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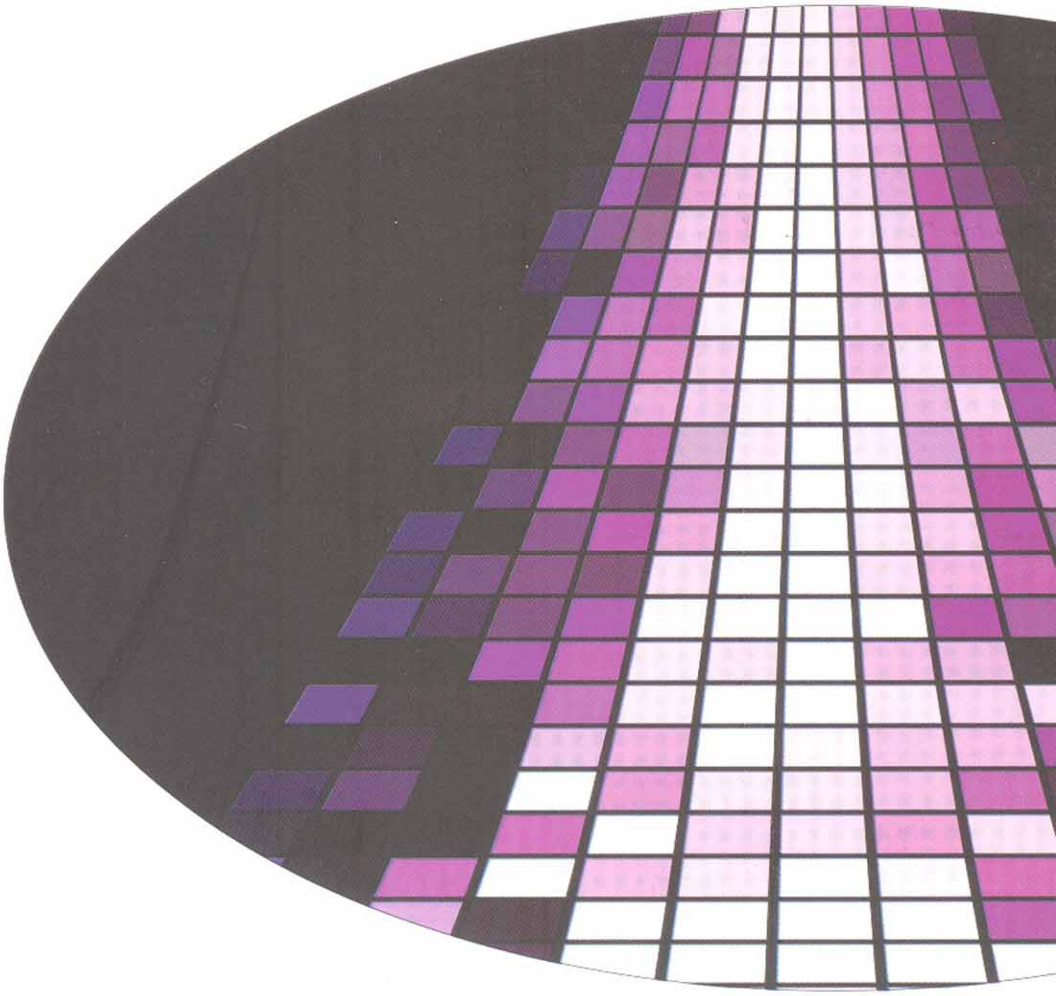

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Catalyst Role of Government R&D Inducing Hybrid Management in Japan: Lessons for Emerging Economies

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Abstract

Japan has achieved conspicuous technology advancement and subsequent productivity increase by overcoming threats and constraints of sustainable development of economy and society. The achievement can be attributed to a sophisticated combination of industrial efforts and government stimulation. This paper analyzes the government role in inducing industrial strength in Japan. Empirical analyses were conducted focusing on technology driven development trajectory between Japan and the US over the last two decades. The results reveal that Japan incorporates sophisticated mechanism enabling the hybrid management of technology fusing indigenous strength and learning ability. While the combination of government and industry stagnated in the 1990s, a swell of reactivation emerged in the early 2000s. This can largely be attributed to revitalization of the mutual interaction between government and industry. Such a catalyst role of government R&D inducing the hybrid management demonstrated by Japan would provide a new insight in emerging economies.

Keywords: *Government R&D; inducing policy; catalyst role; hybrid management; innovation system.*

INTRODUCTION

The global society now faces serious world-scale problems, such as global warming, financial crisis, and population aging. Under such a difficult situation, each country recognizes clearly that innovation is significant for resolving these problems, and strengthens innovation policy for long-term growth in the twenty-first century.

Japan has achieved conspicuous technology advancement and subsequent productivity increase by overcoming threats and constraints of sustainable development of economy and society. This ability realized the high-tech miracle in the 1980s. This achievement can be attributed to a sophisticated combination of industrial efforts and government stimulation. While the combination stagnated in the 1990s called a lost decade, a swell of reactivating emerged in the early 2000s. This can largely be attributed to the reactivation of fusing efforts between indigenous strength and learning from global best practice both were triggered by government catalyst. Amid a once-in-a-century financial crisis and its subsequent

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economic impacts, Japan manages to maintain the hybrid management of technology fusing indigenous strength and learning ability.

Recently in Japan, as well as other major countries, innovation has been prioritized as a significant source of sustainable growth and a strategic tool to enhance competitiveness of the nation. The new growth strategy presented by the Japanese cabinet in June 2010 aims to realize the "strong economy, strong public finances and strong social security." The strategy focuses on solving economic and social problems and creating new markets and jobs for the solution, and prioritizes the promotion of innovation in environment and energy as well as health care. To achieve this goal, collaboration between government and industry is crucial. The government should support industrial efforts and improve the business and social environment to maximize efficiency and effectiveness of activities in industry. The industry should take the opportunity by the government to increase its capability of innovation. Key strategic concerns are an optimal combination of the government role and industrial strength. Many studies argued the roles of public policies in innovation and competitiveness (Goh, 2004; Dosi et al., 2006; Breznitz, 2007; Leahy and Neary, 2007). The Japanese innovation systems are also investigated, including roles of Ministry of International Trade and Industry (MITI; reorganized into Ministry of Economy, Trade and Industry in 2001) in the rapid economic growth in the 1970s and 1980s (Johnson, 1982; Okimoto, 1989; Callon, 1995; Wakabayashi et al., 1999), and the institutional conditions necessary for successful catch-up with advanced countries (Freeman, 1988; Odagiri and Goto, 1993; Watanabe and Zhao, 2006).

This paper conducts an empirical analysis on technology driven development trajectory between Japan and the US over the last two decades. The analysis focuses on the government role in inducing industrial strength by making effecting utilization of both indigenous and external resources. The paper is constructed as follows. It reviews trends of innovation systems and its dynamics in Japan. It further introduces the analytical framework of the study, briefly describing the data construction. The next section describes results of analysis. Followed by findings and policy implications.

JAPAN'S INNOVATION SYSTEM AND ITS DYNAMICS

Japan has overcome various threats and constraints since the end of World War II by innovation despite being a small country and poor in natural resources. Its experiences in each decade since the 1960s can be described as follows:

- Japan confronted a shortage of labour force amid its high economic growth in the 1960s. Japan overcame it by learning and absorbing the

US advanced innovation systems and enhancing power saving and automated technologies.

- Japan experienced the oil crisis twice and a severe energy shortage in the 1970s. To overcome them, Japan promoted R&D on energy saving and alternative energy technologies. The government stimulated industrial R&D, and the industry activated its learning and improved its technologies. This sophisticated balance between the both of them led to successful innovation.
- Japan succeeded in substitution of technology for energy by its advanced innovation, and achieved the high-tech miracle in the 1980s. However, it also caused the trade friction with the US and the following appreciation of the yen against the dollar. This new limiting condition for economic and social development in Japan induced an innovation in highly productive manufacturing technology and cooperative technology development system with foreign countries.
- Contrary to the US, where the information and communications technology (ICT) ushered the new economy, Japan lagged behind in R&D and practical application of ICT in the 1990s. Both of the government and the industry rushed to build the ICT infrastructure and accelerated R&D and dissemination of telecommunication equipments. Especially Japan created a unique mobile phone market. Japanese mobile phone industry developed sophisticated technologies for unique services and added functions of superior, highly functional mobile phones, and expanded the domestic markets by such unprecedented products.
- In the 2000s, Japan began to show signs of recovery while the US slowed its economy after IT bubble burst. However, at the same time, Japan has been concerned about bipolarization of Japanese firms that can be divided into two groups on their profitability as a result of severe global competitions. Some efforts to redress of such a bipolarization could be a new driving force for innovation.

Through these above experiences, Japan has established a mechanism to convert a threat for sustainable development into an opportunity for innovation. Despite many handicaps, Japan achieved conspicuous technology advancement and subsequent productivity increase, especially in the 1980s as mentioned above (Watanabe, 1992, 1994, 1995, 1999). This can be attributed to a sophisticated combination of industrial efforts and government stimulation. Industry made every effort in developing and learning strategic technologies while government stimulation was focused on constructing a socio-economic system in which technology could maximize its potential performance (Watanabe et al., 2001; Watanabe, 2002; Watanabe and Zhao, 2006). Japan's success in overcoming threats and constraints by innovation can be attributed to great efforts to escape from a threat for sustainable development, and high level of learning, assimilation and improvement ability. These features are rooted in Japan's unique institutional systems, and a co-evolution between innovation and institution activate a role of the government catalyzing industrial R&D.

ANALYTICAL FRAMEWORK

In order to analyze catalyst role of government R&D inducing the hybrid management of technology, framework of analysis should satisfy the following identifications:

(i) Contribution of learning ability to multi-factor productivity (MFP) growth,

(ii) Enhancement factors of industry's learning ability, and

(iii) Mutual interaction between indigenous strength and learning effects.

Following data were taken from OECD Science and Technology Indicators to analyze:

V: gross domestic product

R: national R&D investment

R_g: government R&D investment

R_i: industrial R&D investment

R_{gi}: government investment for industrial R&D

R/V: national R&D intensity

R_g/V: government R&D intensity

R_i/V: industrial R&D intensity

R_{gi}/R_i: government support for industrial R&D (GSIR)

? MFP/MFP: annual average growth rate of multi-factor productivity

Utilizing these data, technology stock (T) was computed by the following equation:

$$T_t = R_{t-m} + (1 - ?)\, T_{t-1} \qquad (1)$$

where Tt: technology stock at time t; R_{t-m}: R&D investment (fixed prices) at time t-m, m: time-lag between R&D and commercialization; and ? : rate of obsolescence of technology.

Under the competitive circumstances where nation aims at maximizing the productivity of its technology stock, marginal productivity of technology ?V/?T corresponds to the relative price of technology P_t as follows:

$$?V/?T = P_t \tag{2}$$

RESULTS

Contribution of learning ability to MFP growth

Many scholars have discussed and analyzed learning concept, and a number of studies have shown that the unit cost of producing manufactured goods tends to decline significantly as more are produced. It has been argued that this effect is the result of the development of increasing skill in production attained by what Arrow (1962) has termed "Learning-by-Doing." More recently, Rosenberg (1976) has shown that similar gains can accrue to the end users of a product as their skill or understanding grows through "Learning-by-Doing."

Following Watanabe and Zhao (2006), using price of technology P_T, and nations technology stock T, market learning in fusing global best practice can be depicted by the following function with dynamic learning coefficient as a function of time t:

$$P_T = AT^{?(t)} \tag{3}$$

$$l(t) = \sum_{i=0}^{n} a_i t^i \tag{4}$$

where A: scale factor; T: technology stock; ?(t): dynamic learning coefficient at time t; and a_i; coefficient.

Taking the logarithms, following equation can be obtained:

$$\ln P_T = \ln \frac{\partial V}{\partial T} = \ln A - \sum_{i=0}^{n} a_i t^i \ln T \tag{5}$$

Using Backward Elimination Method (BEM) with 5% significant level criteria over the period 1985-2004, the dynamic learning coefficients in Japan and the US were identified as shown in Table 1. Comparative evaluation of the significance of the identified coefficient was conducted by comparing i = 0 - 4 in $a_i t^i$ and confirmed that i =2 and 3 for Japan and the US, respectively are statistically most significant. The result demonstrates that while Japan's dynamic learning coefficients can be developed by a quadratic equation by time trend, the US can be developed by a cubic equation.

Table 1: Correlation between MPT and technology stock in Japan and the US (1985-2004)

Japan

$$\ln \frac{\partial V}{\partial T} = 40.772 - 0.753D - \left(3.297 - 1.096 \cdot 10^{-2} \cdot t + 3.342 \cdot 10^{-4} \cdot t^2\right) \cdot \ln T$$

(5.18) (–2.74) (–5.25) (4.48) (–3.28)

adj. R^2 = 0.779 , DW = 1.78

D: dummy variable; *D* = 1 in 1988, 1990, 2004, other years = 0.

US

$$\ln \frac{\partial V}{\partial T} = 0.637 - 0.738D - \left(0.152 - 1.745 \cdot 10^{-2} \cdot t + 2.125 \cdot 10^{-3} \cdot t^2 - 7.588 \cdot 10^{-5} \cdot t^3\right) \cdot \ln T$$

(1.84) (–6.76) (–4.43) (4.43) (–4.43) (4.43)

adj. R^2 = 0.573, DW = 1.25

D: dummy variable; *D* =1 in 1988 (start of Bush administration), other years = 0.

On the basis of this analysis, the dynamic learning coefficients of both countries can be depicted as the functions of time t illustrated in Figure 1. Looking at the figure, we note that while Japan appreciated higher learning coefficient as demonstrated by OECD (1997), it continued to decline from the middle1980s and over the 1990s. This can be attributed to (i) X-inefficiency in putting-up with a success in the 1980s and (ii) organizational inertia impeding flexible adaptation to a new paradigm of an information society and mature economy (Watanabe and Zhao, 2006). However, it changed to recovering trend from the beginning of the 2000s with slight increase.

Contrary to Japan's trend, the US reversed the declining trend in its learning coefficient in the beginning of the 1990s. The US enhanced its competitiveness in the 1980s and the 1990s stimulated by the major three proposals, the Young Report, the New Young Report, and Made in America, in the late 1980s. This effort recovered the economic growth driven by IT. However, in the late 1990s, the US again faced the threat of deteriorating competitiveness, as cautioned by the Council on Competitiveness (COC, 1996, 1998) and American Electronics Association (AeA, 2005).

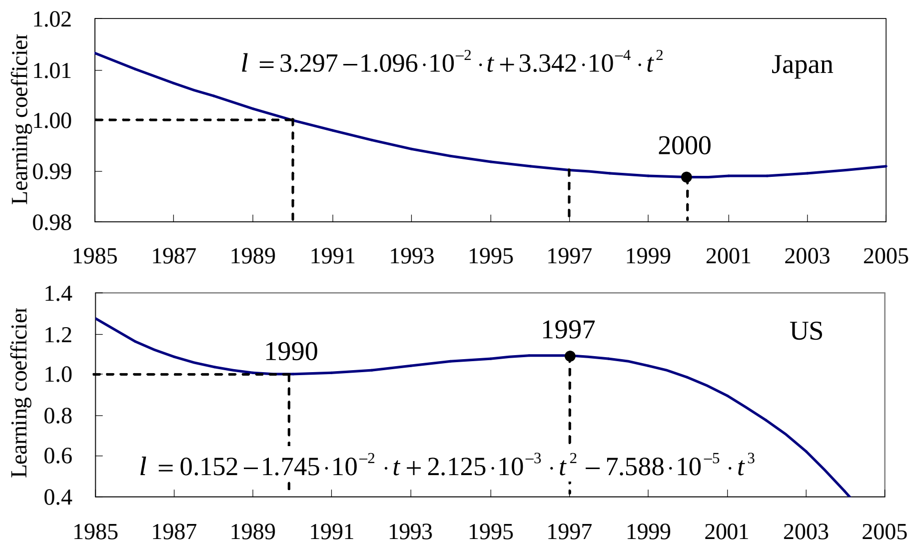

Figure 1 Trends in dynamic learning coefficients in Japan and the US (1985-2004) - Index: 1990 = 1.

Enhancement factors of industry's learning ability

Nations capability of effective utilization of external R&D resources depends on the dynamism in government R&D inducing industrial R&D ($R_{gi} \rightarrow R_i$) with its contribution to growth ($R_i \rightarrow V$). In addition, feed back mechanism in allocating the fruit of growth to government R&D ($V \rightarrow R_g$) and its strategy to appropriate R&D budget for the inducement of industrial R&D ($R_g \rightarrow R_{gi}$) is essential. This dynamism illustrated as Figure 2 incorporates varieties of interactions with varieties of time-lags. For example, successive impacts of $R_{i-1} \rightarrow V$, $V_{-1} \rightarrow R_g$, and $R_{g-1} \rightarrow R_{gi}$ (where R_{i-1}, V_{-1}, and R_{g-1}: impact of R_i, V, and R_g in the preceding period) provide similar interactive impact of $R_i \rightarrow R_{gi}$ which depicts R_i inducement of R_{gi}.

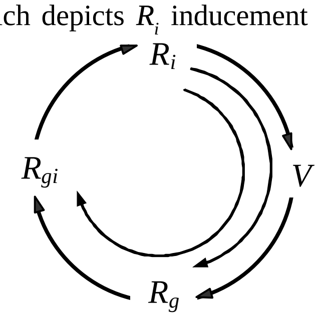

Figure 2: Dynamism developing nation's capability of effective utilization of external resources.

This dynamism can be depicted by the following function:

$$W = F(X, Y, Z) \tag{6}$$

where W: nation's capability of effective utilization of external resources; X: productivity of industry R&D; Y: government R&D intensity; and Z: government strategy to appropriate R&D for the inducement of industrial R&D.

Taylor expansion to the third term obtains the following equation:

$$\ln W = a + b\ln X + c\ln Y + d\ln Z + e\ln X\ln Y + f\ln Y\ln Z + g\ln Y\ln Z + h\ln X\ln Y\ln Z \tag{7}$$

Since $\ln W$, $\ln X$, $\ln Y$ and $\ln Z$ can be represented by $l(t)$ (learning coefficient), V / R_i (productivity of industrial R&D), R_g / V (government R&D intensity), and R_{gi} / R_g (t), equation (7) can be developed as follows:

$$\begin{aligned} l(t) &= a + b\frac{V}{R_i} + c\frac{R_g}{V} + d\frac{R_{gi}}{R_g} + e\frac{V}{R_i}\cdot\frac{R_g}{V} + f\frac{V}{R_i}\cdot\frac{R_{gi}}{R_i} + g\frac{R_g}{V}\cdot\frac{R_{gi}}{R_g} + h\frac{V}{R_i}\cdot\frac{R_g}{V}\cdot\frac{R_{gi}}{R_g} \\ &= a + b\frac{V}{R_i} + c\frac{R_g}{V} + d\frac{R_{gi}}{R_g} + e\frac{R_g}{R_i} + f\frac{R_{gi}}{R_i}\cdot\frac{V}{R_g} + g\frac{R_{gi}}{V} + h\frac{R_{gi}}{R_i} \\ &= a + \left(h + b\frac{V}{R_{gi}} + c\frac{R_g}{R_{gi}}\cdot\frac{V}{R_g} + d\frac{R_i}{R_g} + e\frac{R_g}{R_{gi}} + f\frac{V}{R_g} + g\frac{R_i}{V}\right)\cdot\frac{R_{gi}}{R_i} \end{aligned}$$

Thus, learning coefficient can be depicted as follows:

$$l(t) = a + H(t)\cdot\frac{R_{gi}}{R_i} \tag{8}$$

where $H(t)$: Learning inducement function (LIF); and a: coefficient.

Using Backward Elimination Method (BEM) with 5% significant level criteria, the dynamic learning coefficients were estimated in Japan and the US over the period 1985-2004 as summarized in Table 2. From the result, learning inducement function (LIF; *H(t)*) in Japan and the US over the period 1985-2004 can be identified as shown the table.

Table 2: Learning coefficients in Japan and the US *(1985-2004)*

Japan

$$l(t) = 4.545 - 2.752\cdot10^{-2}\cdot\frac{V}{R_i} + 0.896\cdot10^{2}\cdot\frac{R_{gi}}{R_g} - 0.255\cdot\frac{R_{gi}}{R_i}\cdot\frac{V}{R_g} - 1.288\cdot10^{4}\cdot\frac{R_{gi}}{V} + 1.061\cdot10^{2}\cdot\frac{R_{gi}}{R_i}$$

(13.33) (–3.90) (3.85) (–3.76) (–5.19) (4.77)

adj. $R^2 = 0.802$, $DW = 1.57$

$$l(t) = 4.545 + \left(1.061\cdot 10^{2} - 2.752\cdot 10^{-2}\cdot \frac{V}{R_{gi}} + 0.896\cdot 10^{2}\cdot \frac{R_i}{R_g} - 0.255\cdot \frac{V}{R_g} - 1.288\cdot 10^{4}\cdot \frac{R_i}{V}\right)\cdot \frac{R_{gi}}{R_i}$$

$$= 4.545 + H(t)\cdot \frac{R_{gi}}{R_i}$$

US

$$l(t) = 0.754 + 3.318\cdot 10^{-2}\cdot D - 1.351\cdot 10^{-2}\cdot \frac{V}{R_i} + 5.874\cdot 10^{-2}\cdot \frac{R_{gi}}{R_i}\cdot \frac{V}{R_g} - 0.789\cdot \frac{R_{gi}}{R_i}$$

(2.63) (2.84) (−2.72) (2.67) (−3.01)

adj. R^2 = 0.778 , *DW* = 1.10

D: dummy variable; *D* = 1 in 1985 (Plaza Accord), other years = 0.

$$l(t) = 0.754 + 3.318\cdot 10^{-2}\cdot D + \left(-0.789 - 1.351\cdot 10^{-2}\cdot \frac{V}{R_{gi}} + 5.874\cdot 10^{-2}\cdot \frac{V}{R_g}\right)\cdot \frac{R_{gi}}{R_i}$$

$$= 0.754 + 3.318\cdot 10^{-2}\cdot D + H(t)\cdot \frac{R_{gi}}{R_i}$$

H(t): Learning inducement function (LIF)

Figure 3 compares trends in LIFs in Japan and the US. Looking at the figure, we note that the magnitude of LIF in Japan exceeds that in the US over the whole period examined except in the early to the middle of the 1990s. While it declined in the early 1990s, it recovered in the beginning of the 2000s. The magnitude of LIF in the US changed to decrease in the 2000s, while it increased in the late of the 1980s and the 1990s.

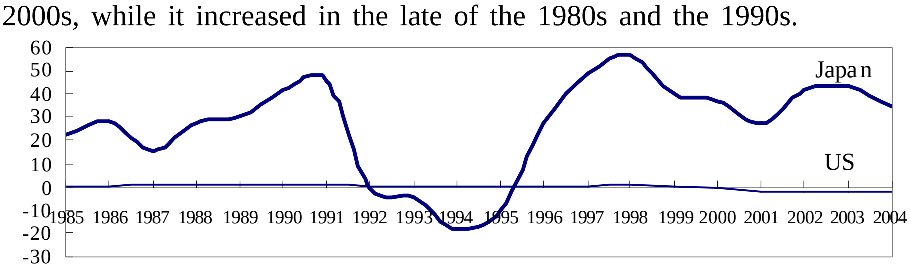

Figure 3: Trends in learning inducement function in Japan and the US *(1985-2004)*.

Differentiating by time, equation (8) can be developed as follows:

$$\frac{\Delta l}{l} = \frac{H\cdot\left(R_{gi}/R_i\right)}{l}\cdot\left(\frac{\Delta H}{H} + \frac{\Delta\left(R_{gi}/R_i\right)}{R_{gi}/R_i}\right) \quad (9)$$

In equation (9), R_{gi}/R_i can be decomposed as follows:

$$\frac{R_{gi}}{R_i} = \frac{V}{R_i} \cdot \frac{R_g}{V} \cdot \frac{R_{gi}}{R_g} \tag{10}$$

where V/R_i (productivity of industrial R&D): industry's indigenous strength; R_g/V (intensity of government R&D): resource allocation of the nation; and R_g/R_i (government support for industrial R&D, GSIR): government R&D appropriation.

Based on equations (9) and (10), Table 3 compares contributing factors to learning coefficients in Japan and the US over the period 1985-2004. The table indicates the learning inducement effects of government support for industrial R&D (GSIR) depends on the magnitude of LIF (*H(t)*) and substitute relation between LIF and GSIR. Japan decreased its magnitude of LIF in the 1990s when GSIR substituted for LIF due to stagnation of industrial R&D. However, Japan recovered the substitution of LIF for GSIR in the beginning of the 2000s, which induced its learning coefficient to increase. On the other hand, the US followed the same pattern of Japan's substitute relation between LIF and GSIR in the late 1980s over the period 1985-2001, and increased its learning coefficient in the period 1993-1997. In the beginning of the 2000s, the US changed its substitute relation to complement of GSIR and LIF resulted in continuing to decrease its learning coefficients.

Table 3: Factors contributing to learning ability in Japan and the US (1985-2004

Japan	1985-1992	1993-1997	1998-2001	2001-2004
? ?/?	-0.37%	-2.04%	-1.63%	1.54%
$H \cdot (R_{gi}/R_i)/?$	0.12	0.03	0.22	0.17
? H/H	1.91%	-70.48%	-11.94%	12.38%
(? R_{gi}/R_i)/(R_{gi}/R_i)	-5.03%	5.77%	4.65%	-3.30%
(? V/R_i)/(V/R_i)	-1.13%	-0.42%	-1.76%	-1.24%
(? R_g/V)/(R_g/V)	-0.33%	-0.84%	3.38%	-1.25%
(? R_{gi}/R_g)/(R_{gi}/R_g)	-3.57%	7.03%	3.03%	-0.81%
	Stimulate catalysis function	Stagnation of catalysis inducement		Reactivation of catalysis function

US	1985-1992	1993-1997	1998-2001	2001-2004
? ?/?	-13.18%	2.38%	-4.76%	-21.72%
$H \cdot (R_{gi}/R_i)/?$	1.44	0.54	-0.25	-3.18
? H/H	-2.57%	10.42%	31.42%	3.24%
(? R_{gi}/R_i)/(R_{gi}/R_i)	-6.57%	-5.99%	-12.27%	3.58%
(? V/R_i)/(V/R_i)	-1.38%	-1.39%	-3.02%	3.83%
(? R_g/V)/(R_g/V)	-3.53%	-4.06%	-1.86%	2.96%
(? R_{gi}/R_g)/(R_{gi}/R_g)	-1.66%	-0.53%	-7.39%	-3.21%
	Similar to Japan's catalysis function			Stagnate catalysis function

Fusing function of government support between indigenous strength and learning effects

Similar to equation (6), it is assumed that MFP growth rate can also be depicted as follows:

$$W = F(X, Y, Z) \qquad (6)'$$

where $W = MFP$; $X = V/R_i$ (Productivity of industrial R&D); $Y = R_g/V$ (Government R&D intensity); and $Z = R_{gi}/R_g$ (Appropriation of government R&D for industrial R&D inducement).

Provided that operation income to R&D (OIR) is governed by the learning inducement function (LIF; $H(t)$) and government support for industrial R&D (GSIR), the following equation can be obtained:

$$OIR = c + b \cdot H(t) \cdot (R_{gi}/R_i) \qquad (11)$$

where b and c: coefficients. Empirical analyses show that the equation can be demonstrated in four Japanese leading electrical machinery firms, Hitachi, Panasonic, Canon, and Sharp.

From equations (8) and (11), equation (12) can be obtained as follows:

$$OIR = c + b \cdot (?(t) - a) = a' + b \cdot ?(t) \qquad (12)$$

where a, b and c: coefficients; $a' = c - ab$.

Equations (9) and (12) lead to equation (13) as follows:

$$\frac{\Delta OIR}{OIR} = b \cdot \frac{l}{OIR} \cdot \frac{\Delta l}{l} \qquad (13)$$

Provided that LIF ($H(t)$) is governed by industrial R&D intensity (R_i/V) induced by productivity of government R&D (V/R_g), following equation can be depicted:

$H = a" + b"\cdot(R_i/R_g) = a" + b"\cdot?$ (14)

where $\frac{R_i}{R_g} = h = \frac{V}{R_g} \cdot \frac{R_i}{V}$; and *a"* and *b"*: coefficients. Empirical analyses show that the equation can be demonstrated by both Japan and the US over the period 1985-2004.

Prompted by the foregoing demonstration, R&D expenditure can be developed as follows:

$R = R_i + R_g = (1 + ?)\ R_g$ (15)

Thus,

$$\frac{\Delta MFP}{MFP} = \frac{\partial V}{\partial T} \cdot \frac{R}{V} = \frac{\partial V}{\partial T} \cdot \frac{R_g}{V}(1+h) \quad (16)$$

$$P_T = AT^{-l(t)} = F(T, l) = F(R, l) = F(R_g, h, l) \quad (17)$$

$$l(t) = c + H(t) \cdot \frac{R_{gi}}{R_i} \text{ thus, } l = F\left(H, \frac{R_{gi}}{R_i}\right) \quad (18)$$

From equations (16), (17), and (18),

$$H = F\left(\frac{\Delta MFP}{MFP}, \frac{R_g}{V}, \frac{R_{gi}}{R_i}\right) \quad (19)$$

Empirical analyses of equation (19) in Japan and the US over the period 1985-2004 demonstrate statistically more significant than that of not including R_{gi}/R_i. These results indicate that LIF is governed by*DMFP/MFP, R_g/V, and R_{gi}/R_g*.

DISCUSSION OF RESULTS

Foregoing analyses suggests that that Japan incorporates sophisticated system function maintaining resilience by means of *DMFP/MFP*, R_g/V, and R_{gi}/R_g dynamism as demonstrated in Figure 4.

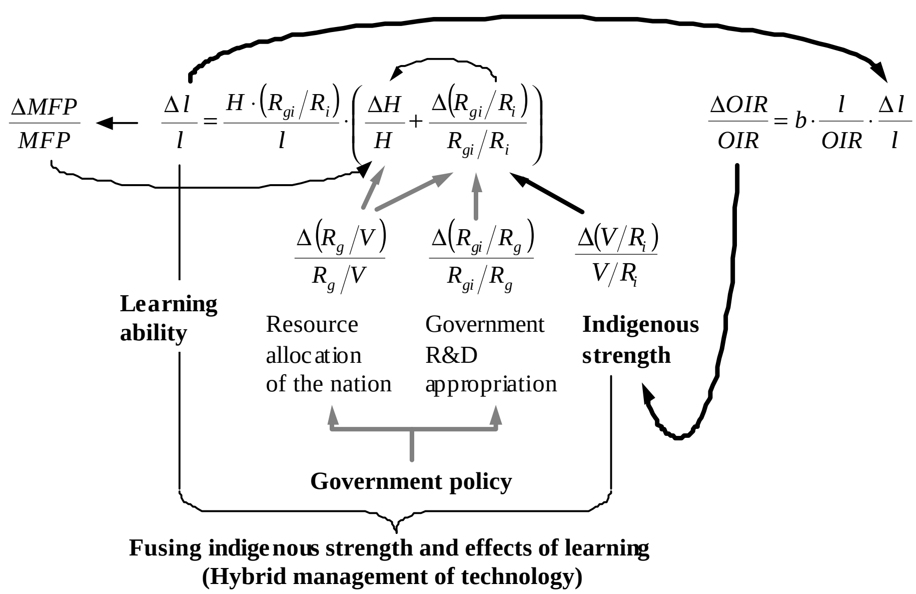

Figure 4: Catalyst role of GSIR in inducing hybrid management of technology.

The sophisticated mechanism enabling Japan's hybrid management of technology in the early 2000s consists of the following steps:

1. **Learning ability (**l) contributes to MFP growth.
2. Improvement of learning ability is governed by learning inducement function (LIF; *H(t)*) and government support for industrial R&D.
3. Learning ability increases operating income to R&D (OIR) in firm.
4. Growth of OIR leads to enhance indigenous strength and learning ability.
5. Fusing industrial R&D and learning ability realizes the hybrid management of technology.

Learning abilities of Japan and the US show contrasting trends as depicted in Figure 1. While Japan's learning coefficient (l) continued to decline over the 1990s, it changed to increasing trend from the beginning of the 2000s. Contrary to such trend, increasing trend in the US learning coefficient changed to the declining trend from the late 1990s. As shown in Section 4, enhancement of learning coefficient depends largely on learning inducement function (LIF; *H(t)*). Japan's high level of LIF induces catalyst function of government support for industrial R&D (GSIR; R_{gi}/R_i). Enhanced learning ability increases high level of operating income to R&D (OIR) leading to increasing indigenous strength in industry, which in turn induces higher LIF. Government policy also stimulates the efforts to heighten LIF as well as activates industrial R&D by appropriate resource allocation and government R&D. This sophisticated mechanism leads to the hybrid management between indigenous strength and the effect of learning.

These findings suggest that substitution of LIF for GSIR can be considered the matching condition between government and industrial efforts as well as learning ability and indigenous strength, which is essential for sustainable inducement of the hybrid management of technology. This substitution is incorporated in Japan's mechanism to convert a threat for sustainable development into an opportunity for innovation. While it stagnated in the 1990s, the substitution reactivated in the 2000s. This resilience is governed by dynamism between MFP growth, government R&D intensity, and GSIR.

CONCLUSION

Confronting severe competition with demanding customers, industry in Japan has developed its indigenous strength in technologies with intensive efforts in learning, absorbing and assimilating best practices in the external market. Japanese government stimulated these industrial efforts by constructing a socio-economic system efficiently in which government and industrial efforts co-evolve. Such a sophisticated combination functioned well in the 1980s and government stimulation of this co-evolutionary dynamism was appraised as a sophisticated catalyst role.

While the dynamism stagnated in the 1990s called as a lost decade, a swell of reactivating emerged in the early 2000s. This can largely be attributed to the reactivation of fusing efforts between indigenous strength and learning from global best practice.

This paper conducted empirical analyses focusing on the inducing function of government R&D in Japan and the US over the last two decades. The results reveal that that Japan incorporates sophisticated mechanism enabling the hybrid management of technology with resilience function shown in Figure 4.

Noteworthy findings obtained include:

- Effects of learning made significant contribution to multi-factor productivity (MFP) growth.
- While Japan's learning coefficient continued to decline over the 1990s, it changed to increasing trend from the beginning of the 2000s. Contrary to such trend, increasing trend in the US learning coefficient changed to the declining trend from the late 1990s.

- Enhancement of learning coefficient depends largely on learning inducement function (LIF).
- Japan's high level of LIF induces catalyst function of government support for industrial R&D (GSIR).
- Enhanced learning ability increases high level of operating income to R&D (OIR) leading to increasing indigenous strength in industry, which in turn induces higher LIF leading to the hybrid management between indigenous strength and the effect of learning.
- LIF substitution for GSIR can be considered the matching condition essential for sustainable inducement of the hybrid management of technology.
- Japan incorporates explicit function this substitution. While it stagnated in the 1990s, it reactivated in the 2000s. Dynamism between MFP growth, government R&D intensity, and government support for industrial R&D governs this resilience.

These findings provide the following implications suggestive to effective utilization of potential resources in innovation:

- Construction of a co-evolutionary dynamism between effective R&D and learning would be decisive for firms' competitiveness enhancement.
- The hybrid management of technology fusing indigenous strength and effects of learning is thus important.
- It should be noted that this co-evolution accelerates LIF substitution for GSIR leading to improving the catalysis role of government R&D.
- While this endeavour further accelerates the co-evolutionary dynamism, it may change to disengagement as Japan experienced in the 1990s.

Given that Japan has been revitalizing its mutual interaction between indigenous strength and learning effects since the early 2000s, its inherent strengths should produce a mutually inspiring development cycle between Japan and the US. The dominant competitive position has shifted repeatedly between Japan and the US as mentioned in Section two. However, Japan changed its institutional systems during the race and realized the co-evolution between the advancement of indigenous strength and the development of learning ability. This recognition was postulated by Fujio Mitarai, President of the Japan Business Federation and former Chairman and CEO of Canon Inc.: "Finance and development should be global while human affairs should be local." This postulate suggests that Japan has balanced its management style with international standards. Vogel (2006) also points out that Japan has never emulated the American model. After scrutinizing their options, government officials and industry leaders chose to modify or reinforce preexisting institutions rather than abandon them. Thus, Japan has chosen what it should learn (or not learn) in order to co-evolve its own institutional systems. Such choice is a key factor for maintaining the hybrid management mechanism with resilience function.

Rapid globalization in recent years accelerates pace of change in technology and global markets, and expands competitions and collaborations between innovation actors (Archibugi and Pietrobelli, 2003). Many firms exploit international markets to improve their profits through exports of their goods, sales of licences and patens, foreign production of goods internally generated, and so on. Multinational firms develop R&D activities both in the home and the host countries strategically, such as acquisition of existing laboratories or direct foreign investments in host countries. Universities and public institutions also conduct joint projects and exchanges of knowledge, information, and talents with foreign organizations. The globalization of innovation could be both a threat and an opportunity for sustainable development of a country. While a country succeed to benefit from global resources and opportunities for innovation, it could lose its resources flowing out to abroad.

Globalization has brought greater opportunity for people to access to more capital, goods, services, and technology, and helps to promote efficiency of productivity. On the other hand, it has made social and economic system more interdependent and increased vulnerability to crises. These risks have been heightened since cross-country social and economic linkages amplify the effects of various shocks and transmit them more quickly (Prasad et al., 2003). Facing such new threats and constraints for sustainable development of economy and society from globalization, Japan has continued to restructure the hybrid management mechanism in both the national and corporate levels. In the national level, reorganization of science and innovation administrative organization has been discussed subsequently. This reorganization aims to promote the world class R&D more flexibly and efficiently. It enables various collaborations beyond borders that include collaborations between ministries and agencies, public and private sectors, and domestic and foreign sectors. Japan will start the fourth science and technology basic plan in 2011, which indicates policy directions for five years. Under the plan, the government will promote innovation through diversity. Innovation requires new, unique ideas through thinking differently. Diversity can ensure there is a large pool of knowledge, skills, life experience, perspectives, and expertise (European Commission, 2008). The government will start some measures for diversity-led innovation such as establishing a platform for sharing the situation and future vision and planning strategy for innovation and building open innovation centers to exchange ideas and information from industry, academia and government. Not only have such government efforts, Japanese firms also have continued efforts to seek an approach to globalization. Toyota, for example, has recalled Prius hybrid around the world in early 2010. This crisis has reminded Toyota and other Japanese firms the responsibility for quality and reliability of products and services in the global market. Management worldwide is getting a bigger issue for Japanese firms. In April 2010, Nippon Sheet Glass (NSG Group) named a former senior executive of DuPont group as its president and CEO. While most top managers of Japanese firms are Japanese, NSG Group is seeking personnel who can cope with its global operations in twenty-nine countries. In the same month, a Ministry of Economy, Trade and Industry panel said in a report that the government of Japan and the private sector will collaborate to tap into the water business in other countries, aiming to garner 6 percent of overseas markets in 2025. The collaboration suggests that the government will be a new catalyst for the industry succeeding in the globalization of innovation.

Global problems solving is the great challenge of the early 21st century. Global problems transcend the capabilities and resources of any one country and sector, and its solution necessarily involve cooperation between all of them. In this context, the hybrid management mechanism in Japan would provide an approach to problem solving to both of emerging and developed countries. For emerging countries, an optimal combination of the government role and industrial strength is necessary to ensure their sustainable development. They should bring together ideas and policies to meet economic and environment objectives different from those in the mass consumption society. Developed countries could contribute to these efforts in emerging countries by proposing solutions for sustainable development. Fusing function of government support between indigenous strength and learning effects in industry is necessary for developed countries to choose appropriate experience and expertise for each emerging country. Such approach to problem solving based on the hybrid management mechanism would create the co-evolution between emerging and developed counties which provide realize global sustainable development. Further analysis should focus on Japan's strategy for maintaining the hybrid management mechanism amid ongoing globalization of innovation.

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