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Innovation Ecosystem for Sustainable Development

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1. Introduction

Innovation has significantly contributed to growth and development of society in the 20th century. Advances in science and technology have boosted the productivity and competitiveness of industry, and also have vastly improved living standards and the quality of life. At the same time, however, rapid growth of industrial production has increased consumption of energy and natural resources enormously. Subsequent impacts on the environment have caused various threats to endanger the survival of life such as global warming and excessive use of energy, land and water resources.

Sustainable development is of the most concern to the global society today (Millennium Ecosystem Assessment, 2005; Intergovenmental Panel on Climate Change [IPCC], 2007; World Business Council for Sustainable Development [WBCSD], 2008). While it has often focused on environmental concerns, sustainable development has three dimensions: economic, environmental and social (World Commission on Environment and Development, 1987; Senge & Carstedt, 2001; Sheth et al., 2011). The challenge of sustainable development necessitates fundamental changes in the way of growth and development in the world. Industries should develop their business model not only based on economic performance, but also taking account of the environment and social impacts as well. Governments should adopt legislation and regulation on economic activities and environmental issues to enhance sustainability consideration and social awareness.

Achieving these goals requires innovation for improving the triple bottom line: economic, environmental and social well-being. Innovation is an essential driver for sustainable development. It enables industries to increase productivity while decreasing resource uses and environmental impact. It also delivers new value to satisfy high standards of living.

With the growing awareness of the significance of innovation for sustainable development, a concept of an 'innovation ecosystem' has been postulated (President's Council of Advisors on Science and Technology [PCAST], 2004; Council on Competitiveness, 2004; Industrial Structure Council, 2005). In this concept, innovation is considered a comprehensive system interacting closely with surrounding environment rather than a linear and mechanical progression. This consideration means not only optimizing internal innovation processes but also optimizing externally. An innovation ecosystem needs to adjust all public and private sector stakeholders as well as adapt itself to changes in the external environment.

This chapter attempts to analyze dynamics of innovation systems from perspective of sustainable development. An empirical analysis focusing on stability properties rather than process complexity of ecosystem was conducted. Section 2 reviews the dynamics and features of innovation ecosystem to sustain stability. Section 3 describes the mutual inspiration cycle between Japan and the US in the last three decades. Section 4 explains the new global trends in innovation for sustainable development. Finally, Section 5 briefly summarizes and concludes this chapter.

2. Properties of innovation ecosystem

The concept of innovation ecosystem often stresses that innovation occurs through interactive networks at various levels (Council on Competitiveness, 2004; Iansiti & Levien, 2004; Industrial Structure Council, 2005; Organisation for Economic Co-operation and Development [OECD], 2008). These networks are a broad and complex array of stakeholders in both of public and private sectors. An important function of innovation ecosystem consists of governmental organizations that fund R&D activities, many areas of policy which impact the effectiveness of innovation, large and small firms who transform research and new knowledge into the market place, universities, research institutes, and different kinds of infrastructure such as transportation and telecommunications. All stakeholders are related to one another in a complex manner in innovation processes as a part of an innovation ecosystem. Their behaviors improve the performance of an ecosystem and, in doing so, improve individual performances.

Strong performance of an innovation ecosystem requires reduction of uncertainty in innovation processes (Klein & Rosenberg, 1986; Iansiti & Levien, 2004). The changes in a highly turbulent environment increase the uncertainty not only on technological performance but also on the market response and ability of stakeholders to absorb and utilize the requisite changes effectively. This correlation between change and uncertainty in an innovation ecosystem necessitates autonomic reaction of each stakeholder and coordination of the network of stakeholders. This combination of autonomy and coordination enables an innovation ecosystem to improve its performance enough to survive uncertain global circumstances, achieving sustainable development.

A natural ecosystem provides a suggestive analogy for sustaining an innovation ecosystem. Stability is an important characteristic of a natural ecosystem reflecting complex homeostatic processes, especially in the face of environmental variability (Millennium Ecosystem Assessment, 2005). As with a natural ecosystem, stability in the face of external shocks is an important goal of an innovation ecosystem sufficient to meet demands for sustainable development. Ecosystem stability requires three factors: resistance, resilience and functional redundancy (Allison & Martiny, 2008). Resistance is the capability of a system to remain in the same state in the face of disturbance. Resilience is the rate at which a system returns to its initial state after being disturbed. Functional redundancy is the ability of a system to carry out a functional process in a similar rate regardless of disturbance. Resistance can be described as inertia, and resilience has some aspects including elasticity (rapidity of restoration following disturbance) and amplitude (zone from which a system will return to a stable state) (Westman, 1978). Allison & Martiny (2008) explains the potential impacts of disturbance on an ecosystem with these three factors. When a disturbance is applied to an ecosystem, it might be resistant to the disturbance and not change. Alternatively, if an ecosystem is sensitive to the disturbance and does change, it could be resilient and promptly recover to its initial state. Finally, an ecosystem which is not resilient might perform like the original state if the constituent members of an ecosystem are functionally redundant. This process to absorb external disturbance is deeply correlated with internal interaction process between its components. Marten (2001) pointed out three emergent properties of interaction in an ecosystem: co-existence, co-evolution and co-adaptation. Co-existence is built into an evolutionary game between species. Co-adaption (fitting together) is a consequence of co-evolution (changing together). Species in an ecosystem has an ability to change as circumstance demands. They change the way in which they interact with other species, and as a consequence, organize themselves through co-adaption. Co-evolution is essential to coordinate an ecosystem internally in a stable manner. These processes to maintain stability of ecosystem both internally and externally are combined in such a way that the ecosystem as a whole continues to function on a sustainable basis.

The natural ecosystem analogy suggests that a competence to address rapidly changing circumstances is necessary for sustainable development. Like a natural ecosystem, an innovation ecosystem is characterized by various participants interacting with each other. They co-exist, co-evolve and co-adapt with each other, and through this interaction, improve performance of the innovation ecosystem as a whole. Meanwhile, the innovation ecosystem resist, resilient and functionally redundant to external disturbances. This function to maintain both of internal and external stabilities has been recognized by the current global society facing an increasingly uncertain future. Serious demands for sustainable development in economic, environment and social dimensions are a new challenge for an innovation ecosystem.

3. Co-evolutionary cycle between the innovation ecosystems in Japan and the U.S.

While the U.S. was the primary leader in innovation over the course of the 20th century, it confronted a challenge from Japan in the 1980s (Council on Competitiveness, 2004). After the two energy crisis of the 1970s, Japan achieved notable energy efficient improvement in the 1980s that contributed to high economic growth driven by manufacturing technologies (Watanabe, 1995). The emergence of Japan initiated mutual inspiration between both countries leading to contrasting success in innovation during the last three decades (Fukuda & Watanabe, 2008).

The challenge from Japan triggered efforts to restore the U.S. competitive position. Both public and private sectors released proposals on competitiveness, including the 1985 report of the President's Commission on Industrial Competitiveness, the Report by Council on Competitiveness analyzing competitiveness problems in 1987 and *Made in America* published in 1989, and the federal government enforced new innovation legislation such as the Bayh-Dole Act of 1980, the National Cooperative Research Act of 1984, the National Competitiveness Technology Transfer Act of 1989. Through these efforts, the U.S. established a foundation for a new economy driven by information and communication technology (ICT) in the 1990s.

While the U.S. enjoyed economic success in the 1990s, Japan experienced economic stagnation known as the Lost Decade. During the period, both of public and private sectors in Japan rushed to construct the ICT infrastructure and accelerated R&D and dissemination of telecommunication equipments. Besides, the government enacted the Science and Technology Basic Law in 1995 to support national development through science, technology and innovation, and in response to the Basic Law, adopted the First Science and Technology Basic Plan in 1996 for a period extending to the end of Japanese Fiscal Year 2000. As a result of these efforts, Japan began to show signs of recovery in the early 2000s. However, it confronted the reality that the revitalization of its manufacturing industry is not whole industry-wide, which resulted in bi-polarization in profitability among high-technology firms.

This cyclical reversal of competitive dominance between Japan and the U.S. suggests that the natural ecosystem analogy explains the dynamism of mutual interaction between both countries. Both countries have co-evolved each other in the rise and fall of competitive advantages over the last three decades, and have survived to maintain stability of their national innovation ecosystems respectively. Their reactions to external disturbances varied over time.

3.1 Japan's success in the 1980s

Japan's conspicuous economic achievement in the 1980s can be attributed to its success in technology substitution for constrained production factors. This is similar to a function of biological ecosystems, where some species slows down and other species speeds up to compensate, in order to maintain homeostasis.

Both of public and private sectors in Japan accumulated efforts to reduce energy dependency after the energy crisis in 1973 (Watanabe, 1992, 1995a). The industry efforts to increase energy technology significantly contributed to improvement of energy efficiency. The government appropriated its R&D budget for energy R&D on a priority basis to induce vigorous energy R&D efforts by industry in the late 1970s and the early 1980s, and national R&D program projects such as the Sunshine Project initiated in 1974 and Moonlight Project initiated in 1978 encouraged networking among industries as well as between the government and industry.

	Production	Energy efficiency	Fuel switching	CO_2 emissions
Japan	3.97	-3.44	-0.59	-0.06
U.S.	2.78	-2.62	-0.11	0.55

Source: Watanabe, 1999.

Table 1. Comparison of development path in Japan and the U.S. (1978-1988) – average change rate; % per annum

The combination of autonomic efforts by industry and coordination by the government achieved a dramatic energy efficiency improvement (Watanabe, 1995b, 1999). As tabulated in Table 1, Japan recorded the highest economic growth (3.97% per year) with a 0.06% decline in CO_2 emissions in the 10 years following the second energy crisis in 1979. This was possible due to conspicuous energy efficiency improvements (3.44% per year). During the same period, the U.S. attained 2.78% economic growth, and CO_2 emissions increased by 0.05%, although its energy efficiency improvement remained at 2.62%. This notable success of Japan enabled the national innovation ecosystem to be resilient to energy shocks and to improve its performance by means of the fusion of efforts by public and private sectors.

3.2 Reversal of competitive advantage between Japan and the U.S. in the 1990s

Contrary to its economic success in the 1980s, Japan suffered a serious economic downturn and declined its competitiveness severely in the 1990s (IMD, 2002). This dramatic decline in competitiveness can be attributed to resistance of the national innovation ecosystem to emergence of ICT.

Japan continued to cling to a growth-oriented development trajectory in which economic growth leverages further growth, largely because its successes in the decades of high economic growth owed to the traditional development trajectory (Watanabe, 1995a; Fukuda & Watanabe, 2008). As a consequence of this strong resistance, the contribution of technological progress to economic growth decreased dramatically during the decade (European Commission, 2001). Table 2 demonstrates trends in TFP (total factor productivity) growth rate, R&D intensity (the ratio of R&D investment to GDP) and marginal productivity of technology (MPT) in Japan and the U.S. during the period from 1975 to 2001. TFP growth rate in Japan was 2.8 % per year in the late 1980s, significantly higher than that of the U.S., 0.9 % per year. However, the reverse occurred in the 1990s. The growth rate in Japan fell to negative 0.3% per year in the first half of the decade and slightly recovered to 0.2 % per year in the second half. During the decade, Japan maintained a high level of R&D intensity around 3.0 % (Ministry of Ministry of Education, Culture, Sports, Science and Technology of Japan, 2002, 2003). Since TFP growth rate is measured by the product of R&D intensity and MPT, the dramatic decline in TFP growth rate notwithstanding such high R&D intensity can be attributed to the remarkable decrease in MPT.

		1975-1985	1985-1990	1990-1995	1995-2001
Japan	TFP growth rate	1.4	2.8	-0.3	0.2
	R&D intensity	2.2	2.8	2.9	3.1
	MPT	0.6	1.0	-0.1	0.1
U.S.	TFP growth rate	1.0	0.9	0.9	1.5
	R&D intensity	2.3	2.7	2.6	2.6
	MPT	0.4	0.3	0.3	0.6

Table 2. Trends in growth rate of TFP, R&D intensity and Marginal Productivity of Technology (MPT) in Japan and the U.S. (1975-2001) – average change rate; % per annum

In contrast, the U.S. increased its TFP growth rate from 0.9 % per year to 1.5% per in the 1990s due to doubling of MPT as tabulated in Table 2. While Japan suffered from a misleading option, the U.S. successfully shifted its growth trajectory to a new trajectory which maintains sustainable growth based on developing new functionality (Watanabe, 1995; Fukuda & Watanabe 2008). ICT has a feature that closely interacts with individuals, organizations, and society during the course of its diffusion (Watanabe et al., 2004). This feature enhanced the U.S. industry efforts to expand outsourcing, disseminate products and services quickly, and improve relationships with customers. Furthermore, intensive R&D efforts in both the government and industry achieved dramatic progress in ICT. Thus, the U.S. innovation ecosystem successfully substituted ICT for manufacturing technologies and promptly increased adaptability to a new paradigm of ICT.

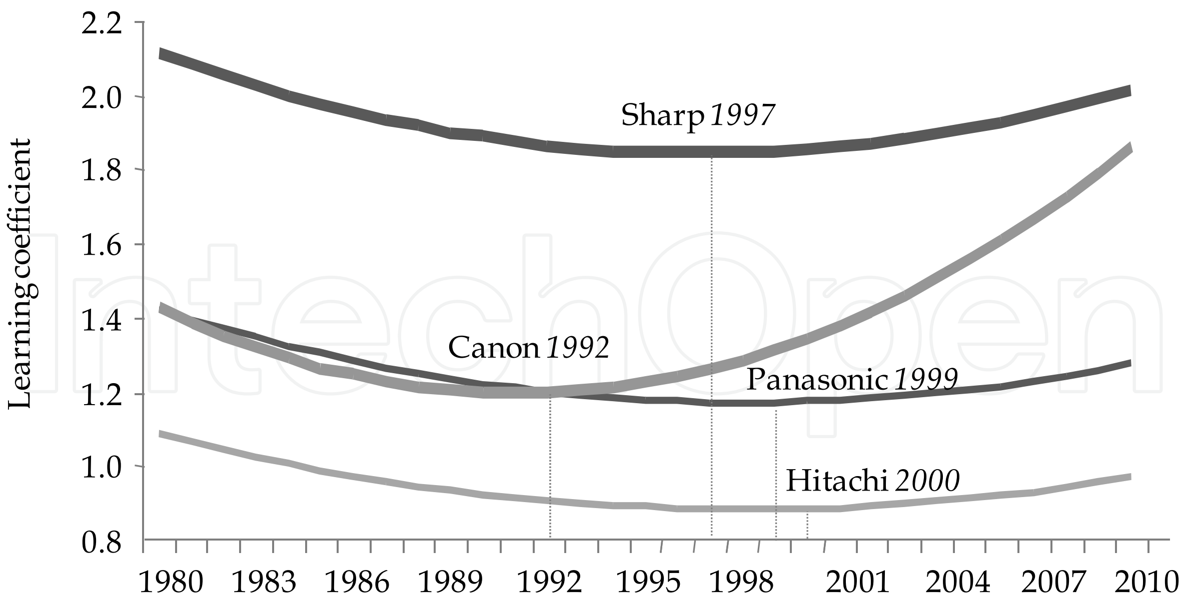
3.3 New reality for Japan and the U.S. in the 2000s

Facing the new century, Japan and the U.S. confronted a new reality of global competition in innovation.

While the U.S. enjoyed the benefits of ICT in the 1990s, threats to its competitiveness emerged internally and externally. During the decade, the U.S. capacity of innovation stagnated (Porter et al., 1999). One of the causes underlying the stagnation was emerging shortage in the R&D talent pool. The number of R&D workers as a percentage of the total workforce declined. Many international R&D talents were trained in the U.S. and returned their home country on completion of their studies. Another cause was declining investment in R&D by cutbacks at the Federal level. Total spending on basic research has declined steeply as a percentage of GDP. In addition, private research showed clear signs of becoming much shorter term. Meanwhile, catch-up competitors in emerging countries achieved rapid growth to threaten the U.S. global competitiveness. China and India accelerated their GDP growth faster than major advanced countries (OECD, 2010). These disorders suggest inertia of the U.S. innovation ecosystem which caused it to lose adaptability to rapid changes in the global economy.

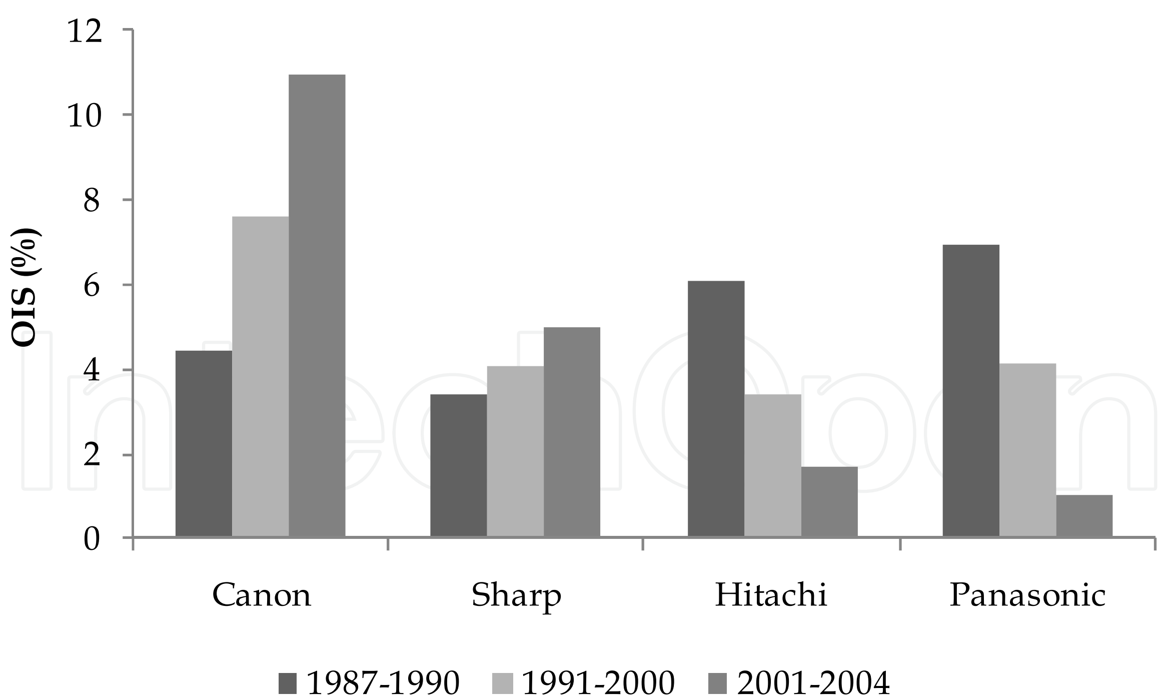
On the other hand, Japan made every effort to learn from the accomplishment of the U.S. in the 1990s. Japanese high-technology firms learned from and assimilate the experiences of the U.S. to achieve greater gain from ICT thorough competition in the global markets. Even as high-technology industry overall strengthened learning efforts, some firms improved its learning ability more effectively than others. Consequently, a discrepancy firms endeavoring to learning from the global markets and clinging to traditional business behaviors increased (Fukuda & Watanabe, 2008; Watanabe, 2009). Fig. 1 illustrates trends in learning coefficients in four leading electric machinery firms. The coefficients in Canon and Sharp reversed to steadily increase in 1992 and 1997, respectively. While Hitachi and Panasonic also started to increase their coefficients in the end of the century, those increases were not significant. The difference in their learning results led to a difference in profitability. The operating income to sales (OIS) of these four has changed in two different trajectories as demonstrated in Fig. 2. Canon and Sharp increased their average operating income to sales (OIS) steadily over all three periods examined. Comparing the average OIS in the 2000s with that of the 1980s, Canon doubled its OIS and Sharp increased it by 50%. On the other hand, Hitachi and Panasonic decreased their OIS sharply. Hitachi reduced its average OIS by 48% in the 1990s and 66% in the 2000s, and Panasonic decreased its average OIS by 41% in the 1990s and 86% in the 2000s.

These trends imply that the Japanese innovation ecosystem was resilient to the economic downturn in the 1990s. Although the national innovation ecosystem revitalized its performance through learning from competitors, its composition changed to being more heterogeneous after the downturn.



Source: Fukuda & Watanabe, 2008.

Fig. 1. Learning coefficients of Japanese four leading electric machinery firms (1980-2003: estimate; 2004-2010: prediction based on trends in 1980-2003).



Source: Nikkei Financial Data, 2005.

Fig. 2. Operating income to sales (OIS) of Japanese four leading electric machinery firms (1987-2004).

4. Co-evolutionary dynamism in innovation ecosystem for global sustainability

In the 2000s, the global economy entered an unprecedented new era of global competition due to the continuous rapid growth of emerging countries. Their growth became a new engine of new global growth. New demand from emerging countries created broader markets to offer greater business opportunities. However, at the same time, it became threats to global sustainability. Global production growth increased consumption of energy and natural resources as well as widened a gap between rich and poor.

Confronting such sever circumstances, major developed countries promoted innovation activities to secure their growth and welfare. The U.S. took various measures to activate its innovation performance including fostering R&D talents, stimulating high-risk research and catalyzing alliances between stakeholders. The European Union was launched the Lisbon Strategy in 2000 to build more creative innovation systems during the decade. Individual countries, such as the United Kingdom, Germany and France, also established national innovation strategies. Japan, Taiwan, Singapore and South Korea systematically focused on the direction of innovation to drive their growth.

While developed countries made intensive efforts to maintain their competitiveness, emerging countries expanded their markets and productivity. This was particularly the case in China and India as tabulated in Table 3. Their annual GDP growth rates exceeded or approached two-digit levels until the global financial crisis after the collapse of Lehman Brothers in 2008. In contrast, the growth rate in Japan maintains low level and in the U.S. remains lower than that in the 1990s.

	Average 1990-1999	Average 2000-2008	2007	2008	2009
China	12.5	13.1	17.6	12.0	10.2
India	8.1	9.6	13.1	8.5	7.7
Japan	3.8	4.0	5.4	1.0	-5.4
U.S.	5.5	4.9	4.9	2.2	-1.7

Source: International Monetary Fund, World Economic Outlook Database, April 2011.

Table 3. Growth of GDP (PPP) in four countries – average change rate; % per annum

These contrasting growth trajectories depend on development and utilization of ICT. Fukuda et al. (2011) conducted an empirical analysis to examine ICT contribution to the economic development in 40 countries consisting of both of emerging and developed countries including OECD members, ASEAN original members, Taiwan and BRIC. The results reveal that emerging and developed countries take contrasting approaches to functionality development by ICT as demonstrated Fig. 3. In developed countries, increase of ICT driven functionality development results in decrease of marginal productivity of ICT (*MPI*), whereas it improves *MPI* in emerging countries. This distinct difference suggests that developed countries have fallen into the paradox of ICT development which resulted from a vicious cycle between ICT driven functionality development and its marginal productivity improvement while emerging countries have maintained a virtuous cycle during the global financial crisis, resulting in significant contribution of ICT to their economic growth.

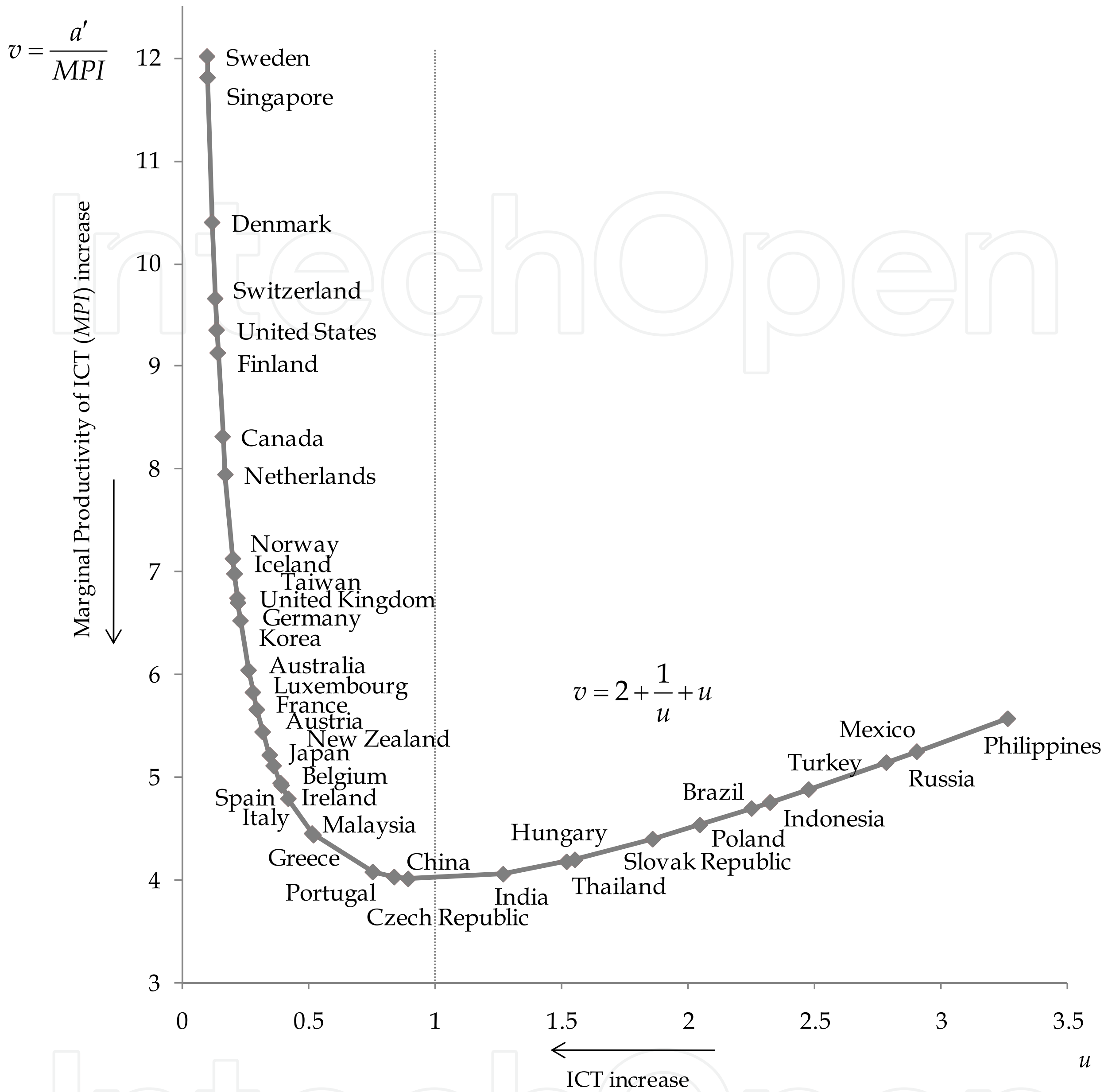


Fig. 3. ICT driven growth trajectory of 40 countries (2009).

While emerging countries are expected to continue to increase consumption steadily, their propensity to consume is not necessarily below that of developed countries as demonstrated in Table 4. Contrary to the gap in GDP per capita, household consumption as a share of GDP in emerging countries is almost at the same level as in developed countries. This contrast suggests that there should be certain structural impediments to consumption-led growth in emerging countries.

Inspired by this observation, Fukuda & Watanabe (2011) conducted an empirical analysis to identify the optimal trigger for the consumption effects on economic growth in 37 out of 40 countries examined above (except 3 countries whose data was not available). Since investment in both public and private sectors is the large component of GDP by expenditure as well as consumption, the analysis emphasized the role of investment. The results indicate contrasting approaches to development trajectory of marginal productivity of investment per capita (*MPi*) induced by GPD per capita increase between emerging and developed countries as illustrated in Fig. 4. While economic growth in emerging countries largely depends on consumption growth rather than investment increase, they confront a vicious cycle where per capita GDP growth leads to *MPi* decrease. Developed countries, on the other hand, leverage investment for their growth.

	HFCE per GDP (PPP) (%)	GDP per capita (PPP) (current $)
Emerging countries [a]	56.9	3945.1
Developed countries [b]	58.2	39458.7

[a] 8 countries: Brazil, China, India, Indonesia, Malaysia, Philippine, Russia and Thailand
[b] 29 countries: Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Taiwan, Turkey, United Kingdom and United States.
Source: International Monetary Fund, World Economic Outlook Database, April 2011.

Table 4. Household final consumption expenditure (HFCE) per GDP and GDP per capita in 37 countries (2009) – median in each economic development level

The analysis also reveals that emerging and developed countries take contrasting approaches to investment driven development. Emerging countries have encountered an autarky cycle of consumption driven development. Although they have increased GDP by consumption growth strongly, they simultaneously suffered from the drop of *MPi* along with GDP growth. As a result, they cling to an autarky cycle where consumption contributes to life improvement and then brings GDP growth. On the contrary, developed countries enjoy a virtuous cycle between GDP, consumption and investment growth. Here, GDP growth induces consumption increase. Increased consumption, in turn, increases GDP to induce investment. Investment stimulates further GDP growth, which increases consumption demand for more attractive goods and services. The new demand contributes to a better quality of life and then leads to GDP growth.

A possible trigger for inducement of investment by growth in emerging countries can be 'frugality'. Frugality does not just mean second-rate or low cost (The Economist, 2010), but satisfies new demand on the ground in emerging countries. Their new demand come from their own unique economic, environmental and social situations which are completely different from those in developed countries, and implies the necessity of new functionality to improve their life. Emerging countries will necessitate more in-market, low-cost innovations that make new products are services satisfying frugality for their sustainable development. This necessity urges firms to change their business strategy in emerging countries. Historically, they have relied on local adaptation strategy to deliver their products and services and make a few adaptations for local markets. However, it is shifting to in-market development starting with local innovation to create new global products and services. Developed countries need to be a greater focus not on activities oriented toward their own perspectives but on demand of emerging countries from their own perspective

(Jose, 2008; Landrum, 2007). Frugality is the requirement to satisfy new demand of emerging countries from their own perspective for more attractive products and services, which would trigger a shift from a closed cycle to an investment driven cycle of growth.

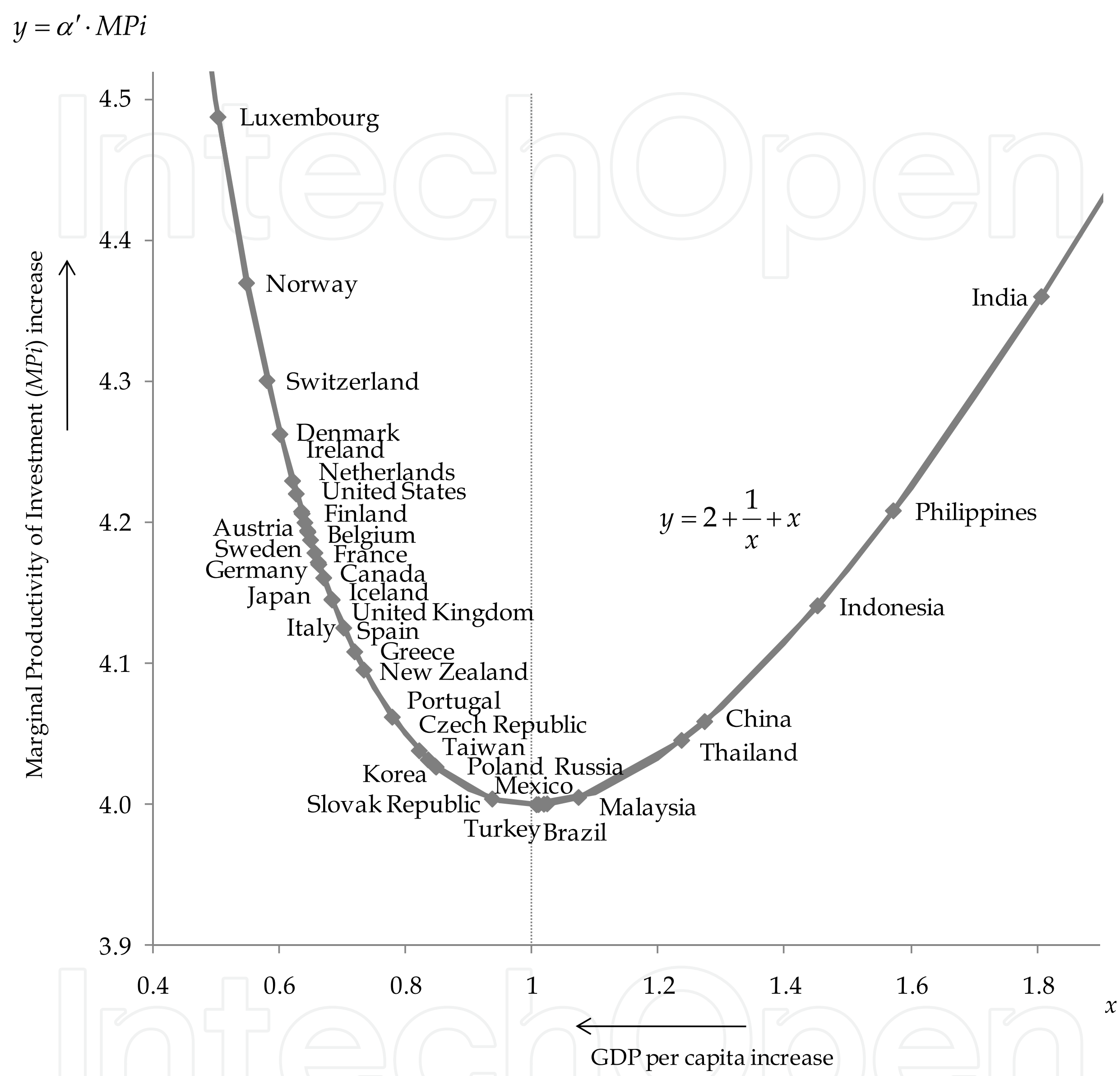


Fig. 4. Investment Driven Development Trajectory of 37 Countries (2009).

All the above results imply the necessity of co-evolution between emerging and developed countries in the new era of global competition. The co-evolution will resolve the paradox of ICT confronted by developed countries, and will enable emerging countries to shift from an autarky cycle to an investment driven cycle of growth. ICT is an essential tool for new functionality development, and effective growth driven by investment is necessary for life improvement in sustainable way. Frugality is a key for fusing the ability of emerging countries to leveraging ICT and the approach of developed countries to effective growth driven by investment. It could lead a way to exploring the new functionality which induces investment for their economic and social well beings, and further contribution to global sustainability.

The co-evolution between emerging and developed countries toward frugality will improve adaptability of innovation ecosystems of both countries to the era of global competition. Emerging countries are facing limitations in their growth cycle heavily depending on consumption growth whereas their vigorous growth is becoming a key driver of the global economy. On the other hand, developed countries are suffering economic stagnation and seeking an opportunity to boost their growth in emerging countries. Both emerging as well as developed countries need new partners to co-adapt to rapidly changing circumstances through co-evolving each other. The co-evolution with new partners will improve the performance of a national innovation ecosystem to survive the global competition as well as overcome threats for global sustainability economically, environmentally and socially.

5. Conclusion

Sustainable development is a serious global concern today and requires new innovation urgently. Innovation creates new value through new products and services, and contributes to long-term wealth creation and higher living standards. Continuous innovation is necessary for sustainability of each country as well as the global society.

Given innovation is a complex and multidimensional, its dynamics is best seen as an ecosystem where various stakeholders are interacting and networking each other. A natural ecosystem provides a suggestive analogy for sustaining an innovation ecosystem. A biological ecosystem maintains stability by resistance, resilience and functional redundancy to external disturbance, and species co-exist, co-evolve and co-adapt to address changing circumstance demands. This combination of autonomy of species and coordination of an ecosystem achieves sustainable development of ecosystems.

A techno-economic analysis can provide insight into mechanisms of an innovation ecosystem. It explains what kind of and how production factors including labor, capital, energy and materials, and technology stock contribute to productivity increase for sustainability corresponding to the environmental condition. It also demonstrates substitution possibilities between production factors for maintaining sustainable growth in the face of the constraints of certain production factors. Thus, a mechanism enabling Japan's success in overcoming energy crises can be analyzed as technology (which is constraints free production factor) substitution for energy (which is critical constraint for Japan). These mechanisms suggest dynamism between inputs, outputs and the external environment of both of them. A nation’s policy environment, common infrastructure, culture and tradition influence dynamics between input and output where they both affects and are affected each other. A techno economic analysis incorporating these institutional factors helps to elucidate a complex and dynamic innovation ecosystem.

Japan and the U.S. have developed their national innovation ecosystem through the co-evolutionary cycle with the U.S. during the last three decades. The reversal of competitive dominance between both countries corresponds to a paradigm shift in each decade as follows:

- In the 1980s, Japan has achieved conspicuous economic development. This achievement can be attributed to its success of technology substitution for constrained production factors, primarily energy, after the energy crises in the 1970s.

- In the 1990s, however, the U.S. recovered its dominant competitive position over Japan. The U.S. successfully substituted ICT for manufacturing technology. This success resulted in timely switch from a traditional trajectory in which economic growth leverages further growth to a new trajectory which maintains sustainable growth based on developing new functionality.
- Facing the 2000s, the U.S. is again confronting a new reality due to the emergence of catch-up competitors such as India and China, as well as a move in Japan toward new innovation. This confrontation can be attributed to resistance of the national innovation ecosystem to rapid changes in the global economy.
- Japan began to show signs of recovery in the early 2000s due to learning from competitors in the 1990s. However, at the same time, the recovery sheds light on a profitability gap in Japanese high-technology. High-profit firms endeavor to learning from the global markets whereas low-profit firms cling to traditional business behaviors.

During the above mutual co-evolutionary competition with the U.S., Japan has maintained the system stability by means of transferring external disturbance to a springboard for innovation. This maintenance of ecosystem stability can be attributed to a sophisticated combination of autonomic efforts by industry and coordination by the government, which contributes to fusing indigenous structural strength in the ecosystem and learning from competitors. However, the national innovation ecosystem exposes limitations in the function due to resistance to the new era of global competition, coinciding with the U.S. confrontation with a new reality.

These limitations of both national innovation ecosystems necessitate co-evolution with new partners of innovation to address rapidly changing circumstances. The global financial crisis after the Lehman Brothers collapse in 2008 explicitly indicated that emerging countries is driving the global economic growth. Amid a shift of the center of innovation gravity from developed countries to emerging countries, co-evolution with emerging countries is becoming a big challenge for not only Japan and the U.S. but also other developed countries. Meanwhile, threats to global sustainability are growing seriously. Rapid growth of emerging countries is increasing industrial production as well as consumption in the world enormously, and in turn, endangers the economic, environmental and social survival of life.

Frugality is a key to new functionality satisfying local demand of people in emerging countries. Most of people in emerging countries are rising as the new middle class. They contribute to sustainable development of emerging countries, which affects global sustainability amidst the economic structural shift to emerging countries. The new middle class's contribution to global sustainability comes through its consumption growth for life improvement and its investment inducement to further economic growth leading consumption demand for more attractive goods and services. Frugality would trigger the shift from an autarky cycle between the consumption and GDP increases to investment driven development

The co-evolution between emerging and developed countries would generate frugality oriented new functionality development trajectory. Developed countries have accumulated their efforts to serve demands in emerging countries. On the other hand, emerging countries have leveraged ICT for economic growth and promoted innovation in their own unique economic, environmental and social situations. Fusing these efforts would realize the co-evolution between them leading to sustainable development in emerging countries and global sustainability as well.

Japan has overcome the oil crisis twice and a severe energy shortage and has subsequently improved energy efficiency in the 1970s by joint efforts of government and industry. These efforts accelerated learning and assimilation of spillover technology which contributed to dramatic decrease of energy consumption in each segment of manufacturing industry. The success in declining unit energy consumption has enabled Japan to establish an energy efficient and eco-friendly society. Its primary energy consumption and carbon-dioxide emission in 2003 are 106 and 68.9 tons of oil equivalent/GPD respectively, both of which are lower than half of those of the world's average. This conspicuous energy efficiency will remain an indigenous strength of Japan's innovation ecosystem and a driving force of innovation toward sustainable development.

A competence to address rapidly changing circumstances in the world is crucial to sustainable development. Perspectives on innovation ecosystems provide precious suggestion for continuous improvement of the competence. Mutual inspiration between stakeholders as well as stakeholders and an innovation ecosystem achieve this improvement. Furthermore, mutual co-evolution between innovation ecosystems enhances each performance enough to survive severe competition and threats for global sustainability. Sustainable development is a big challenge for all innovation ecosystems.

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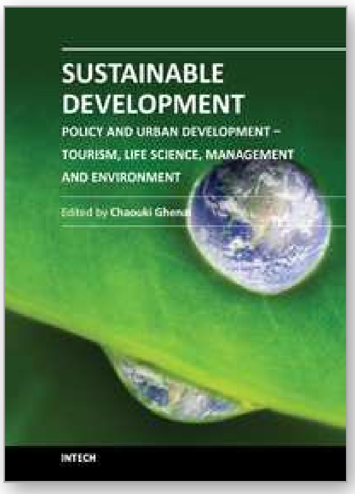

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The technological advancement of our civilization has created a consumer society expanding faster than the planet's resources allow, with our resource and energy needs rising exponentially in the past century. Securing the future of the human race will require an improved understanding of the environment as well as of technological solutions, mindsets and behaviors in line with modes of development that the ecosphere of our planet can support. Sustainable development offers an approach that would be practical to fuse with the managerial strategies and assessment tools for policy and decision makers at the regional planning level.

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