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Description	一般講演要旨

１Ｃ１４

ハイブリッド技術経営－IT の自己増殖機能の内生化と製造技術の共進
Hybrid Management of Technology – *Domestication of Self-propagating Function of IT and Co-evolution with Manufacturing Technology*

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1. Introduction

While Japan incorporates an explicit function on the co-evolution between innovation and institutional systems, it shifted to the opposite in the 1990s, resulting in a lost decade due to a systems conflict between indigenous institutional systems and a new paradigm in an information society as a consequence of the mis-option of the growth trajectory clinging to a growth oriented trajectory, not functionality development trajectory.

A swell of reactivation emerged in the early 2000s can be attributed to Hybrid management fusing the “East” (indigenous strength) and the “West” (lessons from an IT driven new economy) typically observed in mobile driven innovation that led to a functionality development trajectory. Canon has incorporated such fusing system, thereby is able to maintain sustainable functionality development.

On the basis of the theoretical and empirical analysis taking Japan’s mobile phones development and also Canon’s hybrid management, new business model toward a post-information society and corresponds to enterprise 2.0 is postulated.

2. Functionality Development

2.1Growth Trajectory Option

Growth trajectory option can be contrasted as illustrated in **Fig. 1**.

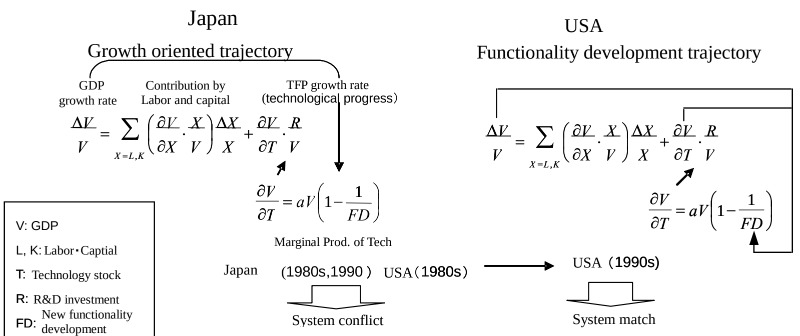


Fig. 1. Growth Trajectory Option. Source: Watanabe et al. (2003).

2.2 Measurement of Functionality Development

Provided that production of innovative goods V in high-technology firms are governed by technology stock (T), their production function can be depicted as follows:

$$V = F(X,T) = F(X(T)) \approx F(T) \qquad (1)$$

where V: production of innovative goods; X: labor (L) and capital (K); and T: technology stock.

Their diffusion trajectories by technology stock (T) can be developed in line with the epidemic function (2) that leads to a **simple logics growth function** (LGF) and **LGF within a dynamic carrying capacity** depicted by equations (3) and (3-2).

$$\frac{\partial V}{\partial T} = bV(1-\frac{V}{N}) = bV(1-\frac{1}{FD}) \qquad (2) \qquad\qquad V = \frac{N}{1+ae^{-bT}} \qquad (3)$$

where b: velocity of diffusion; N: carrying capacity; $FD = N/V$: functionality development; N_k: ultimate carrying capacity; and a', a_l, a_k, b_k: coefficients

$$V = \frac{N_K}{1+ae^{-bT} + \frac{a_K}{1-b_K/b}e^{-b_K T}} = \frac{N_K}{1+ae^{-bT}\cdot\left(1+\frac{a_K}{a}\cdot\frac{1}{1-b_K/b}e^{(b-b_K)T}\right)} \approx \frac{N_K}{1+ae^{-bT}\cdot e^{\frac{a_K}{a}\cdot\frac{1}{1-b_K/b}(1+(b-b_K)T)}}$$
$$\approx \frac{N_K}{1+ae^{\frac{a_K}{a}\cdot\frac{1}{1-b_K/b}}\cdot e^{-b\left(1-\frac{a_K}{a}\right)T}} \approx \frac{N_K}{1+a\left(1+\frac{a_K}{a}\cdot\frac{1}{1-b_K/b}\right)\cdot e^{-b\left(1-\frac{a_K}{a}\right)T}} \equiv \frac{N_K}{1+a'e^{-b'T}} \qquad (3\text{-}2)$$

While emergence of innovation creates new functionality, it obsolesces immediately. Therefore, IT’s new functionality development corresponds to the effort to prolong this obsolescence. In equation (3-2), since $a\left(1+\frac{a_K}{a}\cdot\frac{1}{1-b_K/b}\right) > a$， $b(1-a_K/a) < b$, initial level of FD increases and velocity to obsolescent decreases as a_K/a increases. Thus, a_K/a demonstrates "prolongation ability"[1]. Successive innovation depicted by the **bi-logistic model** demonstrates this ability.

3. Functionality Development Dynamism

3.1 Emergence Development in Japan's Mobile Phones

Given the two co-existing innovation diffusion as depicted by the following **bi-logistic model**, the level of diffusion and its timing when each respective functionality development emerges can be identified as summarized in **Table 1** and illustrated in the left hand-side of **Fig. 2**.

$$V = V_1 + V_2 = \frac{N_1}{1 + a_1 \exp(-b_1 t)} + \frac{N_2}{1 + a_2 \exp(-b_2 t)} \quad (3\text{-}3)$$

N_1 and N_2: carrying capacities; a_1 and a_2: initial stage of diffusion; b_1 and b_2: velocity of diffusion; and t: time trend.

Table 1 Estimation of the level of diffusion and timing by the bi-logistic growth

Development phase	Level of diffusion	Timing	FD
V_1	N_1/n_1	$t_1 = n(a_1/(n_1-1))/b$	n_1
V_2	N_2/n_2	$t_2 = \ln(a_2/(n_2-1))/b$	n_2

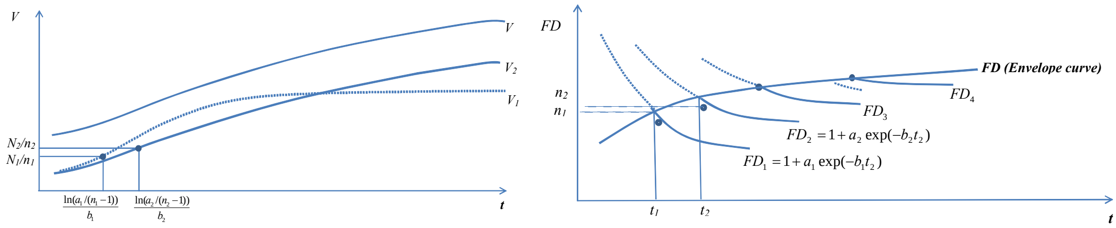


Fig. 2. Scheme of functionality development corresponding to the diffusion of the successive innovation.

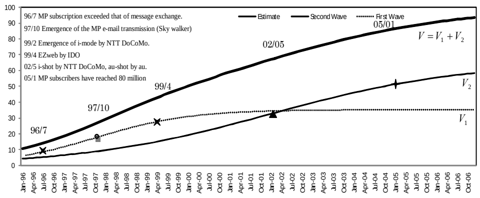
3.2 Functionality Development Function

Japan's mobile phones development over the period Dec. 1995-Dec. 2006 is Their diffusion dynamism is illustrated in **Fig. 3.** and summarized in **Table 2**.

Table 2 Estimation of Japan's mobile phones diffusion by the bi-logistic growth*(Dec1995-Dec 2006)***

	N_1	a_1	b_1	N_2	a_2	b_2	adj. R^2
Parameter	35.147	5.198	0.074	65.418	14.028	0.036	0.999
t-value	2.25*	3.26*	4.59*	3.81*	1.33**	6.74*	

*: indicates significant at the 1% level. **: indicates significant at the 10% level.



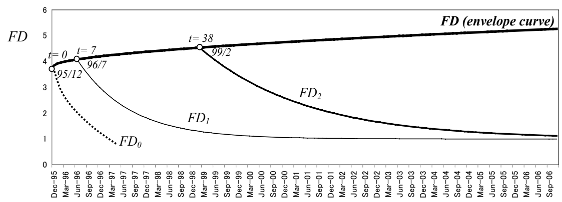


Fig. 3. Diffusion dynamism of Japan's mobile phones *(December 1995-December 2006).*

Fig. 4. Trajectory of functionality development phones in Japan's mobile *(1996-2006).*

FD increases as *t* increases with diminishing returns to scale with respect to *t*.

$\frac{dFD}{dt} = H \cdot t^{\mu}$ therefore, $FD = \frac{H}{\mu+1} t^{\mu+1} + C$ where $\mu < 0$ and $H > 0$; and C: integral constant ($= FD_{t=0}$).

Since $FD_{t=0}$ describes the primitive emergence in Japan's mobile phone, and estimated to 3.838 by means of the level of new functionality at same time.Therefore, it is estimated that the value of H and μ are equal to 0.048 and –0.330, respectively. On the basis of this estimation, functionality development can be expressed as follows: $FD = 0.072\, t^{0.670} + 3.838$ (7)

Consequently, trend in trajectory of functionality development as demonstrated in **Fig. 4** shows a sustainable increase in functionality development for Japan's mobile phones over the decade.

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[1] When $a_K/a = x$, FD can be expressed as: $FD = 1 + a(1 + x \cdot \frac{1}{1 - b_K/b}) e^{-b(1-x)T}$ Under the fixed a condition, take differentiation of FD with respect to x,

$\frac{dFD}{dx} = \frac{a}{1 - b_K/b} e^{-b(1-x)T} + abt(1 + x \cdot \frac{1}{1 - b_K/b}) e^{-b(1-x)T} > 0$ as $a > 0, b > 0$ and $a_K/a < 1$

3.3 Sources of Self-propagating Functionality Development

Since high technology products can be considered as the crystal of technology stock, the epidemic function can be developed incorporating technology stock T instead of time t as follows (Watanabe et al., 2003):

$$V(T)=\frac{N}{1+ae^{-bT}} \quad (3) \qquad \text{Since } b<<1,\ FD=\frac{N}{V(T)}=1+b\exp(-aT)\approx 1+b(1-aT) \quad (4)$$

Taking partial differentiation of equation (3) with respect to technology stock T, the following equation depicting marginal productivity can be obtained:

$$\frac{\partial V}{\partial T}=bV\left(1-\frac{V}{N}\right)=bV\left(1-\frac{1}{FD}\right) \quad (2)$$

where $FD\equiv N/V$: degree of functionality development (Watanabe et al., 2005).

$T=T_i+zT_s$ where T: gross technology stock; T_i: indigenous technology stock; T_s: technology spillover pool; z: assimilation capacity $\left(z=\dfrac{1}{1+\dfrac{\Delta T_s/T_s}{\Delta T_i/T_i}}\cdot\dfrac{T_i}{T_s}\right)$; and zT: assimilated spillover technology.

$$FD=1+a(1-b(T_i+zT_s))=1+a-abT_i-abzT_s=2+(a-1)p+(a-1)q-abT_i-abzT_s=\left[1+(a-1)p\left[1-\frac{ab}{(a-1)p}T_i\right]\right]+\left[1+(a-1)q\left[1-\frac{ab}{(a-1)q}zT_s\right]\right]$$
$$=[1+a_1(1-b_1T_i)]+[1+a_2(1-b_2zT_s)]\approx(1+a_1\exp(-b_1T_i))+(1+a_2\exp(-b_2zT_s)) \quad (4\text{-}2)$$

where $b_1\equiv\left(\frac{ab}{(a-1)p}\right)$, $b_2\equiv\left(\frac{ab}{(a-1)q}\right)$, $a_1\equiv(a-1)p$, $a_2\equiv(a-1)q$ and $p+q=1$. Since $a>1$, $a_1>1$ and $a_2>1$.

This is equivalent to the successive FDs (FD_1 and FD_2) generated by the bi-logistic growth function as:

$$V=V_1+V_2=\frac{N_1}{1+a_1\exp(-b_1T_i)}+\frac{N_2}{1+a_2\exp(-b_2zT_s)} \quad (3\text{-}3')$$

where V_1: 1st wave generated by indigenous technology stock T_i; and V_2: 2nd wave generated by assimilated by spillover technology zT_s.

Therefore, functionality development generated by assimilating spillover technology is equivalent to those generated by the bi-logistic growth function with V_1 and V_2.

4. Sustainable Functionality Development

4.1 Requirement to Sustainable Functionality Development

Under the competitive circumstance where firms aim at maximizing their profits, equation (2) should be equivalent to relative prices as follows:

$$\frac{\partial V}{\partial T}=P=P_T/P_V$$

(2') Equation (2') can be developed as follows:

$$\frac{\partial V}{\partial T}=\frac{\Delta V}{\Delta T}=aV\left(1-\frac{V}{K}\right)=aV-a\frac{V^2}{K}=P \quad (2'')$$

where P: relative prices of technology; P_T: technology prices of innovative goods; and P_V: prices of innovative goods.

Differentiate equation (2'') by time t,

$$\Delta P=a\Delta V-2a\Delta V\frac{V}{K}=a\Delta V\left(1-2\frac{V}{K}\right)=aP\Delta T\left(1-\frac{2}{FD}\right) \qquad \frac{\Delta P}{P}=a\Delta T\left(1-\frac{2}{FD}\right)$$

Functionality development (FD) can be depicted as follows:

$$FD=\frac{2}{1-\dfrac{1}{a\Delta T}\dfrac{\Delta P}{P}}=\frac{2}{1-\dfrac{1}{aT}\dfrac{\Delta P/P}{\Delta T/T}}=\frac{2}{1-\dfrac{1}{aT}\dfrac{\partial\ln P}{\partial\ln T}}\equiv\frac{2}{1-\dfrac{\kappa}{aT}} \quad (5)$$

A case of Canon printers requirement to sustainable functionality development (FD) increase ($dFD/dT>0$) can be obtained as summarized as follows:

Functionality development (FD) can be depleted as follows → dFD/dT > 0 is the question

$$FD=\frac{2}{1-\dfrac{1}{a\Delta T}\dfrac{\Delta P}{P}}=\frac{2}{1-\dfrac{1}{aT}\dfrac{\Delta P/P}{\Delta T/T}}=\frac{2}{1-\dfrac{1}{aT}\dfrac{\partial\ln P}{\partial\ln T}}=\frac{2}{1-\dfrac{\kappa}{aT}} \quad (5)$$

where a : diffusion velocity, and κ : elasticity of technology to its relative prices ($=\partial\ln P/\partial\ln T$).

(5) Requirement to Sustainable Functionality Development: A case of Canon's Printers

Requirement to sustainable functionality development (FD) increase (dFD/dT > 0) can be obtained:

$$\frac{d}{dT}\left(1-\frac{\kappa}{aT}\right)=-\frac{1}{a}\frac{d}{dT}\frac{\kappa}{T}=-\frac{1}{a}\left(-\frac{\kappa}{T^2}+\frac{1}{T}\cdot\frac{d\kappa}{dT}\right)=-\frac{\kappa}{aT^2}\left(\frac{d\ln\kappa}{d\ln T}-1\right)<0 \quad (6)$$

Under the condition when $\kappa\left(=\frac{\partial\ln P}{\partial\ln T}\right)>0$, this requirement is equivalent to

$$\frac{d\ln\kappa}{d\ln T}>1 \quad (7)$$

Since elasticity of technology to its elasticity to price ($\frac{d\ln\kappa}{d\ln T}$) is smaller than 1 equation (7) can be satisfied by incorporating **the effects of external learning by means of two factors learning** as follows:

$$P=AT^{\kappa_1}PC^{\gamma}=A'T'^{\kappa_2} \quad (8)$$

where PC : cumulative PC shipment;
T': gross technology stock that incorporated the effects of external learning;
κ_1, γ and κ_2 : elasticities; and A, A' : scale factors.

In this condition, equation (7) requirement is equivalent to equation (9):

$$\frac{d\ln\kappa_2}{d\ln T'}>1 \quad (9)$$

Since **printers technology is induced by the dissemination of PC**, it can be depicted by equation (10):

$$T=B\cdot PC^{\phi} \quad (10)$$

where B : scale factor and ϕ: elasticity.

Taking logarithm of equation (8) and substituting PC in equation (10) for PC in equation (5-8), the following equation is obtained:

$$\ln P=\ln A+\kappa_1\ln T+\gamma\ln PC=\ln A+\kappa_1\ln T+\frac{\gamma}{\phi}(\ln T-\ln B)$$
$$=(\ln A-\frac{\gamma}{\phi}\ln B)+(\kappa_1+\frac{\gamma}{\phi})\ln T=\ln A'+\kappa_2\ln T' \quad (11)$$

From equation (11), the following identifications can be confirmed:

$$\ln A'=(\ln A-\frac{\gamma}{\phi}\ln B) \quad (12)$$

$$\kappa_2\ln T'=(\kappa_1+\frac{\gamma}{\phi})\ln T \quad (13)$$

Taking logarithm of equation (13),

$$\ln\kappa_2+\ln\ln T'=\ln(\kappa_1+\frac{\gamma}{\phi})+\ln\ln T \quad (14)$$

Differentiate equation (14) with respect to $\ln T'$

$$\frac{d\ln\kappa_2}{d\ln T'}+\frac{1}{\ln T'}=\frac{d\ln(\kappa_1+\frac{\gamma}{\phi})}{d\ln T'}+\frac{1}{\ln T}\frac{d\ln T}{d\ln T'} \quad (15)$$

($\frac{d\ln(\kappa_1+\frac{\gamma}{\phi})}{d\ln T'}$ is small enough with positive value)

$$\frac{d\ln\kappa_2}{d\ln T'}=\frac{d\ln(\kappa_1+\frac{\gamma}{\phi})}{d\ln T'}+\frac{1}{\ln T}\frac{d\ln T}{d\ln T'}-\frac{1}{\ln T'}>\frac{1}{\ln T}\frac{d\ln T}{d\ln T'}-\frac{1}{\ln T'}>1 \quad (16)$$

Thus, equation (7) requirement can be developed by the following inequality:

$$\frac{d\ln\kappa}{d\ln T}>1 \;■\; \frac{1}{\ln T}\frac{d\ln T}{d\ln T'}>1+\frac{1}{\ln T'} \;■\; \frac{1}{Y}\cdot\frac{dY}{dX}>1+\frac{1}{X}\left(\begin{array}{l}X\equiv\ln T'\\ Y\equiv\ln T\end{array}\right)$$

Provided that initial state of Y and X as Y_0 and X_0, respectively ($Y_0=X_0$ given that no external learning at the initial state), the above inequality can be developed as follows:

$$\frac{Y}{X}>e^{X-X_0}$$

From equation (13),

$$\kappa_2\ln T'=(\kappa_1+\frac{\gamma}{\phi})\ln T \;■\; \kappa_2X=(\kappa_1+\frac{\gamma}{\phi})Y$$

Therefore,

$$\kappa_2=(\kappa_1+\frac{\gamma}{\phi})\frac{Y}{X}>(\kappa_1+\frac{\gamma}{\phi})e^{X-X_0} \quad (17)$$

Inequality (17) depicts the requirement to sustainable functionality development increase under X ($\ln T'$) development.

X can be identified by the following steps:

From equations (11) and (12),

$$\kappa_2X_0=\kappa_2\ln T_0=\ln P_0-\ln A'=\ln P_0-(\ln A-\frac{\gamma}{\phi}\ln B) \quad (18)$$

$$\kappa_2=\frac{\ln P_0-(\ln A-\frac{\gamma}{\phi}\ln B)}{\ln T_0} \quad (19)$$

From equations (11), (17) and (18),

$$X=\frac{(\kappa_1+\frac{\gamma}{\phi})Y}{\kappa_2}=\frac{\ln P-(\ln A-\frac{\gamma}{\phi}\ln B)}{\kappa_2}=\frac{\ln P-(\ln A-\frac{\gamma}{\phi}\ln B)}{\ln P_0-(\ln A-\frac{\gamma}{\phi}\ln B)}\ln T_0 \quad (20)$$

Therefore, $X-X_0=\dfrac{\ln P/P_0}{\kappa_2}$

Substituting this balance for X-X_0 in inequality (17) **(the requirement to sustainable functionality development increase)**,

$$\kappa_2>(\kappa_1+\frac{\gamma}{\phi})e^{\frac{\ln P/P_0}{\kappa_2}} \quad (21)$$

4.2 Sustainable Functionality Develop. by Two Factors Learning and Market Inducement

On the basis of the foregoing analytical framework, an empirical analysis was undertaken taking Canon printers techno-managerial development trajectory. Results are summarized in **Tables 3, 4** and **Figs. 5.**

Table 3 Correlation between tech. stock, cumulative PC and Canon printers tech. prices (1985-2005) TFL: $P = AT^{\kappa_1}PC^{\gamma}$

$\ln P =$	$3.34 + 0.40 \ln T^{0.2}PC$	$-\ 2.5D$	$adj.\ R^2$	0.997	DW 1.60
	(165.75) (67.66)	(-8.14)			

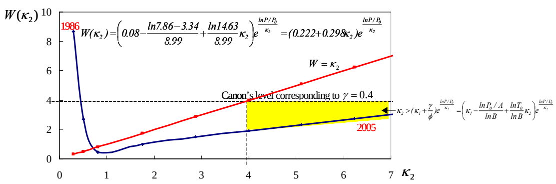
where D: 1986, 2000-2005 = 1, others = 0. $\ln A = 3.34$, $\kappa_1 = 0.08$, $\gamma = 0.40$.

Table 4 Inducement effect of PC in printers technology *(1985-2005)* Technology inducement by PC: $T = B \cdot PC^{\phi}$

$\ln T = 8.99 + 0.26 D_1 \ln PC + 0.40 D_2 \ln PC + 0.40 D_3 \ln PC + 0.30 D_4 \ln PC - 1.92(D_2+D_3)$	$adj.\ R^2$	0.997	DW 1.00
(27.63) (10.20) (12.77) (14.13) (17.20) (-3.22)			

where D_i (i = 1 ~ 4): dummy variables: (D_1: 1986-1990 =1, D_2: 1991-1997 =1, D_3: 1998-2000 = 1, D_4: 2001-2005 = 1; other years =0); T: 10 thousand yen at 1995 fixed prices; and PC: unit. $\ln B = 8.99$, $\varphi = 0.30$. P_0 and T_0 are 7.86 and 14.63.

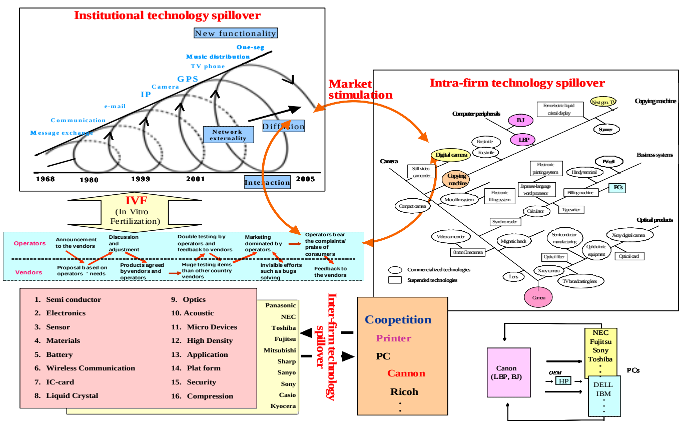
Based on Tables 3 and 4, correlation between κ_2 and γ in Canon's Printer *(1986-2005)* can be enumerated as follows:



$$\kappa_2(\gamma) = \left(\kappa_1 + \frac{\gamma}{\phi}\right) e^{\frac{\ln P/P_o}{\kappa_2}} = \frac{\ln 7.86 - 3.34}{\ln 14.63} + \frac{8.99}{\ln 14.63} \cdot \frac{\gamma}{0.30} = -0.476 + 11.17\gamma$$

Depending on two factors learning and inducement by PC through coopetition, Canon printers have satisfied requirement for sustainable functionality development leading to its co-evolutionary hybrid management as demonstrated in **Fig. 5.**

Fig. 5. Correlation between κ_2 and $w(\kappa_2)$ in Canon's printer development trajectory *(1986-1998)*.



On the basis of these functions, Canon has constructed a comprehensive hybrid management consisting of the following 5 systems as demonstrated in **Fig. 6,** thereby enabled its co-evolutionary domestication:

(i) Market stimulation by providing attractive innovation (e.g. digital camera),

(ii) Institutional technology spillover activating self-propagation,

(iii) In Vitro Fertilization(IVF) leveraging vendors innovation,

(iv) Domestication by inter-firm technology spillover through coopetition, and

(v) Intra-firm technology spillover emerging innovation efficiently.

Fig. 6. Scheme of Canon's co-evolutionary domestication.

5. Conclusion

Co-evolutionary dynamism between innovation and institutional systems is decisive for an innovation driven economy which may stagnate if institutional systems cannot adapt to innovations, and Japan's economy in the 1990s is one example. Its reactivation emerged in the early 2000s can largely be attributed to hybrid management fusing the "East" (indigenous strength) and the "West" (lessons from an IT driven new economy).

Noteworthy success in such hybrid management can be seen in Canon's business model centered by intra-technology spillover, IVF and coopetition which corresponds to the hybrid system of collective management as Microsoft system and open source management as Google.

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