6** postulates changing faces of entrepreneurial features corresponding to the transformation of the characterization of technology.

Table 6 Changing Faces of Entrepreneurial Features Corresponding to the Transformation of the Characterization of Technology

	- 1980s	1990s	After the early 2000s
Paradigm	Industrial society	Information society	Post-information society
Core technology	Manufacturing technology (MT)	ICT	Service oriented manufacturing
Key features	Given Provided by suppliers	To be formed during the course of interaction with institutions	On demand formation
Optimization scope	Individual firms / organization	Institutions as a whole	Ubiquitous optimization
Technopreneurial norm	R&D intensity (R/S)	Operating income to R&D (OI/R)	
Technopreneurial strategy	Internal generation	External acquisition	
Entrepreneurial features	Homogenous indigenousness	Non-homogenous features	

5. Conclusion

From the analysis above, Japan's system of MOT indigenously incorporates an explicit function to induce this co-evolutionary dynamism which was elucidated and consequent suggestions include:

(i) Characterization of technology through the course of interaction with institutions is in a self-propagating way.
(ii) Institutional elasticity (e.g. flexibility, adaptability an openness to foreign ideas) is essential.
(iii) Cumulative learning by interactions would be the key in incorporating the new functionality.
(iv) Consequently, transformation to technopreneurship in leading firms with cumulative learning efforts is observed.

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