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Interim Report IR-05-057

National Innovation Ecosystems: The Similarity and Disparity of Japan–US Techology Policy Systems toward a Service-Oriented Economy

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November 2005

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This Interim Report is a pre-print version of an article to be published by the *Journal of Services Research* in 2006 following the journal's peer review. Further information: www.jsr-iimt.net.

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Abstract

Coinciding with the announcement of the National Innovation Ecosystem proposed by the US Council on Competitiveness, Japan's Industrial Structure Council proposed a significant shift from a technology policy to an innovation policy based on the ecosystem concept.

Aiming at analyzing the complex mutual relations between human activities centered around industry and the surrounding environment, Japan's Ministry of International Trade and Industry postulated the concept of *industrial ecology* in the early 1970s, similar to that initiated in the USA in the early 1990s by the National Academy of Engineering, which corresponds to the mutually inspiring cycle in the two nations.

The basic principle of industrial ecology suggests substitution among available production factors in a closed system in order to achieve sustainable development under certain constraints. Based on this concept, Japan achieved notable energy efficiency improvements in the 1980s that can be attributed to technology substitution for energy.

Contrary to its economic stagnation in the 1980s, the USA achieved a significant economic development in the 1990s, while Japan experienced a "lost decade" due to economic stagnation. The US success can be attributed to information technology (IT) substitution for the traditional manufacturing technology, leading to a new functionality development corresponding to the requirement of an information society. However, after the bursting of the IT bubble, the USA has again been confronting the "new reality."

While the USA and Japan demonstrated contrasting success through mutual inspiration, given the new paradigm of a post-information society moving toward a ubiquitous society in the early 20th century, they need a new approach to sustaining their national innovation. Recognition of this led both countries to reexamine the broader application of the ecosystem, leading to the concept of the National Innovation Ecosystem.

Based on an empirical review of the technology policies of the USA and Japan over the last three decades with a focus on the ecosystem perspective, this paper attempts to demonstrate the hypothetical view outlined above and to provide new insights for a service-oriented economy.

Keywords: Innovation policy, industrial ecology, substitution, Japan–US comparisons, ubiquitous society.

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National Innovation Ecosystems: The Similarity and Disparity of Japan–US Technology Policy Systems toward a Service-Oriented Economy

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1. Introduction

Coinciding with the announcement of the National Innovation Ecosystem proposed by the US Council on Competitiveness, Japan's Industrial Structure Council proposed a significant shift from a technology policy to an innovation policy based on the ecosystem concept.

Aiming at analyzing and evaluating the complex mutual relations between human activities centered around industry and the surrounding environment, Japan's Ministry of International Trade and Industry (MITI)[1] postulated the concept of *industrial ecology* in the early 1970s (Watanabe, 1972, 1994), similar to that initiated in the USA in the early 1990s by the National Academy of Engineering (Erkman, 1997).

The basic principle of industrial ecology suggests substitution among available production factors in a closed system in order to achieve sustainable development under certain constraints. Based on this concept, Japan achieved notable energy efficiency improvements in the 1980s that can be attributed to technology substitution for energy (Watanabe, 1995a; 1999).

Contrary to its economic stagnation in the 1980s, the USA achieved significant economic development in the 1990s, while Japan experienced a "lost decade" due to economic stagnation. The US success can be attributed to information technology (IT) substitution for the traditional manufacturing technology, leading to a new functionality development corresponding to the requirement of a shift from the *growth-oriented trajectory based on manufacturing technology* to the *IT-driven new functionality development trajectory* in an information society that emerged in the beginning of the 1990s.

Both the USA and Japan demonstrated contrasting success through mutual inspiration during the 1970s, 1980s, and 1990s, also with regard to the postulation of the concept of industrial ecology in the early 1970s and 1990s, respectively. However, given the new paradigm of a post-information society moving toward a ubiquitous society in the early 20th century that requires a shift from a *function-oriented* to a seamless, *solution-oriented* trajectory with all-actor participation and on-demand

[1] MITI renamed Ministry of Economy, Trade and Industry (METI) on January 6, 2001 under the structural reform of the Japanese government.

institutions—which is quite similar to an evolutional ecosystem—they need a new approach based on co-evolutionary dynamics to sustaining their national innovation.

Marten (2001) stressed that co-existence, co-adaptation and co-evolution are emergent properties of an ecosystem. He defines co-existence as existing together and co-adaptation as fitting together, while co-evolution is defined as changing together. According to Marten, co-existence and co-adaptation, while being built into the game, are not as dynamic as is typical of a sustainable ecosystem. Co-evolution plays an essential role in sustaining an ecosystem in an evolutionary way. Thus, in order to correspond to a ubiquitous society, which is quite similar to an evolutional ecosystem, co-evolution, i.e., changing together, is essential for national innovation.

Marten further identified the significant role of co-evolution in complex circumstances by comparing an ecosystem to a TV set. Both systems are similar in incorporating a selection of parts that function together. A TV set has a large number of electronic components, each precisely suited to the other components in the set. There are, however, some important differences between an ecosystem and a TV set. An ecosystem has a higher level of redundancy than a TV set, and this gives it greater reliability and resilience. Because TVs are designed to be constructed as economically as possible, there is only one component for each function. In contrast, each important function in an ecosystem is normally performed by several different components. An ecosystem and a TV set are also different in another important aspect, i.e., biological components in themselves incorporate complex adaptive systems with the ability to change as circumstances demand. In contrast to a TV set, in an ecosystem, depending on the circumstances, plants and animals can change the way in which they interact with other species. This adaptive and, furthermore, changing function is particularly important for a firm's sustainable development in a ubiquitous society—a function of the ecosystem which may be mainly attributed to resilience based on co-evolutionary dynamics. A resilient ecosystem based on co-evolutionary dynamics is the backbone of a sustainable environmental system in a ubiquitous society.

Recognition of the foregoing postulation has led both Japan and the USA to reexamine the broader application of the ecosystem, leading to the concept of the National Innovation Ecosystem.

Based on an empirical review of the technology policies in Japan and the USA over the last three decades with a focus on the ecosystem perspective, this paper attempts to demonstrate the hypothetical view outlined above and to provide new insight for a service-oriented economy.

Section 2 reviews the mutually inspiring cycle between Japan and the USA and its consequences to the National Innovation Ecosystem. Section 3 reviews Japan’s success in the application of an ecosystem with sustainable growth by means of technology substitution for energy in the 1980s. Similarly, Section 4 reviews the US success in an information society in the 1990s by means of IT substitution for manufacturing technology, thereby creating a new functionality development initiated trajectory. Section 5 analyzes a possible development of the new dimension of the function of the ecosystem, as well as the co-evolution between innovation and institutional systems. Section 6 briefly summarizes new findings, policy implications, and identifies the focus of the future work.

2. The Mutually Inspiring Cycle and Its Consequence for the National Innovation Ecosystem

2.1 The mutually inspiring cycle between Japan and the USA

Both the USA and Japan demonstrated contrasting success through mutual inspiration during the 1970s, 1980s, and 1990s, also with regard to the postulation of the concept of industrial ecology in the early 1970s and 1990s, respectively. *Figure 1* demonstrates this mutually inspiring co-evolutionary development cycle in Japan and the USA over the period 1950-2010.

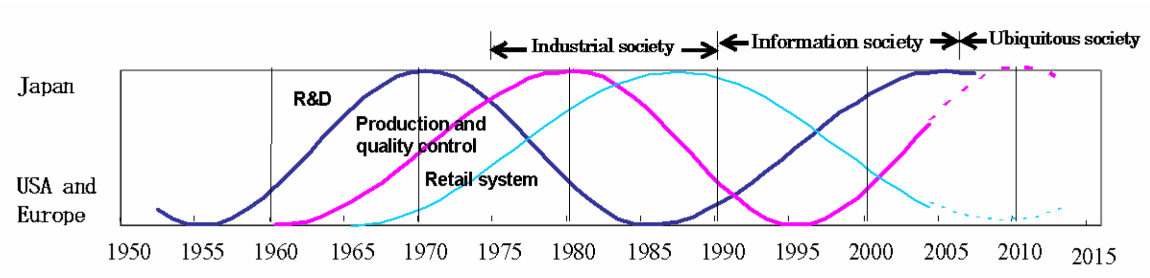

Figure 1. The mutually inspiring co-evolutionary development cycle in Japan and the USA (1950-2010).

Inspired by the UK Engineering Research Association (ERA) in the 1950s, MITI attempted to introduce this system in order to increase the international competitiveness of Japan's industrial technology. The government implemented the Law of the Engineering Research Association in 1961 which initiated the linkage of R&D to government, universities, and industry. The ERA system is well adapted in Japan's institutional systems. One unique institutional development can be seen in Japan's R&D consortia system: it balances the cooperation and competition of the participants and leverages the inducement of the industry's vigorous R&D, providing a mechanism to activate inter-firm technology spillovers.

Inspired by Japan's success (National Research Council, 1990), the USA emulated this R&D consortia system by enacting the National Cooperative Research Act in 1984 and encouraged the linkage of R&D which, supported by the advancement of IT in the 1990s, functioned well in establishing links between universities and industry as demonstrated in *Figure 2*. This created the foundation for the IT-driven new economy in the 1990s.

While Japan experienced a lost decade in the 1990s, it sustained intensive efforts on learning and absorbing advanced technologies and systems from its competitors. This is similar to what it achieved in its catching-up stage. These efforts induced learning and absorbing from the US initiatives in linking universities and industry. These effects stimulated the revitalization of the role of the Japanese universities in the early 20th century.

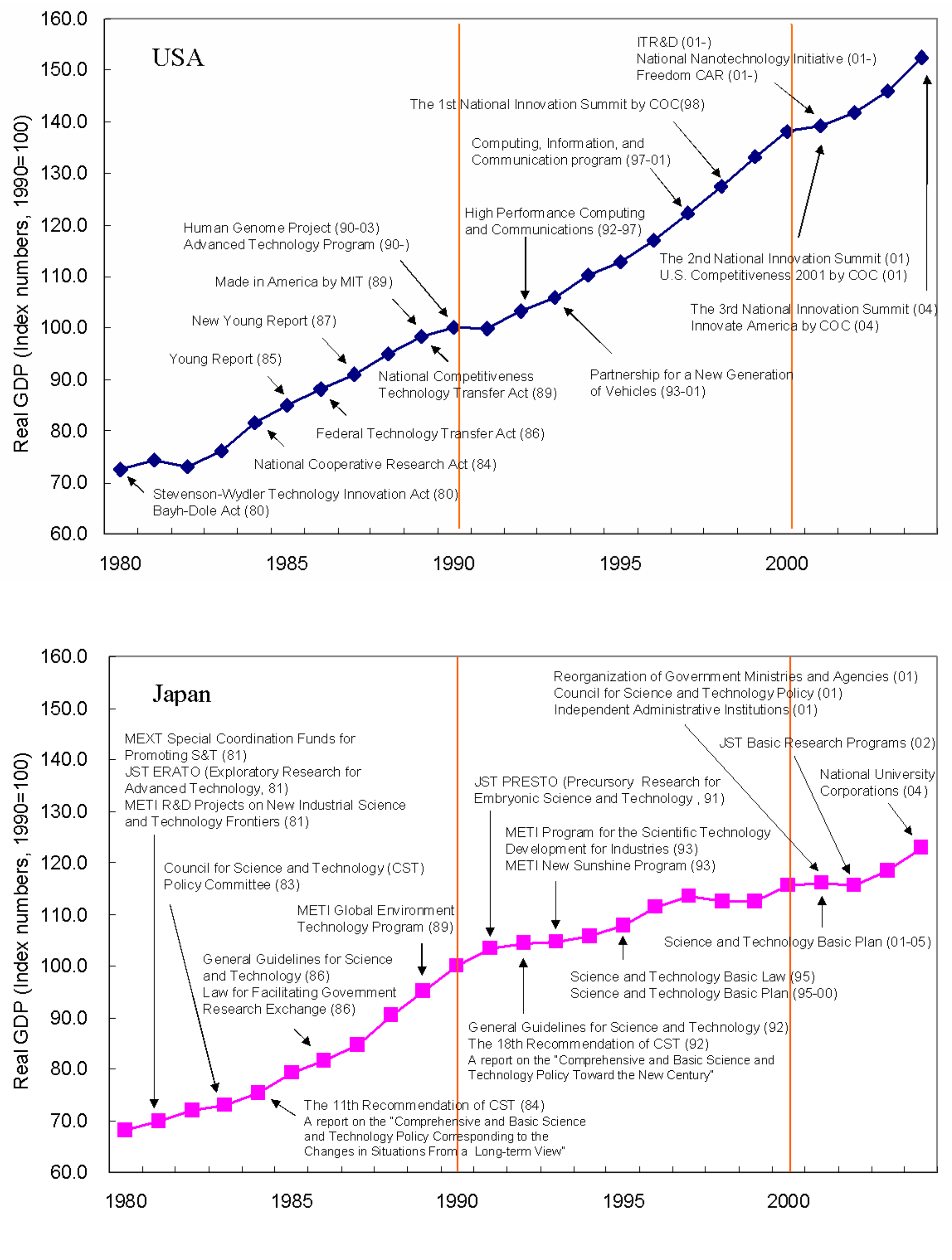

Figure 2. Parallel paths of science and technology policy trajectories in the USA and Japan (1980-2004).

2.2 Application of industrial ecology in industrial and information societies

MITI's attempt to develop a new policy principle at a turning point of Japan's industrial development in the beginning of the 1970s by introducing industrial ecology was in line with a similar policy cycle (Watanabe, 1972).

Aiming at analyzing and evaluating the complex mutual relations between human activities centered around industry and the surrounding environment, MITI postulated the concept of industrial ecology in the early 1970s, similar to that initiated in the US in the early 1990s by the National Academy of Engineering (Erkman, 1997).

The basic principle of industrial ecology suggests substitution among available production factors in a closed system in order to achieve sustainable development under certain constraints. Based on this concept, Japan achieved notable energy efficiency improvements in its industrial society of the 1980s that can be attributed to technology substitution for energy (Watanabe, 1999).

Contrary to its economic stagnation in the 1980s, the US achieved a significant economic development in the 1990s, while Japan experienced a lost decade due to economic stagnation. The US success can be attributed to IT substitution for traditional manufacturing technology, leading to a new functionality development corresponding to the requirement of a shift from the *growth-oriented trajectory based on manufacturing technology* to the *IT driven new functionality development trajectory* in an information society that emerged in the beginning of the 1990s.

However, after the bursting of the IT bubble in 2001, the USA has again been confronting the "new reality" (American Electronics Association, 2005) similar to that experienced in the 1980s (Council on Competitiveness, 1987). Given the new paradigm of a post-information society toward a ubiquitous society in the early 20th century that requires a shift from a *function-oriented* to a seamless, *solution-oriented* trajectory with all-actor participation and on-demand institutions—which is quite similar to an evolutional ecosystem—they need a new approach based on co-evolutionary dynamics to sustaining their national innovation as illustrated in *Figure 3*.

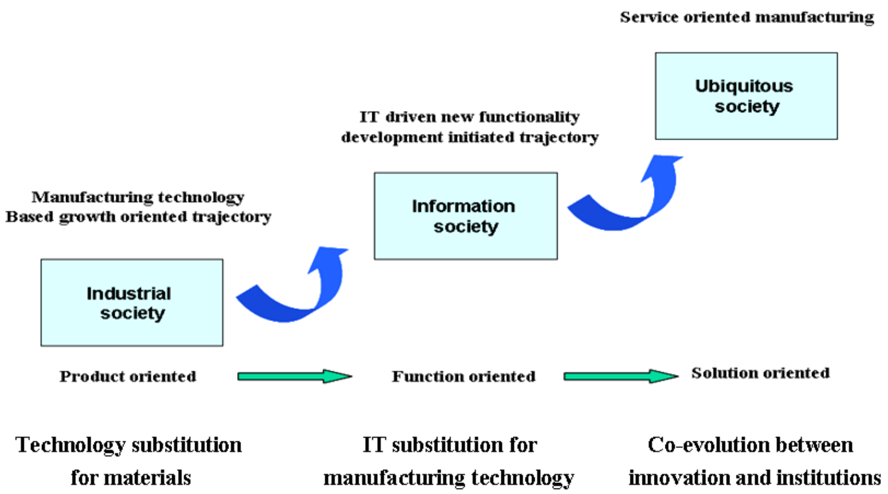

Figure 3. Paradigm shift and consequent development trajectory from an industrial society to an information society and to a ubiquitous society.

2.3 National Innovation Ecosystem for a post-information society

Coinciding with the announcement of the National Innovation Ecosystem proposed by the US Council on Competitiveness (21st Century Innovation Working Group of the Council on Competitiveness, 2004), Japan's Industrial Structure Council proposed a significant shift from a technology policy to an innovation policy based on the ecosystem concept (Industrial Structure Council, 2005). The scheme of the National Innovation Ecosystem proposed by the Council on Competitiveness is illustrated in *Figure 4*; it includes the following propositions:

- Innovation is much more than technology—many additional resources and services are essential for market success;
- As with human health, there is no single attribute adequate to capture innovation dynamics and multiplicity features;
- The success and diffusion of innovation is ultimately determined by the demand side and not just by technical inputs and product features;
- Firms are beyond the dichotomy of technology push and market pull; they are embracing both sides of the equation by collaborating more closely with customers, associating with external sources of innovation, networking resources into new business models, and focusing innovation on global market opportunities, and
- Non-linear dynamics characterize the entire innovation value chain end-to-end at the national and the firm level.

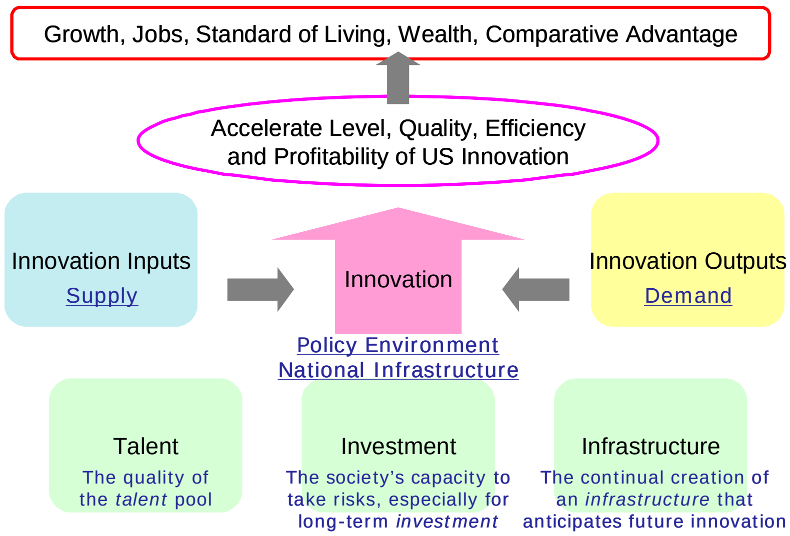

Figure 4. Scheme of the National Innovation Ecosystem.

3. Japan's Success in Technology Substitution for Energy

Japan's success in the economic development into an industrial society is considered to be the result of the industry's efforts to substitute technology for constrained production factors (such as labor and energy) in a manner similar to an ecosystem which compensates in order to maintain homeostasis (checks and balances that dampen oscillations); when one species slows down, another speeds up (Watanabe, 1992; 1994).

The basic concept of such a substitution mechanism in overcoming energy and labor constraints is illustrated in *Figures 5* and *6*.

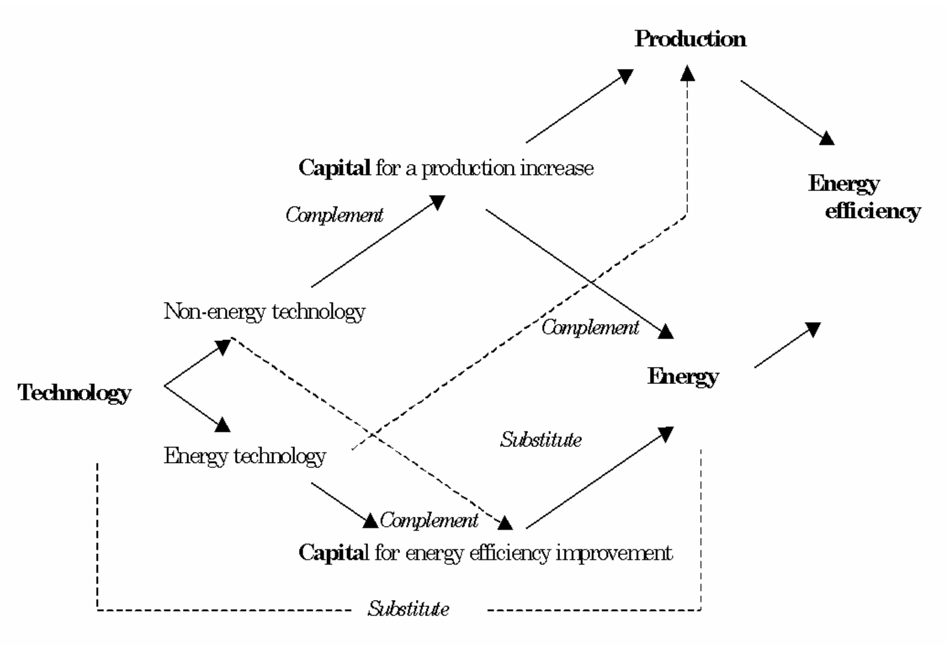

Figure 5. Basic concept of the technology option for sustainable growth under energy constraints.

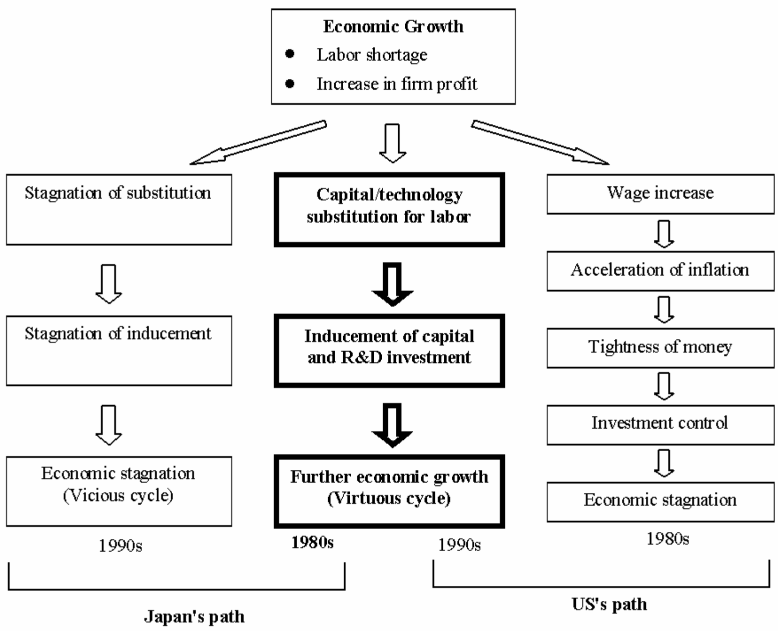

Figure 6. Scheme of capital/technology substitution for labor: comparison of Japan–US paths in the 1980s and 1990s.

With the support of the above mechanism, Japan succeeded in shifting technology substitution for constrained production factors, particularly energy after the first energy crisis in 1973, as demonstrated in *Figure 7*. It was thus was able to shift from an energy-dependent mode to a "greener" mode and achieved dramatic energy efficiency improvement as demonstrated in *Figures 8* and *9* (Watanabe, 1995a; 1999).

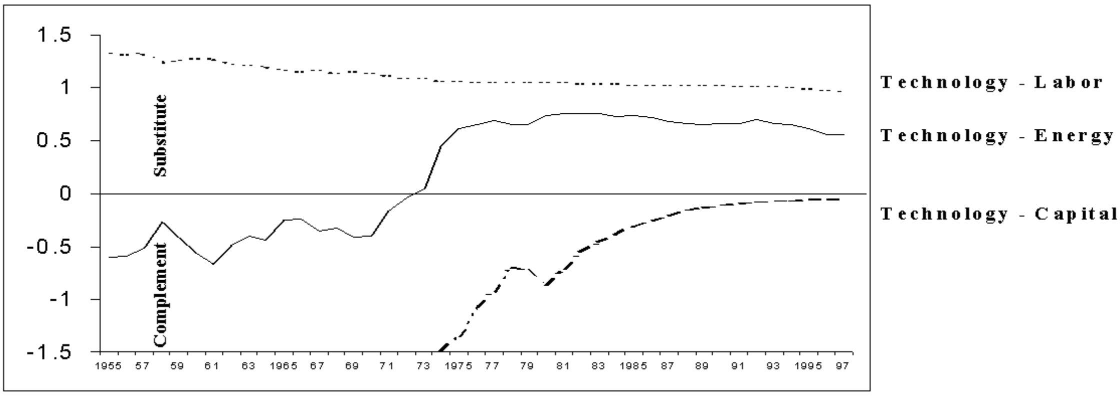

Figure 7. Trends in substitution and complementation among labor, capital, energy and technology in the Japanese manufacturing industry (1955-1997). Allen Partial Elasticity of Substitution.

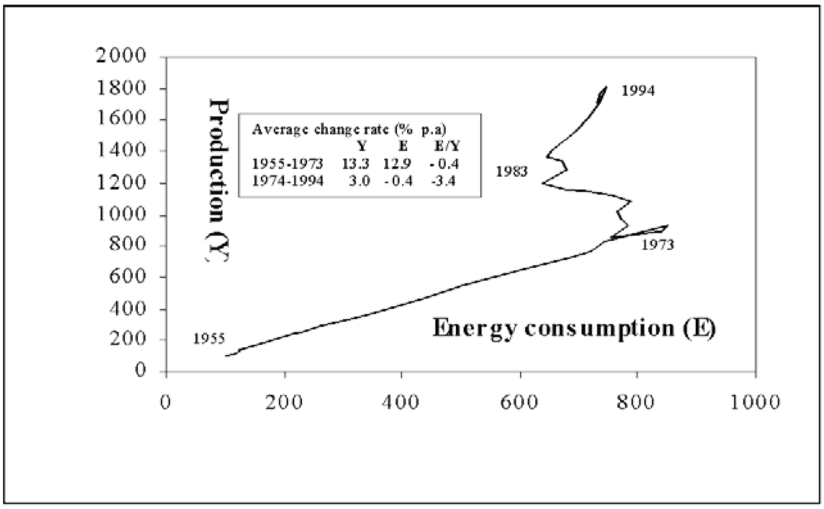

Figure 8. Trends in the Shift from an Energy-Dependent Mode to a Green Mode in the Japanese Manufacturing Industry (1955-1994). Index: 1955=100.

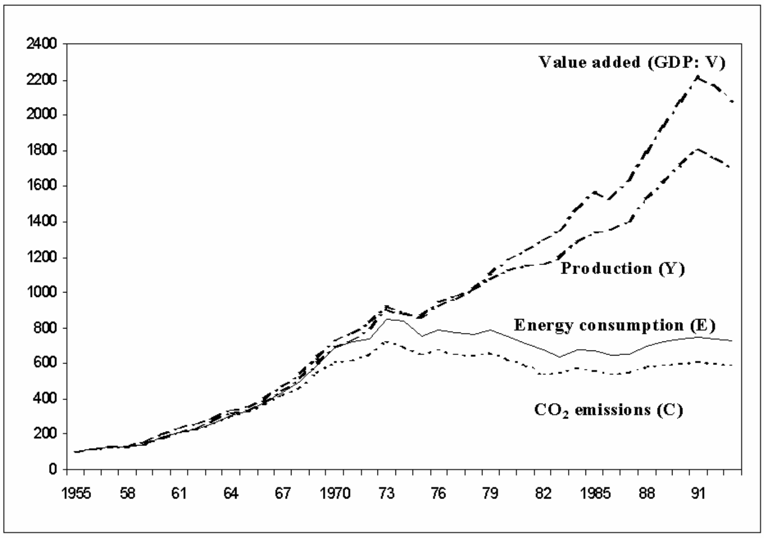

Figure 9. Trends in production, energy consumption and CO_2 discharge in the Japanese manufacturing industry (1955-1994). Index: 1955 = 100.

Thus, Japan recorded the highest economic growth (3.97% p.a.) with a 0.06% decline in CO_2 emissions in the 10 years following the second energy crisis in 1979 as demonstrated in *Figure 10*. This was possible due to a conspicuous energy efficiency improvement (3.44% p.a.) as is shown in *Table 1*. During the same period the USA attained 2.78% economic growth, and the CO_2 emission increased by 0.05%. Its energy efficiency improvement remained at 2.62%.

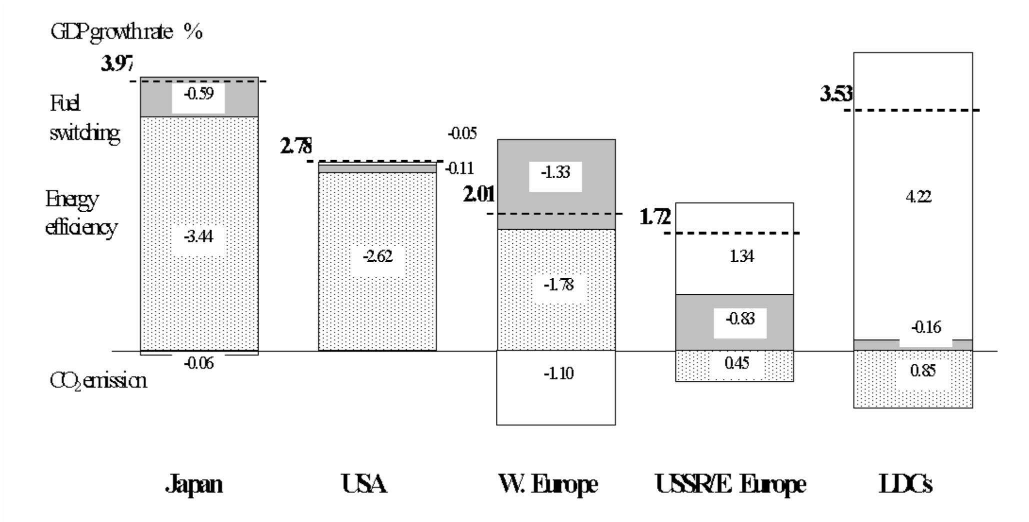

Figure 10. Comparison of development paths in major countries/regions (1979-1988). Average change rate in % per year.

Table 1. Comparison of development paths in major countries/regions (1979-1988). Average change rate in % per year.

	Production (ΔY/Y)	Energy efficiency (Δ(E/Y)/(E/Y))	Fuel switching (Δ(C/E)/(C/E))	CO_2 emissions (ΔC/C)
Japan	3.97	-3.44	-0.59	-0.06
USA	2.78	-2.62	-0.11	0.05
W. Europe	2.01	-1.78	-1.33	-1.10
USSR/E. Europe	1.72	0.45	-0.83	1.34
LDCs	3.53	0.85	-0.16	4.22

[a] Production is represented by *GDP*.
Sources: Y. Ogawa by using IEA's IEA Statistics, Energy Balances of OECD Countries, and Energy Statistics and Balances of non-OECD Countries, 1992.
[b] $\Delta Y/Y = -\Delta(E/Y)/(E/Y) - \Delta(C/E)/(C/E) + \Delta C/C$.

4. US Success in IT Substitution for Manufacturing Technologies

4.1 Switch to the new functionality development trajectory

Since the beginning of the 1990s the reversal of the competitiveness between Japan and the USA could be clearly observed. While Japan demonstrated the world's highest competitiveness in the 1980s, it was exceeded by the USA in the beginning of the 1990s. Since then, Japan's competitiveness continued to decline and, according to IMD (2002), it scored on the 30th place in the world ranking in 2002. Contrary to this dramatic decline in Japan, the USA has been maintaining its world top position with respect to competitiveness.

The reason for Japan's dramatic decline in competitiveness can be seen in the wrong choice of its growth trajectory. As shown in *Figure 11*, this corresponds to a paradigm shift from the high economic growth era until the end of the 1980s to a mature economy in the 1990s. Contrary to the USA's timely switch in growth trajectory from the "growth oriented development trajectory" (which achieves economic growth leveraged by high economic growth) to the "new functionality development initiated trajectory" (which maintains sustainable growth based on the development of the new functionality), Japan has still been clinging to a traditional growth-oriented trajectory. This can largely be attributed to the inertia following its conspicuous success during the high economic growth period based on the traditional trajectory (Watanabe, 1995b).[2]

[2] GDP can be depicted by the following production function:

$V = F(X, T)$ where *V*: GDP ; *X*: labor (*L*) and capital (*K*) ; *T*: technology stock.

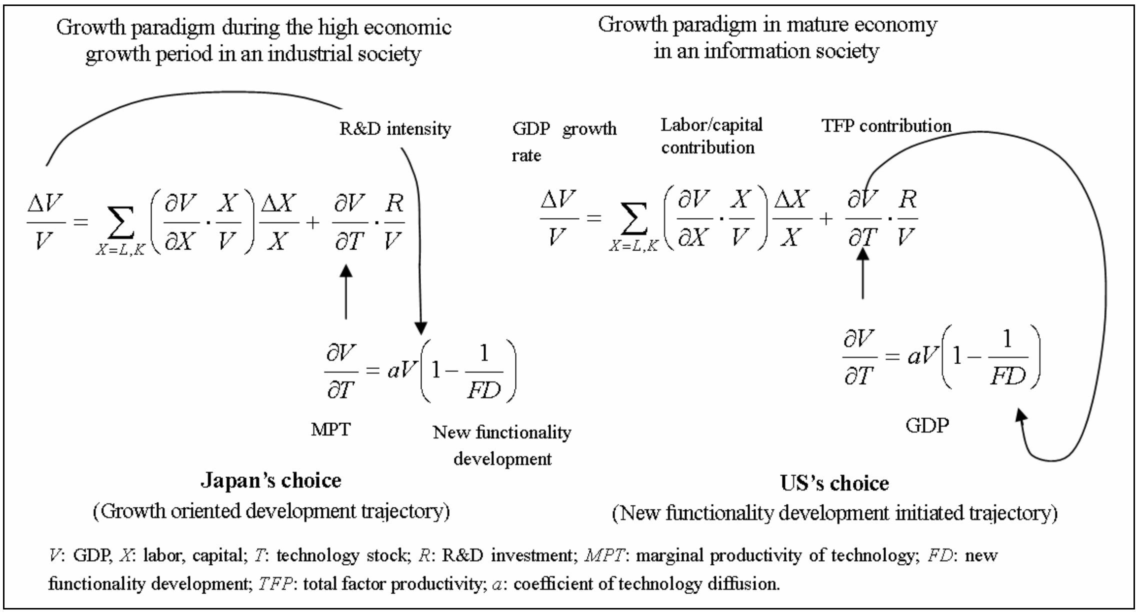

Figure 11. Growth trajectory options in Japan and the USA corresponding to a mature economy.

As a consequence of this wrong choice, the contribution of technological improvement to economic growth, or the contribution of TFP (total factor productivity) growth to GDP growth, dramatically declined in the 1990s resulting in the aforementioned contrast. As demonstrated in *Table 2* and *Figure 12*, Japan clearly contrasted in its TFP growth rates with the USA in the 1980s, which were 2.8% p.a. and 0.9% p.a., respectively, in the period 1985-1990. This contrast changed dramatically in the 1990s, i.e., to minus 0.3% p.a. and 0.9% p.a. in the first half of the 1990s and to 0.2% p.a. and 1.5% p.a. in the second half of the 1990s, respectively.

Table 2. Trends in growth rates of GDP and TFP in Japan and the USA (1960-2001) in % per year.

	1960－1973	1975－1985	1985－1990	1990－1995	1995－2001
Japan	9.7 (6.2)	2.2 (1.4)	3.4 (2.8)	2.0 (-0.3)	1.8 (0.2)
USA	3.8 (1.5)	3.4 (1.0)	3.2 (0.9)	2.4 (0.9)	3.9 (1.5)

$$\frac{\Delta V}{V} = \sum_{X=L,K}\left(\frac{\partial V}{\partial X}\cdot\frac{X}{V}\right)\frac{\Delta X}{X} + \underline{\left(\frac{\partial V}{\partial T}\cdot\frac{T}{V}\right)\frac{\Delta T}{T}} \approx \sum_{X=L,K}\left(\frac{\partial V}{\partial X}\cdot\frac{X}{V}\right)\frac{\Delta X}{X} + \underline{\frac{\partial V}{\partial T}\cdot\frac{R}{V}} \quad \text{where } \Delta V = \frac{dV}{dt}$$

TFP growth rate can be depicted as follows:

$$\frac{\Delta TFP}{TFP} = \left(\frac{\partial V}{\partial T}\cdot\frac{T}{V}\right)\frac{\Delta T}{T} \approx \frac{\partial V}{\partial T}\cdot\frac{R}{V}$$

A firm's competitiveness depends on the TFP growth rate as the contribution of labor and capital is limited under the aging trend in both labor and capital vintage.

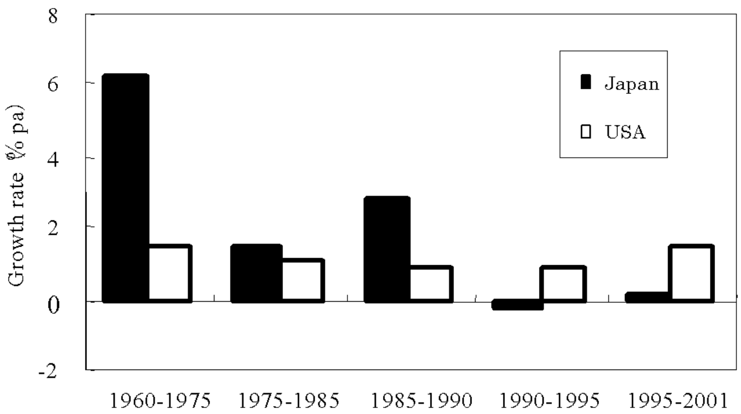

Figure 12. Trends in TFP growth rates in Japan and the USA (1960-2001).
Sources: 1960-1973: OECD Economic Studies (1988); 1975-2001: European Competitiveness Report (2001).

As the TFP growth rate can be measured by the product of R&D intensity (the ratio of R&D investment to GDP) and marginal productivity of technology (MPT), Japan demonstrates a conspicuously high level of R&D intensity in the world as shown in *Figure 13*. Therefore, a dramatic decline in Japan's TFP growth rate—despite of the conspicuous R&D intensity—can definitely be attributed to its dramatic decrease in marginal productivity of technology (see *Figure 14*). It is thus evident that Japan has become a nation of "poor output despite big input" with respect to its technology productivity. In fact, as demonstrated in *Figure 15*, Japan's marginal productivity has demonstrated a clear reversal compared to that of the USA in the 1990s.[3]

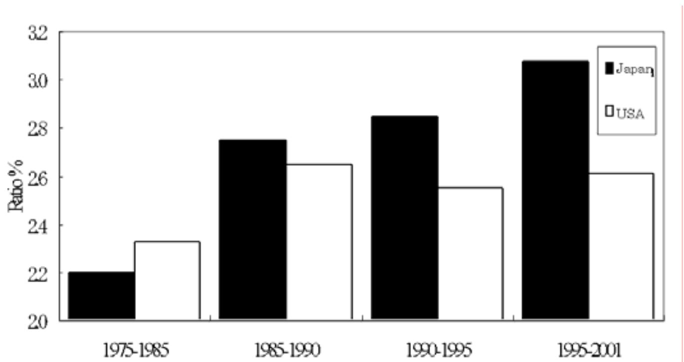

Figure 13. Trends in R&D intensity in Japan and the USA (1975-2001).
Source: White Paper on Japan's Science and Technology (annual issues).

[3] Since the marginal productivity of technology depends on GDP growth and/or new functionality development as shown in the equation in Figure 11, it may be a natural consequence that Japan's marginal productivity of technology has shown such a decline in the absence of any substantial efforts in the new functionality development in a mature economy where high GDP growth cannot be expected.

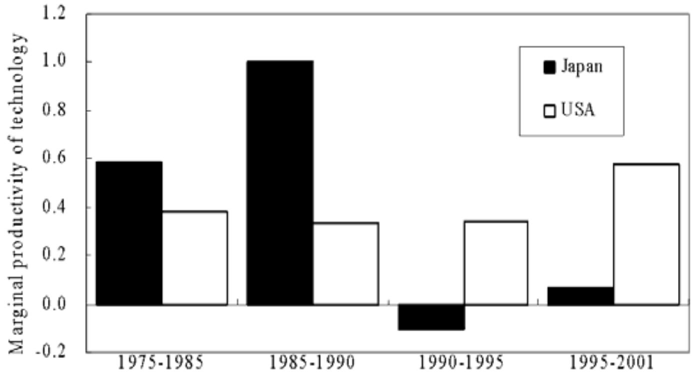

Figure 14. Trends in marginal productivity of technology in Japan and the USA (1960-2001). Marginal productivity of technology = ratio of growth rate of TFP and R&D intensity.

Sources:European Competitiveness Report (2001); White Paper on Japan's Science and Technology (annual issues).

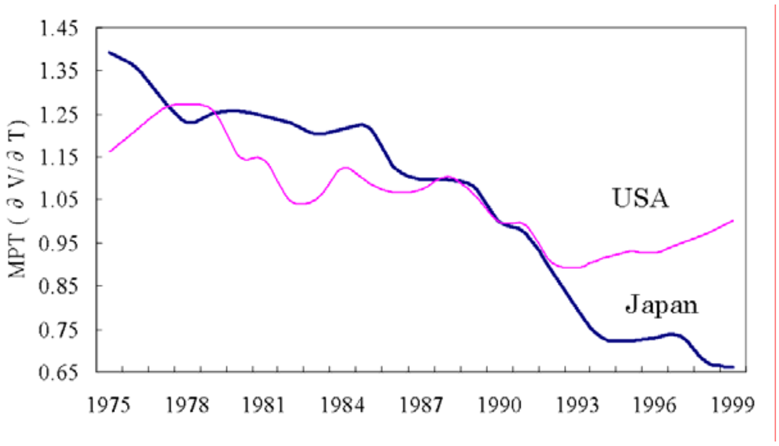

Figure 15. Trends in marginal productivity of manufacturing technology (1975-1999). Index: 1990 = 1.

MPT is computed by means of the technology elasticity to GDP measured by the following production function, with technology stock incorporating a logistic growth coefficient dummy variable (D_x), representing the trend in shift from an industrial society to an information society. The result of the regression analysis for the identification of the elasticity is tabulated below.

$$\ln V = A + \alpha \ln L + \beta \ln T + \gamma_1 \ln T + \gamma_2 D_x \ln T$$

$$D_x = \frac{1}{1+e^{-at-b}} = \frac{1}{1+e^{-\frac{\ln((1-\eta)/\eta)}{\varepsilon}t + \ln\frac{1-\eta}{\eta}(1+\frac{t_0-\varepsilon}{\varepsilon})}}$$

	α	β	γ_1	γ_2	*adj. R^2*	*DW*
Japan	0.586 (5.77)	0.370 (3.00)	0.367 (3.39)	-0.009 (-408)	0.995	1.42
USA	0.667 (6.87)	0.312 (7.36)	0.357 (10.31)	0.003 (1.65)	0.990	1.17

This striking difference in marginal productivity of technology between the USA and Japan can be attributed to the difference of the elasticity of the marginal productivity of the manufacturing technology to the shift to an information society as shown in *Figure 16*.

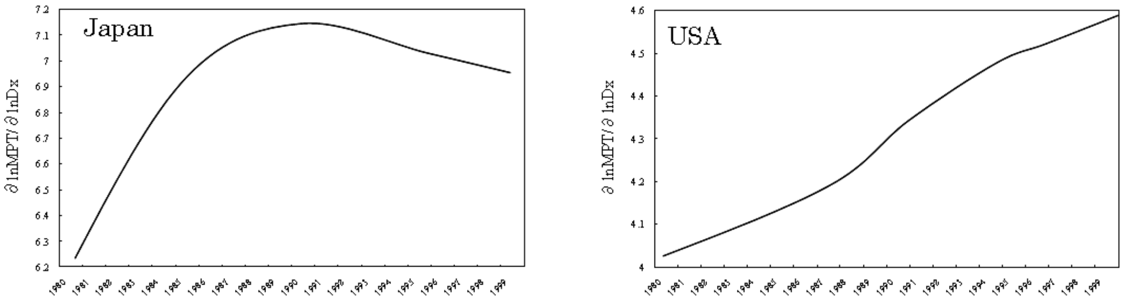

Figure 16. Comparison of the elasticity of marginal productivity of manufacturing technology to the shift to an information society in Japan and the USA (1980-1999).

The elasticity of MPT to the shift to an information society was computed by the following approach. The result of the regression analysis for the identification of the elasticity is tabulated below.

MPT can be depicted by the following equation:

$MPT = F(V, T, D_x)$

Taylor expansion to the secondary term:

$ln\ MPT = A + \alpha_1\ lnV + \alpha_2\ lnT + \alpha_3\ lnD_x + \beta_1\ lnV\ lnT + \beta_2\ lnV\ lnD_x + \beta_3\ lnT\ lnD_x$

Partial differentiation of this equation by $\ln D_x$ leads to the elasticity of the marginal productivity of the manufacturing technology and to the shift to an information society as follows:

$$\frac{\partial \ln MPT}{\partial \ln D_x} = \alpha_3 + \beta_2 \ln V + \beta_3 \ln T + \alpha_1 P + \beta_2 P \ln D_x + \beta_1 P \ln T$$

$$P \equiv 2\ r_T \ln T, \quad \frac{\partial \ln V}{\partial \ln T} = r_1 + r_2 D_x \equiv r_T$$

	α1	α1	α1	β1	β2	β3	adj. R^2	DW
Japan	2.430 (2.68)	0.517 (0.52)	0.249 (1.88)	-0.129 (-1.56)	0.064 (1.81)	-0.101 (-3.48)	0.990	0.90
US	1.550 (5.26)	-0.402 (-1.33)	-0.241 (-10.25)	-0.082 (-1.92)	0.009 (1.84)	0.028 (4.95)	0.990	1.38

Figure 16 demonstrates a clear contrast between the USA's and Japan's manufacturing industry in the elasticity of the marginal productivity of its technology to the shift to an information society. Contrary to the USA's acceleration to increase this elasticity, Japan changed to a declining trend in the 1990s. The US success can be attributed to the success in IT substitution for manufacturing technology in order to switch from the growth-oriented development trajectory to the new functionality

development initiated trajectory (Kondo and Watanabe, 2003; Watanabe and Kondo, 2003).

4.2 Confronting the new reality toward a ubiquitous society

Contrary to the conspicuous success in the 1990s based on the IT substitution for manufacturing technology, the US has—after the bursting of the IT bubble in 2001 and in the middle of the transition to a post-information society toward a ubiquitous society—again been confronting the "new reality" (21st Century Innovation Working Group of the Council of Competitiveness, 2004). This is primarily due to the increasing competitiveness of India and China which have learned from the US investment and outsourcing policy, as well as from Japan's revitalization toward a ubiquitous society by integrating its comparative advantages in manufacturing technology with IT; and Japan, in turn, has also learned a great deal from the USA during the course of its lost decade in the 1990s.

The latest report by the American Electronics Association (2005) entitled "Losing the Competitive Advantage" has given the following warning:

- The USA has been confronting new competition with a strong catching-up trend in certain countries (e.g., India, China, Russia, Eastern Europe, and South Korea) as a consequence of their economic reforms as well as of adaptation and utilization of technologies developed primarily by the USA;
- Waning commitments to R&D in the USA are threatening future innovation since the US Federal R&D funding that spawned so many technological breakthroughs in the 20th century is faltering; and
- The US workforce is increasingly unprepared for the 21st century economy due to
    - an increasingly ill-prepared domestic workforce,
    - a steadily depleting stock of high-skilled and educated foreigners, and
    - an aging population.

The report also paid careful attention to certain technologies of Japan as Japan would regain its comparative advantage given the co-evolution between its indigenous strength, primarily in manufacturing technology—developed and incorporated during the course of an industrial society— and the effects of cumulative learning actively absorbed from the USA in an information society and assimilated in its institutional systems.

Figure 17 compares trends in the manufacturing industry production in Japan and the USA over the period 1980–2004, encompassing an industrial society (1980–1990), an information society (1991–2000), and a post-information society toward a ubiquitous society (2001–2004).

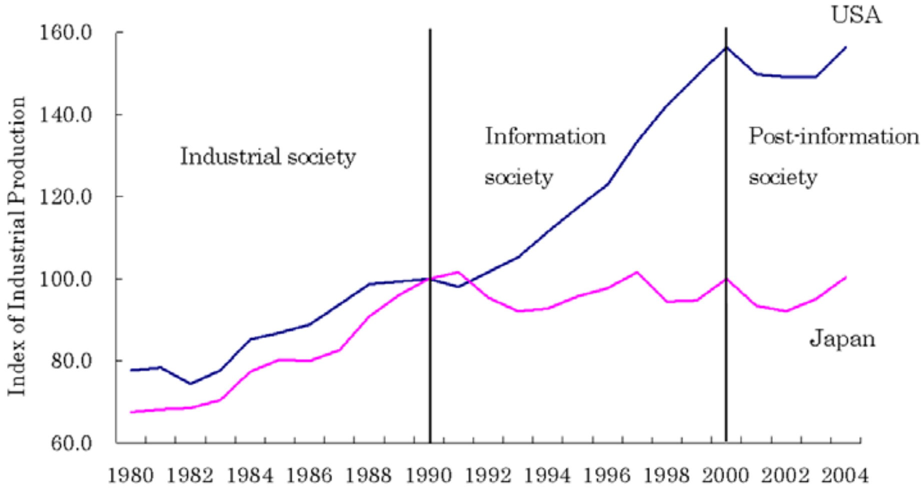

Figure 17. Trends in manufacturing industry production in Japan and the USA (1980-2004). Index: 1990=100.

Sources: The US Federal Reserve (December 22, 2004) and Japan's Ministry of Economy, Trade and Industry (February, 2005).

In order to compare the competitiveness in both countries in the three periods simply by terms of relative growth rates in the manufacturing industry production, the following simple regression analysis is conducted[4]:

$$\ln Y_{US} / Y_{JP} = a + g_1 D_1 t + g_2 D_2 t + g_3 D_3 t$$

where Y_{US}: the US manufacturing industry production; Y_{JP}: Japan's manufacturing industry production; a: scale factor; g_1, g_2 and g_3: balance of the average growth rate between the US and Japan's manufacturing industry in the period of an industrial society, an information society, and a post-information society, respectively; D_1, D_2 and D_3: coefficient dummy variables corresponding to the three periods as indicated below; and t: time trend.

The result of the regression analysis is summarized in *Table 3*.

[4] Given the average growth rates in the USA and Japan are g_{US} and g_{JP}, respectively,
$Y_{US\,t} = Y_{US\,0}(1+g_{US})^t \approx Y_{US\,0} e^{g_{US} t}$
where $Y_{US\,t}$ and $Y_{US\,0}$: production level at time t and initial stage, respectively.
Taking the logarithm,
$\ln Y_{US_t} = \ln Y_{US_0} + g_{US} t$.
Similarly,
$\ln Y_{JP_t} = \ln Y_{JP_0} + g_{JP} t$.
Taking the balance,
$\ln Y_{US_t} - \ln Y_{JP_t} = \ln Y_{US_t} / Y_{JP_t} = (\ln Y_{US_0} - \ln Y_{JP_0}) + (g_{US} - g_{JP}) t \equiv a + gt$
where $a = \ln Y_{US_0} - \ln Y_{JP_0}$, $g = g_{US} - g_{JP}$.

Table 3. Correlation between relative growth rate and relative production level in the US and Japan's manufacturing industry (1980-2004).

	Industrial society 1980-1990	Information society 1991-2000	Post-information society 2001-2004
D_1	1	0	0
D_2	0	1	0
D_3	0	0	1

$$\ln Y_{US}/Y_{JP} = 21.449 - 0.011D_1t + 0.053D_2t - 0.010D_3t - 127.233D_2 + 0.063D \quad adj.R^2\ 0.974 \quad DW\ 1.70$$

(4.15) (-4.13) (17.63) (-4.06) (-16.05) (2.15)

D : dummy variable (1987 = 1, other years are 0).

From *Table 3* the balance of the growth rates between the US and Japan's manufacturing industry in the three periods can be identified as summarized in *Table 4*.

Table 4. Balance of the Growth Rates between the US and Japan's Manufacturing Industry in Three Periods (1980-2004).

Industrial society *1980-1990*	Information society *1991-2000*	Post-information society *2001-2004*
-1.1% p.a. Japan: higher growth	5.3% p.a. US: higher growth	-1.0% p.a. Japan: higher growth

Table 4 suggests that, while the USA demonstrated its higher competitiveness by regaining higher growth during the course of the information society, its competitiveness changed again to lower growth than Japan in the post-information society. This result supports the fear expressed by the American Electronics Association's report.

In order to analyze the prospects of the competitiveness of the US industry in the transition from an information society via a post-information society to a ubiquitous society, *Figure 18* compares values of the world's 6 leading automobile companies between 1999 and 2004, taking into account their sales, equity market value, and net income. Looking at the figure we note that, while the US companies developed their scale by M&A in the 1990s, increased their sales position in the world market and maintained, to some extent, their scale in 2004, their net income dramatically decreased in 2004, resulting in the reversed position of Japan's firms such as Toyota, Nissan and Honda in 2004. This provides supporting documentation to the above-mentioned fear that the USA has been confronting the new reality with a catching-up trend by its competitors.

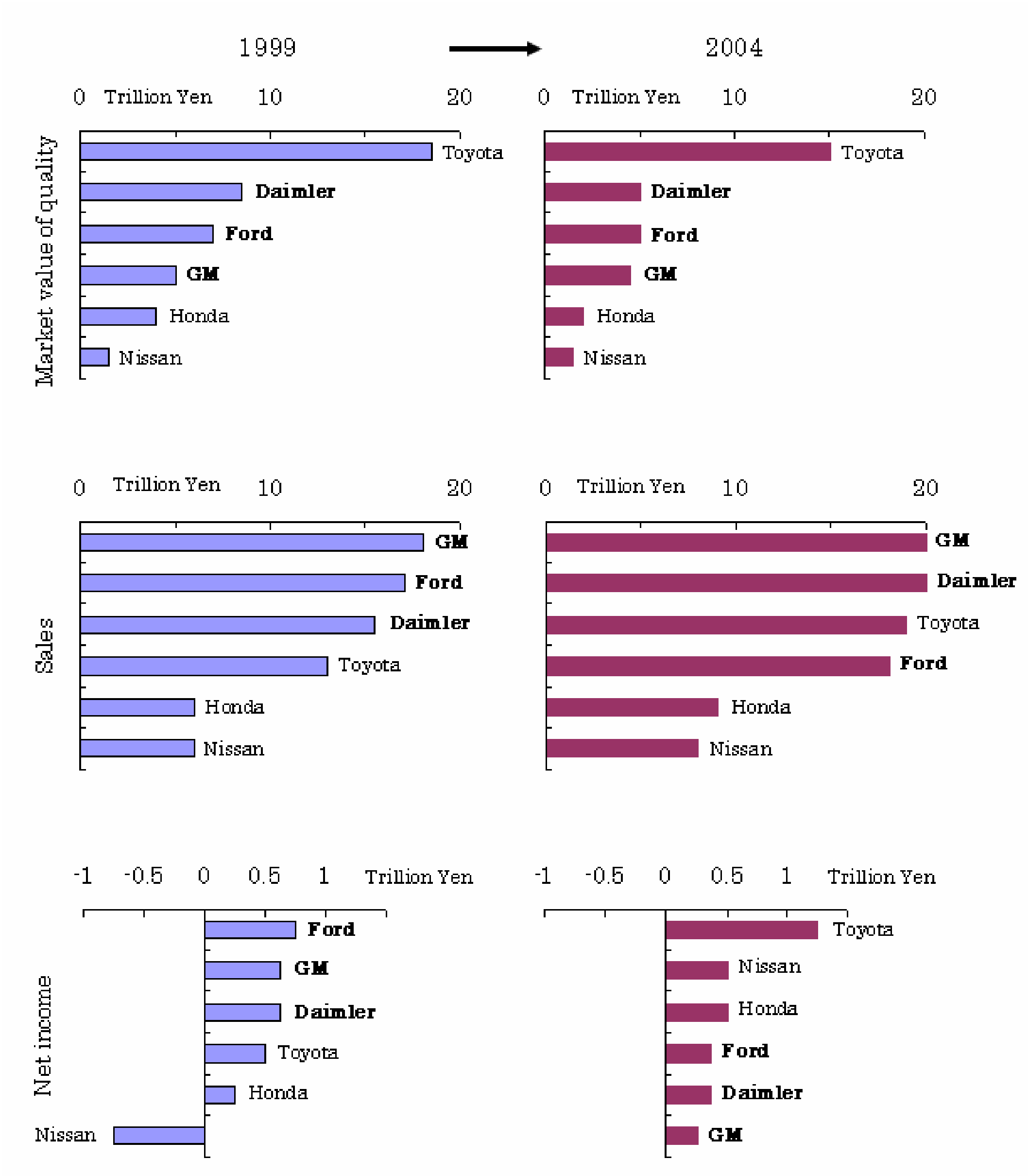

Figure 18. Comparison of sales values, equity market values and net income between 1999 and 2004 in the world's 6 leading 6 automobile companies.

Souce: Nihon Keizai Shimbun (April 15, 2005)

5. The New Dimension of the Ecosystem Function: Co-evolution of Innovation and Institutional Systems

As reviewed in the preceding section, significant developments have emerged in Japan's manufacturing industry in recent years. *Figure 19* illustrates the expansion of Japan's recent innovations. Most of these significant developments are new production and social technologies made possible by

- increasing digitalization of the manufacturing process,
- advanced digital infrastructure or alliance, and
- timely reaction to potential customer demands in the digital economy.

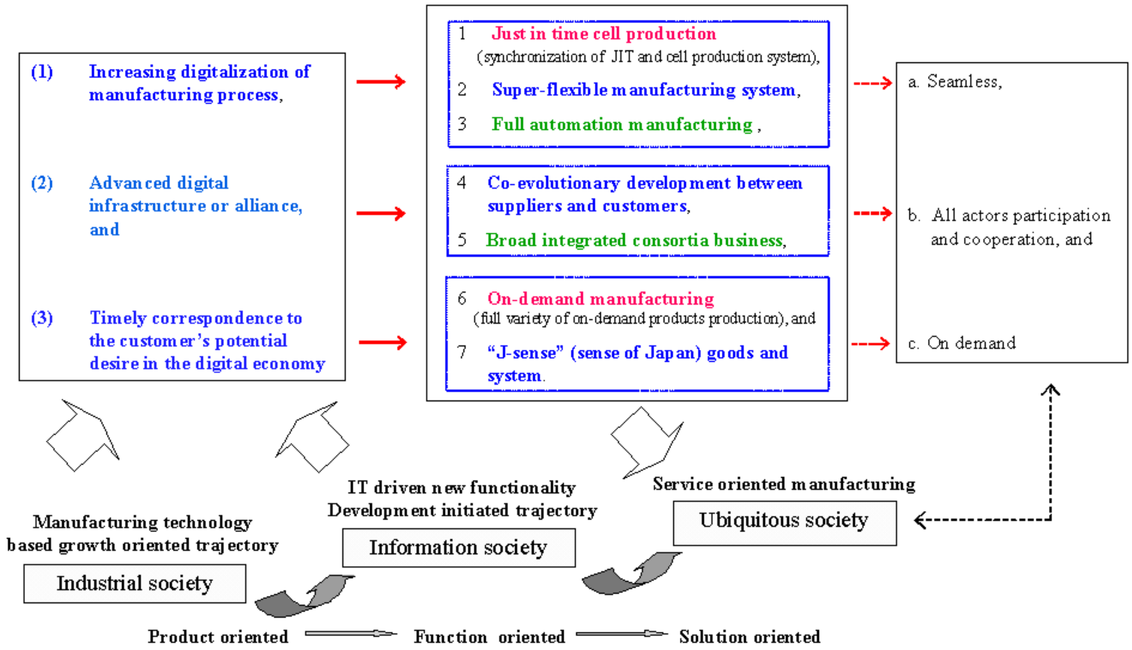

Figure 19. The expansion of Japan's recent innovations.

These innovations are the new backbone allowing for new product functionality as well as customized system-wide solutions. All of them can be attributed to the co-evolution of (i) the indigenous strength in the Japanese manufacturing firms developed and incorporated during the course of an industrial society, and (ii) the effects of cumulative learning actively absorbed from their competitors—primarily from the USA—in an information society and assimilated in their business model.

The above-mentioned significant development in recent years corresponds to the essential and emerging requirements of a ubiquitous society characterized by a seamless trajectory, with all-actor participation and on-demand institutions. This suggests that Japan's indigenous techno-preneur system is again responding to co-evolutionary dynamics between the emergence of innovation and advancement of institutional systems as it has accomplished in an industrial society, and adapting to new requirements in a ubiquitous society, which is above and beyond the requirements of the current information society characterized by functionality-driven self-propagation.

Provided that the foregoing expansion can be incorporated into Japan's institutional systems, a reactivation of Japan's techno-preneur system can be expected and may provide an additional demonstration of the significance of the co-evolutionary dynamics between the emergence of innovation and the advancement of institutional systems as illustrated in *Figure 20*. These dynamics resemble the co-evolutionary dynamics of an ecosystem, demonstrated as a sophisticated system by the Japanese indigenous techno-preneur system in an industrial society.

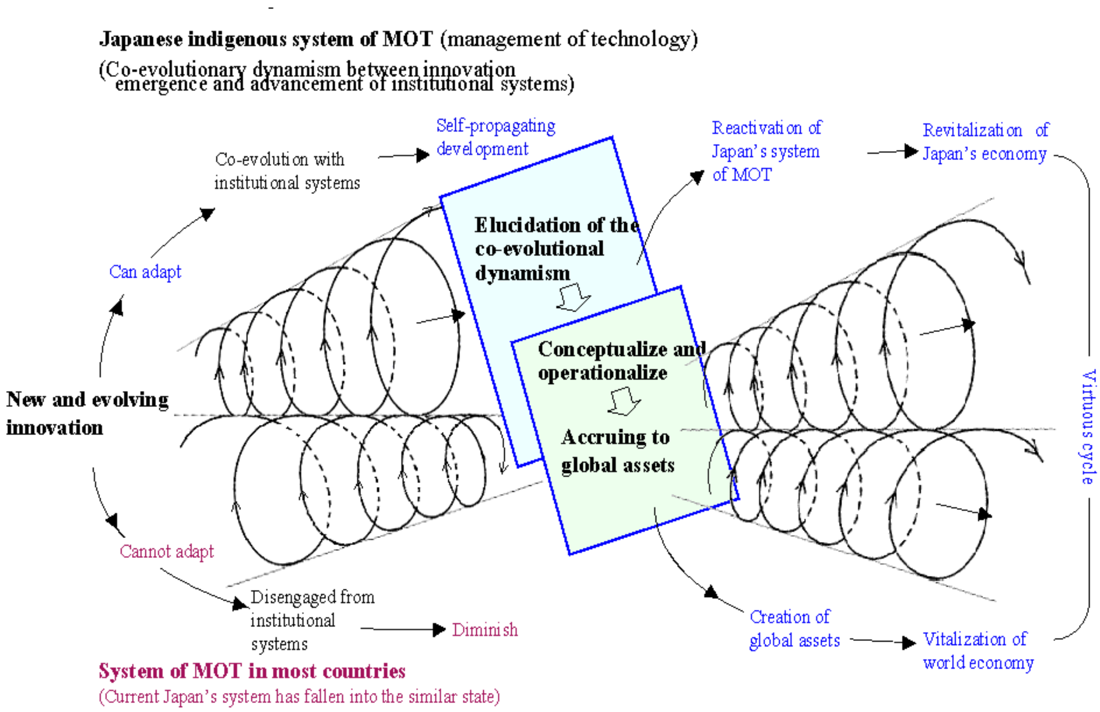

Figure 20. Co-evolutionary dynamics between innovation and institutional systems.

Given the foregoing, an elucidation of Japan's co-evolutionary dynamics in an industrial society up to the end of the 1980s is expected to provide significant insight. This is useful for a conceptualization and operationalization of the co-evolutionary dynamics, adding assets to the global knowledge in a post-information society moving toward a ubiquitous society. Thus, the new dimension of the ecosystem function extending toward a co-evolution of innovation and institutional systems is expected to lead to a new concept of the National Innovation Ecosystem.

6. Conclusion

Prompted by a profound concept of the National Innovation Ecosystem proposed simultaneously by both the USA and Japan in the transition from an information society via a post-information society toward a ubiquitous society, this paper analyzed the significance of the systems concept of the co-evolutionary dynamics involved in an ecosystem.

In the light of the mutually inspiring development cycle between Japan and the USA aiming at higher competitiveness and the consequent comparative advantages and disadvantages exhibited in both countries (in turn, corresponding to a paradigm shift from an industrial society in the 1980s, an information society in the 1990s, and a post-information society moving toward a ubiquitous society in the early 2000s), a comparative empirical analysis of the development trajectories in both countries in each respective paradigm was attempted by means of the application of the co-evolutionary dynamics involved in an ecosystem.

Significant findings are:

- A mutually inspiring co-evolutionary development cycle in Japan and the USA has functioned well through leveraging innovative challenges for both countries to win the competition, leading to cyclical changes in higher competition in Japan in the 1980s and in the US in the 1990s.
- Japan's conspicuous economic achievements in the industrial society in the 1980s can be greatly attributed to its success in incorporating the ecosystem principle with its industrial policy by means of technology substitution for constrained production factors, primarily for energy after the energy crises.
- The reversal of the competitiveness between Japan and the USA in the information society in the 1990s can be definitely attributed to the USA's timely switch from a growth-oriented development trajectory to a new functionality development initiated trajectory by means of IT substitution for manufacturing technology.
- Corresponding to an expansion of the paradigm shift to a post-information society moving toward a ubiquitous society in the early 2000s, the USA has again been confronting the "new reality" due to the emergence of catching-up competitors such as India and China, as well as to the expansion of Japan's new innovations.
- This expansion, which has primarily occurred in Japan, can be attributed to the co-evolution of an indigenous strength developed and incorporated during the course of the industrial society, and the effects of cumulative learning absorbed from the USA in an information society and assimilated in its business model.
- The new reality in the transition from an information society to a ubiquitous society that requires a shift from the function-oriented discipline to the solution-oriented discipline has led both the USA and Japan to the realization of the significance of the co-evolutionary dynamics involved in an ecosystem.

These findings make us to realize the significance of the following policies:

- Technology policy should endeavor to generate innovation with a view to constructing a co-evolution between the innovation development cycle and the advancement of the institutional system.
- Given the systems efficiency in constructing the above co-evolutional dynamics, potential resources in innovation should be effectively explored and utilized in a systems perspective.
- Provided that the requirements of a seamless trajectory with all-actor participation and on-demand institutions characterizing a ubiquitous society can be fulfilled, a multilayer mutually inspiring cycle should be constructed in a global context.

Further work should focus on the elucidation and conceptualization of the co-evolutionary dynamics between innovation and institutional systems accomplished by certain nations under certain historical perspectives.

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