ISSN 0976 - 545X

Journal of Technology Management for Growing Economies

Volume 2 Number 1 April 2011

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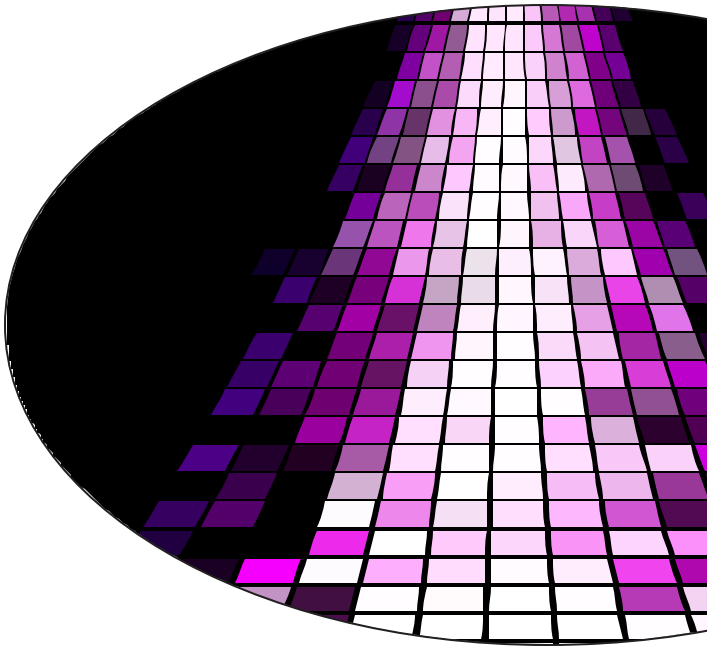

CHITKARA UNIVERSITY

DOI: 10.15415/jtmge.2011.21001

Dual Hybrid Management of Technology: Co-evolution with Growing Economies

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Abstract

Given the increasing significance of the co-evolution between advanced and growing economies for problem-solving innovation that aims at solving global critical issues, this paper attempts an empirical analysis to identify the optimal co-evolutionary trajectory, which could benefit both advanced and growing economies. While Japan has succeeded to develop the hybrid management of technology fusing indigenous strength and learning ability, it has revealed some limitations during the global simultaneous economic stagnation. The analysis suggests that the dual hybrid management of technology co-evolving also with growing economies is decisive to the problem-solving innovation of the nation. This benefits nations in growing economies as well. This paper provides new insights into the problem-solving innovation, and also inducing strategy of growing economies for global sustainability.

Keywords: *Dual hybrid management; problem-solving innovation; co-evolution; growing economies.*

INTRODUCTION

Main stream of innovation in nations in advanced economies has been shifting to problem-solving innovation[1] beyond discipline-oriented one (Barzelay, 2006). In the 20th century, innovation has greatly contributed to economic and social development in the world. It brought technological progresses and new products and services to improve productivity and quality of life. In the 21st century, however, human beings are confronted with serious problems such as global warming, aging and expanding gaps between rich and poor. These problems require urgent attention. Innovation is now expected to be decisive for overcoming the threats for survival (Yoshikawa, 2010).

Major countries have promoted policy for problem-solving innovation in recent years. US President Obama called for a "Green New Deal" in 2009 which aims at creating green jobs and saving energy

Journal of Technology Management for Growing Economies
Vol. 2 No. 1
April 2011
pp. 9-26

(Recovery, 2009). The initiative has stimulated other major countries to invest in energy and environment friendly projects for economic growth. Japan also encourages "green innovation", which was placed at the heart of the New Growth Strategy released in 2010, to achieve economic growth through addressing environmental issues (Cabinet of Japan, 2010).

Given the seamless nature of the problems hanging over the current world under the globalizing economy, co-evolution with growing economies is an indispensable option for problem-solving innovation. Growing economies have potential for not only development of their own economies but also global economic development. They represent not only a large part of the global population and an expansive market in the world, but also unique function as a growth engine of the global economy. Their development creates new demand which stimulates productivity and employment in advanced economies. In addition, it induces systems change in innovation. Thus, addressing problem-solving innovation for growing economies is necessary to sustain the global economy and society.

Co-evolution with growing economies is a big challenge for Japan's innovation system. Japan has established a sophisticated system to induce the hybrid management of technology in the period after World War II (Fukuda and Watanabe, 2010). The hybrid management can be attributed to a subtle combination of industrial efforts and government inducement which enables to fuse indigenous strength and learning ability. However, it reveals some limitations in matching with the growing economies during the global simultaneous economic stagnation. The limitations would be attributed to disengagement between innovation and institutional systems. While the center of innovation gravity shifts from advanced economies to growing economies, there remains organizational inertia in the Japanese innovation system impeding such a shift. This suggests a significance of the hybrid system in a global context aiming at fusing indigenous strength and learning from partners with comparative advantage in certain fields (Watanabe et al., 2009).Thus, the dual hybrid management of technology which is co-evolving with growing economies, would be decisive in accomplishing problem-solving innovation of a nation, which in turn benefits nations in growing economies.

This paper attempts to demonstrate the foregoing hypothetical views and provide new insights to problem-solving innovation and also to

inducing strategy of growing economies for global sustainability. Section 2 reviews trends in innovation in recent years. Section 3 introduces an empirical analysis on Information and Communication Technology (ICT) driven growth in both advanced and growing economies. The section also includes data construction and the methodology for analyses. The next section discusses the importance and necessity of the dual hybrid management of technology. The paper further summarizes new findings and policy implications.

NEW TRENDS IN INNOVATION

The collapse of Lehman Brothers in 2008 sent shockwaves around the world and sparked a global economic and financial crisis which has been impacting even today. Advanced economies are still weak, three years after the collapse while growing economies maintain momentum. The economic contrast affects innovation systems in the world.

The Silicon Valley, home to high technology firms, shows some difficulties in job creation and brain circulation. In the US, the unemployment rate has increased rapidly since the collapse, and remained remains high, around 9.7 percent, through 2010 (Bureau of Labor Statistics, 2010). California is one of the areas showing higher rate than the national average, and even in Silicon Valley, the rate remains around 11.5 percent as shown in Figure 1. Silicon Valley also has been loosing foreign-born science and engineering talent as Figure 2 shows, because of better opportunities back home, strict immigration laws, and the severe economy with its high cost of living (Joint Venture, 2010). These statistics indicate that the innovation system of Silicon Valley is gradually falling down. The Silicon Valley model works when it promotes collective learning and flexible adjustment among specialist producers of a complex of related technologies (Saxenian, 2006), which is quite similar to Japan's hybrid management of technology model. One significant entity has been the contribution of immigrant entrepreneurs in the Silicon Valley. It can, both, produce high-quality university graduates and attract highly-skilled talent from abroad. This benefits the region, not only from steady streams of talent but also creates valuable opportunities for closer integration with other countries, which suggests the significance of the co-evolution with growing economies. The economic recession after the Lehman collapse has decelerated the interactions among entities to loose the network in the innovation system of Silicon Valley.

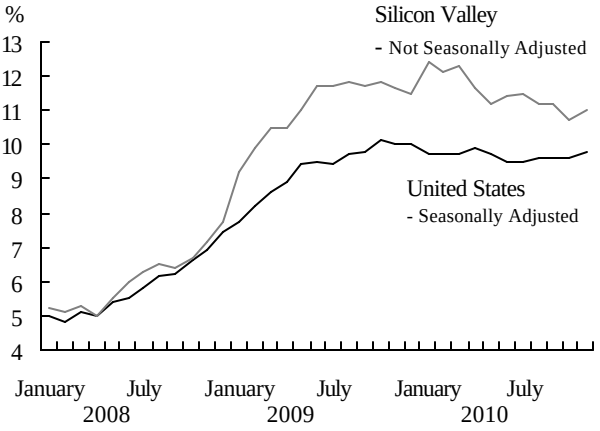

Figure 1: Trends in unemployment rate in the US and Silicon Valley* (January 2008-November 2010).

**Silicon Valley: San Jose-Sunnyvale-Santa Clara, CA Metropolitan Statistical Area*
Source: Bureau of Labor Statistics, United States Department of Labor.

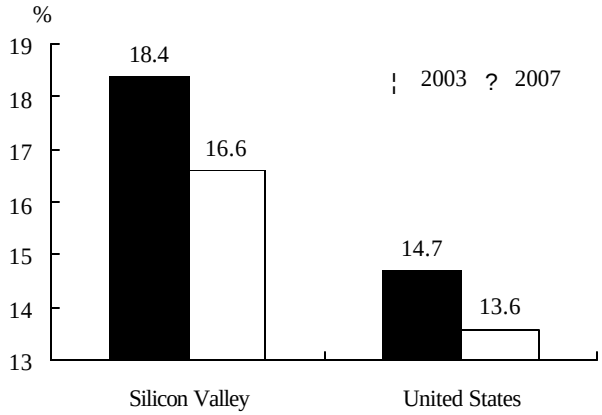

Figure 2: Percentage of S&E Degrees Conferred to Temporary Nonpermanent Residents (2003 and 2007).

Source: Index of Silicon Valley 2010.

Japan has succeeded in developing hybrid management of technology fusing indigenous strength and the effects of learning from global best practice (Watanabe et al., 2009). The hybrid management contributed to the success in rapid economic growth by overcoming the growth constraints by technology substitution, which can be attributed to a sophisticated combination of industrial efforts and government stimulation (Watanabe, 1992, 1994, 1995, 1999, 2009). After the lost decade during the 1990s

when Japan lagged behind in R&D and practical application of ICT as well as suffered the long economic recession, the hybrid management revealed some limitations in the 2000s. While Japan revitalized its economy in the beginning of the decade, the revitalization of its manufacturing sector is not industry-wide, which has led to bi-polarization in profitability among high-technology firms (Fukuda and Watanabe, 2008). They can be divided into two groups; one which is keen to develop it's own core technology and also introduce global learning and the other that disregards learning from competitors and clings to the Not-Invented-Here syndrome.

While the US, Japan and other major countries are facing innovation system failures, nations in growing economies are rapidly developing their innovation capacities. They enhance R&D activities and train skilled human resources to attract global companies to set up their R&D centers. Besides, they are expanding global market share. According to Kharas (2010), the BRIC countries (Brazil, Russia, India and China) accounted for about 24 percent of 2009 global output in purchasing power parity (PPP) terms driven largely by China, the largest country in Asia. Furthermore, the economic center of gravity would shift to Asia, whose percentage of global output could increase from 34 percent in 2009 to 54 percent in 2034. The operating income of Japanese listed companies shows the sign of the shift to Asia. Their profit in emerging countries has increased four times in ten years, and its percentage has risen from 9 percent to 36 percent, as represented in Figure 3. The increase in Asia is especially higher than other areas, as the percentage changed from 6 percent to 27 percent.

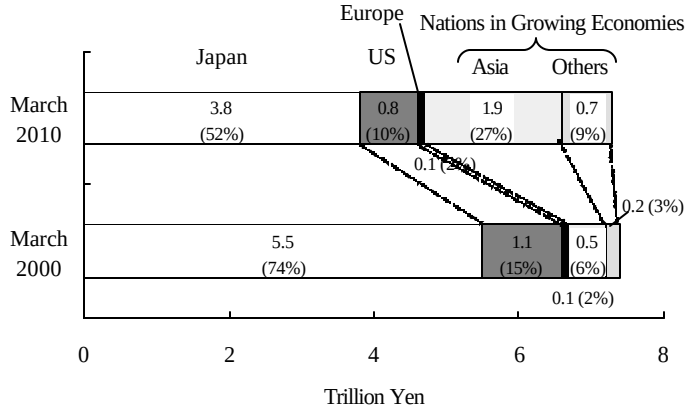

Figure 3: Operating Income of Japanese listed companies by Region (March 2000 and March 2010).

Source: Nikkei

Many global companies are changing their business model to involve the growing economies. They promote reverse innovation which is defined as the development of a product that appeals to emerging market consumers who combine discerning tastes with low disposable income and sell them to some segments within mature markets as well (Immelt et al., 2009). The innovation flows are reverse of the traditional innovation approach which develops a novel product or service in sophisticated market, drops some features and cuts the price, and then exports the altered into emerging markets. Reverse innovation products are developed by frugal engineering which simplifies product design and production process, and procure local parts. Major companies such as GE, Google, IBM, Intel and Microsoft, established their R&D centers in India where many skilled local talent participate in product development. Nations in growing economies also conduct reverse innovation. For example, China has developed the electric bicycle industry since the 1990s (Hang et al., 2010) The market has grown rapidly to be the largest in the world, due to inducement by environment friendly policy and increase of commuters going for work by bicycle. The number of the producers has also increased in recent years, more than 2,600 in 2009, most of which were used to be the bicycle or motor bike producers. Major producers propose new products for potential consumers including females, children and elderly people, and decreased production cost by mass production and product simplification to increase their sales volume. As eco-friendly low cost products, some of them are exported to Europe and Asia. They also conduct R&D on fuel cells with a university or electric vehicles to expand their consumers.

The above trends suggest that innovation systems need further co-evolution between advanced and growing economies. While most of nations in advanced economies suffer the depression of consumption and employment, nations in growing economies rapidly expand their markets and productivity by their identical approach. Nations in growing economies show their potential to develop the global economy and society as well as those of their own. Nations in advanced economies should activate those in growing economies to expand their markets and boost their economies. The activation could generate the mutual inspiration between nations in advanced and growing economies, and furthermore, would enable advanced economies to incorporate the potential of sustainable development of growing economies for sustainable development in their sustainable system. According to Prahalad and Hart (2002), the world economic pyramid consists of four consumer tiers. At the very top of the pyramid are 75 to 100 million affluent Tier 1 consumers composed of middle- and upper

income people in advanced economies and the few rich elites from the growing economies. In the middle of the pyramid, in Tiers 2 and 3, are poor customers in advanced economies and the rising middle classes in growing economies. At the bottom of the pyramid are 4 billion people in Tier 4, which represents a new opportunity for business, government, and civil society to join together in a common cause. Growing economies would create the middle class in the world from not only the middle but also the bottom of the pyramid as a driver of global growth, whose demand would determine what products will be consumed and where they will be made. Growing economies raise a new challenge for advanced economies to help billions of people improve their lives by producing and distributing products and services in culturally sensitive, environmentally sustainable, and economically profitable ways.

GROWTH TRAJECTORIES DRIVEN BY ICT

Contribution of ICT to Economic Growth

Nations in advanced and growing economies demonstrate contrasting economic performances after the collapse of Lehman Brothers as mentioned earlier. In order to compare the economic growth trajectories between them, an empirical analysis was conducted. The analysis aims to examine the contribution of ICT development and utilization to the advancement of both economies. Development and effective utilization of ICT is critical for fostering the national economic growth and development of the nation. It not only forms the basis of rapid and effective communication at all levels; individual, business and government, but also leads to the effective utilization of potential resources in innovations essential for the development of the nation. ICT has strong impacts on economic performance. ICT networks spread throughout the business sector and are made to work to enhance productivity and business performance (OECD, 2003). The use of ICT throughout the value chain contributes to improved firm performance. The smart use of ICT can help firms increase their overall efficiency in combining labor and capital, or multi-factor productivity (MFP). ICT use can also contribute to network effects, such as lower transaction costs and more rapid innovation, which can increase MFP. However, advanced ICT provides the paradox of ICT development demonstrating negative or stagnating impacts on growth and productivity increases. For example, the advancement of the Internet leads to disinterest of younger generations in foreign affairs and studying abroad. Differences in the diffusion of ICT increases the imbalance between generations, income levels

and regions. In addition, the diffusion of the Internet and mobile phones increases the amount of information available to an individual so explosively that he or she faces difficulties in making a choice. It also encourages criminal behavior such as personal information leak, defamation and phishing (ICT Vision Council, 2009). All results in decrease or stagnation of the productivity of the nation.

The empirical analysis was conducted focusing on 40 countries including countries of OECD, EU, ASEAN, Taiwan and BRICs. Network Readiness Index (NRI)[2] developed by the Global Information Technology Report (GITR) 2009-2010: ICT for Sustainability (World Economic Forum, 2010) was used as proxy of the level of ICT development and utilization. Since NRI is defined as a nation's or community's degree of preparedness to participate in and benefit from ICT developments (GITR 2004-2005), and as the main methodological tool to gauge economies' preparedness to leverage ICT advances for increased competitiveness and development (GITR 2009-2010), it is expected to provide a model sufficient for evaluating a nation's relative development and utilization of ICT. At the same time, for economic growth, GDP per capita (PPP $) was used as an index for economic growth. NRI scores for 40 countries were carefully examined by means of cross-evaluations with the correlation between ICT and economic growth as well as with other statistics such as OECD IT Statistics and other resources. Consequently, NRI scores in certain countries as Greece, Italy and Spain were re-evaluated accordingly (see details of the data in Appendix).

Bi-polarization Diffusion Trajectory

ICT induces economic development in the nation and its GDP trajectory can be depicted by the following epidemic function[3]:

$$\frac{\partial Y}{\partial I} = aY(1 - \frac{Y}{\overline{Y}}) \quad (1)$$

where Y: cumulative GDP; I: level of ICT development/utilization;

a: velocity of GDP diffusion; and

$\overline{Y}$: carrying capacity of cumulative GDP.

Equation (1) can be developed by the following logistic function:

$$Y = \frac{\overline{Y}}{1 + e^{-aI-b}} \quad (2)$$

where b: initial state of the diffusion.

Equation (2) can be developed as follows:

$$1-\frac{Y}{\overline{Y}}=\frac{e^{-aI-b}}{1+e^{-aI-b}}=\frac{1}{1+e^{aI+b}}$$

$$\frac{\partial Y}{\partial I}=aY(1-\frac{Y}{\overline{Y}})=a\frac{\overline{Y}}{1+e^{-aI-b}}\frac{1}{1+e^{aI+b}}=\frac{a\overline{Y}}{1+e^{aI+b}+e^{-aI-b}+1}=\frac{a\overline{Y}}{2+e^{aI+b}+e^{-aI-b}}$$

$$\frac{a\overline{Y}}{\partial Y/\partial I}=2+e^{-aI-b}+e^{aI+b}=\frac{a'}{MPI}$$

where $a'\equiv a\,(r+g)\overline{Y}$; and *MPI*: Marginal Productivity of ICT[4].

Given that $v\equiv\frac{a'}{MPI}$, $u=e^{-aI-b}$, therefore, $v=2+\frac{1}{u}+u$, bi-polarization diffusion trajectory can be traced as illustrated in Figure 4.

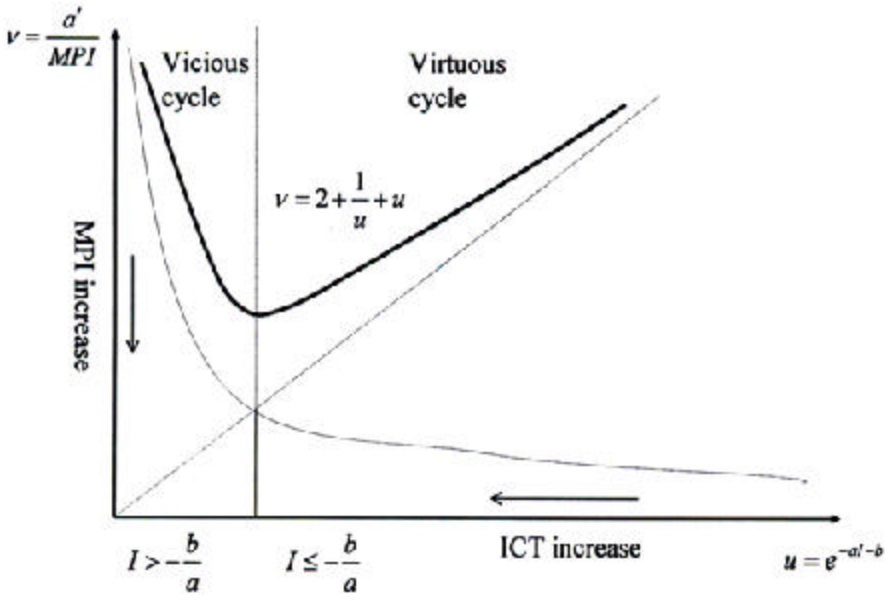

Figure 4: Bi-polarization Diffusion Trajectory.

MPI reaches maximum level when $I = \frac{-b}{a}$ as u= 1 which represents $I = \frac{-b}{a}$ leads to $\frac{dv}{du} = 0$. Therefore, the nation whose $I \leq -\frac{b}{a}$ can enjoy a virtuous cycle between ICT increase and MPI increase. Such a nation can maximize marginal productivity of ICT when its ICT level reaches to $-\frac{a}{b}$. Contrary to such a nation, the nation whose ICT level has exceeded $-\frac{b}{a}$ experiences the paradox of ICT development resulting in a vicious cycle between ICT increase and MPI increase.

COMPARATIVE ICT DRIVEN ECONOMIC GROWTH IN 40 COUNTRIES

Aiming at evaluating this possibility, an empirical assessment is attempted based on the bi-polarization diffusion trajectory as illustrated in Figure 4.

Based on the equation (2), first, fit of the ICT driven logistic growth function for 40 countries in 2009 was analyzed, as summarized in Table 1.

Table 1: Fit of ICT Driven Logistic Growth Function in 40 Countries (2009)

$$Y = \frac{\overline{Y}}{1+e^{-aI-b}} + cD_1 + dD_2$$

where D_1: dummy variable (Luxemburg = 1, other countries = 0),

D_2: dummy variable (China, Greece, India, Indonesia, Italy, Korea, Malaysia, Thailand = 1, other countries = 0)

$\overline{Y}$	a	b	c	d	adj. R^2
47434.9	1.060	0.746	46997.6	-11012.8	0.882
(7.36)	(3.64)	(1.33)	(7.86)	(-4.34)	

[i]Since GDP PPP per capita in Luxemburg is exceptionally higher than other 39 countries, a dummy variable is posed to this country.

[ii] In the logistic regression analysis, the residuals between real data and predicted values in these countries are more than 9000.

Marginal productivity of ICT (MPI) reaches maximum level when $I = \frac{-b}{a}$ which is equivalent to $I = -0.704$ in the standardized value of NRI.

On the basis of these computations, bi-polarizing diffusion trajectory in 40 countries can be illustrated in Figure 5.

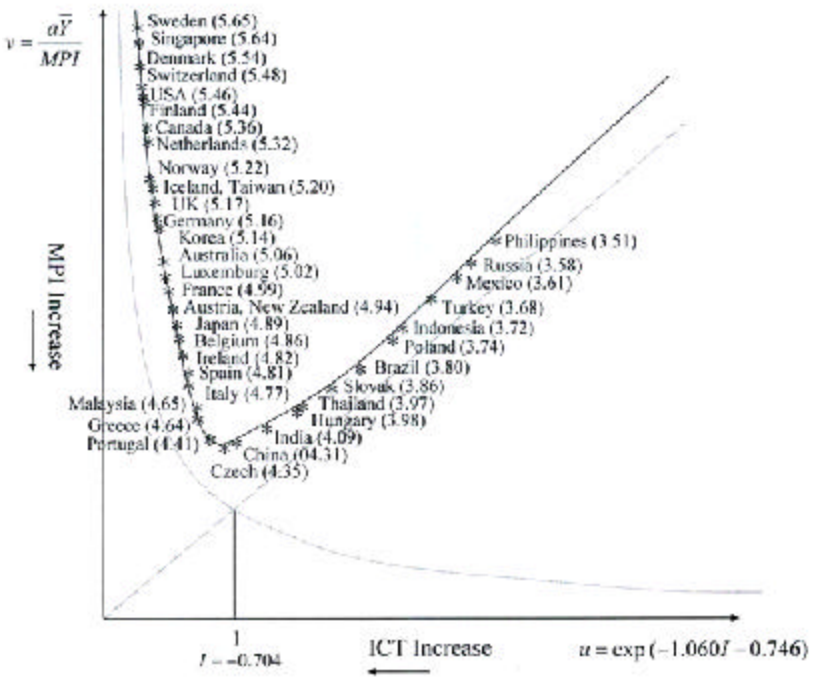

Figure 5: ICT Driven Growth Trajectory in 40 Countries (2009).

Figure 5 suggests that while majority of advanced economies in the 40 countries examined have been confronting the paradox of ICT development and phased up to the state of a diminishing returns of marginal productivity of ICT (a vicious cycle between ICT increase and its marginal productivity increase: $\frac{\partial}{\partial I} MPI = \frac{\partial^2 Y}{\partial I^2} < 0$), growing economies including India and China have been maintaining a virtuous cycle position.

APPROACHES TO FUNCTIONALITY DEVELOPMENT BY ICT

The analysis reveals that advanced and growing economies take contrasting approaches to functionality development by ICT as demonstrated in Figure 6. While advanced economies have fallen into the paradox of ICT development which resulted in a vicious cycle between ICT driven functionality development (FD) increase and its subsequent marginal productivity increase, growing economies have been maintaining a virtuous cycle leading to ICT's significant contribution to their economic growth. Figure 6 suggests that the only possible option for advanced economies is to activate growing economies by means of their advanced ICT and then

effectively utilize its results for their marginal productivity increase that leads to sustainable growth enabling further advancement of ICT for sustainable growth of growing economies.

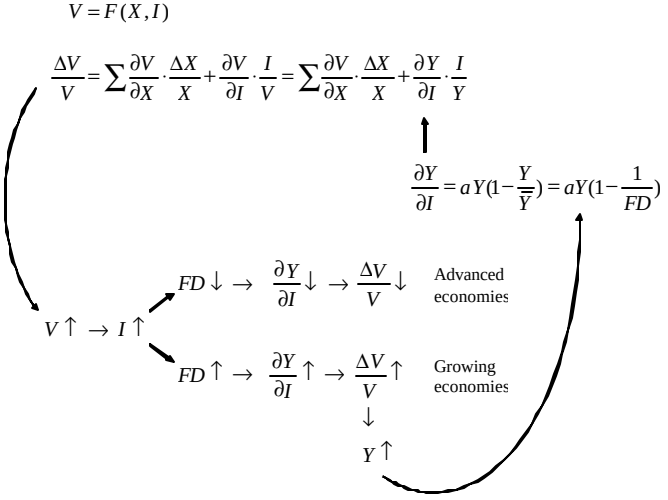

Figure 6: ICT Driven Growth Trajectory Options in Developed and Growing Economies.

Bi-polarization of advanced and growing economies suggests that the co-evolution between these two economies is required for problem-solving innovation towards global sustainability. Growing economies incorporate opportunities for new innovation. They create new demand from their own unique cultural, environmental and economic situations which is completely different from those in advanced economies. Such new demand implies new functionality necessary for solving underlying problems. ICT is an essential tool for problem-solving innovation. It improves productivity and efficiency in both of public and private sectors, serves to create value-added products and services and activate local communities, and also contributes to reduce the effects on the environment including greenhouse gas emissions. Under such a condition growing economies enjoy the benefits of a virtuous cycle between ICT increase and its marginal productivity increase. On the other hand, advanced countries suffer a vicious cycle between them due to the paradox of ICT development mentioned above. The paradox could be resolved if ICT served to develop new functionality meeting new demand from growing economies. Therefore, a possible option for advanced economies is to activate problem-solving innovation from growing economies by means of their developed ICT and then domesticate its results for their own marginal productivity increase, which also enables further advancement of ICT for sustainable growth of growing economies.

DUAL HYBRID MANAGEMENT OF TECHNOLOGY

The new trends in innovation discussed in the preceding sections indicate that the center of innovation gravity has shifted from advanced economies to growing economies. Historically, global development has been initiated by innovation from advanced economies for satisfying their demand in products and services, and transferred them to the rest of the world. However, the innovation systems in advanced economies are now facing a new challenge to adapt to the gravity shift to growing economies. The innovation systems in advanced economies should take into account not only consumers in advanced economies in the top of the global economic pyramid, but also those in growing economies in the middle or the bottom of the pyramid. Furthermore, advanced economies should recognize that growing economies create a surge of the new innovation. Growing economies provide opportunities for the new innovation for a sustainable society. The new innovation is expected to lead to new functionality beyond technology advancement or efficiency improvement, which would solve problems threatening sustainable development.

Japan constructed a noting hybrid management of technology system. The system can be attributed to a sophisticated combination of industrial efforts and government stimulation and a successful fusion of indigenous strength in technology development and learning from global best practice. Government support for industrial R&D functions as a catalyst to induce this fusion. The system, however, lacks a mechanism of learning from growing economies and domesticating its results for mutual benefits. It should be upgraded to adapt to the center of innovation gravity shift from advanced economies to growing economies, and lead to problem-solving innovation for global sustainability. Industry should develop its own core technology and also activate global learning. The accumulation of these efforts could only bring about new functionality necessary for new products and services to ensure a sustainable society. Government, meanwhile, should catalyze such industrial efforts. Government could accelerate industrial efforts through a combination of policy tools including resource allocation, priority setting, funding systems, regulation and taxation as well as education and training.

While growing economies represent potential for the new innovation towards the global sustainability, advanced economies have rich experience leading to global development by innovation for years. The experience could stimulate growing economies to promote new functionality development. The results of empirical analysis on ICT driven growth trajectories suggest this possibility. Advanced economies face the paradox of ICT development that is highly advanced but `ICT leads to negative or stagnating impacts on

growth. This would be due to wrong choice of functionality development options. Most of nations in advanced economies still cling to development of new functionality in their own economies. They are more conscious of affluent Tier 1 consumers in the global economic pyramid than of others who rather create new demand for new functionality. Only the way to be relieved from the paradox would be co-evolution with growing economies thereby advanced economies could acquire potential resources for innovation from growing economies by learning, which leads to the fusion of indigenous strength and learning efforts. This co-evolution facilitates new functionality development beneficial to both advanced and growing economies for their socio-cultural, economic and environmental benefits.

Development dynamism of water industry in Singapore is a good example of the co-evolution between advanced and growing economies (Chew et al., 2010). Singapore has successfully transformed its water industry from a constrained situation with limited capabilities to a situation whereby it is now exporting capabilities worldwide. This success can be attributed to the stepwise approach with explicit vision as: (i) import of technology from advanced economies by learning, (ii) transition from learning to indigenous technology development, (iii) export of accumulated indigenous capabilities to growing economies (iv) fusion of external knowledge acquired from export activities and (v) internal indigenous strength, leading to co-evolutionary domestication. The process generates new functionality for solving global water problem by fusing innovation resources from advanced and growing economies as well as industrial efforts and government stimulation in Singapore.

CONCLUSION

Confronting severe problems threatening human activities, major countries promote problem-solving innovation for creating a sustainable society. Given the seamless nature of the problems under globalization, co-evolution with growing economies is necessary to promote problem-solving innovation.

Japan has succeeded in technology advancement and productivity increase by transferring a threat for sustainable development into a springboard for innovation. This accomplishment can be attributed to the hybrid management of technology fusing indigenous strength and the learning ability. However the hybrid management has revealed some limitations in matching with the growing economies during the global simultaneous economic stagnation. The limitations suggest that the hybrid management should be upgraded to dual hybrid management of technology to adapt to the center of innovation gravity shift from advanced economies to growing economies.

While advanced economies are still recuperating two years after the collapse of Lehman Brothers, growing economies maintain momentum. The contrast affects the innovation systems in both economies. The US, Japan

and other major countries are facing innovation system failures, but at the same time nations in growing economies are rapidly developing their innovation capacities. Aiming at comparing ICT driven economic growth trajectories between advanced and growing economies, an empirical analysis to examine the contribution of ICT development and utilization to the advancement of both economies was conducted. The results suggest that advanced and growing economies take contrasting approaches to functionality development by ICT. While advanced economies have fallen into the paradox of ICT development which resulted in a vicious cycle between ICT advancement and functionality development and subsequent marginal productivity increase, growing economies have been maintaining a virtuous cycle enjoying ICT advancement for their economic growth.

Growing economies provide opportunities for the new innovation leading to new functionality development for global sustainability. The accumulated experiences of advanced countries could stimulate growing economies to promote new functionality development. The stimulation would generate co-evolution between these two economies in external acquisition by learning, domestication of acquired resources, and functionality development fusing accumulated experiences of advanced economies and new demand from problems in growing economies. These efforts could establish the dual hybrid management of technology in co-evolution between advanced and growing economies as well as industrial efforts and government inducement to which Japan should endeavor for its sustainability and also for global sustainability.

Future works should elucidate the co-evolutionary dynamism between advanced and growing economies by focusing on particular cases. Furthermore, it is necessary to conceptualize new functionality development driven by problem-solving innovation for enabling inclusive growth in the world and the global sustainability.

FOOTNOTE

1. Problem-solving innovation means mission oriented innovation for maintaining a sustainable society. It is not just completing development tasks, but providing new products and services necessary to sustain human activity.
2. The Networked Readiness Framework, which includes 3 component indexes (Environment, Readiness and Usage) and 9 sub indexes (Market environment, Political/regulatory environment, Infrastructure environment, Individual/Business/Government readiness and Individual/Business/ Government usage), is utilized to compute the NRI rankings.

3. Given that ICT (I) is decisive to nation's GDP (V), and considering a state of ICT dependent economy, V can be approximated by the following production function:

$V = F(X, I) = F(X(I)) \approx F(I)$ where X: labor and capital.

$$\frac{dV}{dI} = \frac{\partial V}{\partial I} \cdot \frac{dI}{dI} = \frac{\partial V}{\partial I}$$

$Y \approx \frac{V}{r+g}$ where r : depreciation rate; and g: average increase rate of GDP at initial state.

Given that sum of r +$g$is stable as r is low in the emerging nations where g is high while reverse in the matured nations where g is low,

$$\frac{dY}{dI} = \frac{d}{dI} \cdot \frac{V}{r+g} = \frac{1}{r+g} \cdot \frac{dV}{dI} = \frac{1}{r+g} \cdot \frac{\partial V}{\partial I} = \frac{\partial Y}{\partial I}$$

4. $$\frac{\partial Y}{\partial I} \approx \frac{1}{r+g} \frac{\partial V}{\partial I} = \frac{MPI}{r+g}$$

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APPENDIX

Data information - Network Readiness Index (NRI), standardized NRI and GDP per capita (PPP $) in 40 countries in 2009:

Country	NRI[a]	NRI-standardized	GDP PPP per capita[b]
Australia	5.06	0.55	39231
Austria	4.94	0.37	38748
Belgium	4.86	0.25	36048
Brazil	3.80	-1.38	10427
Canada	5.36	1.01	37946
China	4.31	-0.60	6838
Czech	4.35	-0.54	25232
Denmark	5.54	1.29	36762
Finland	5.44	1.13	34650
France	4.99	0.44	33655
Germany	5.16	0.71	36449
Greece[c]	4.64	-0.09	29663
Hungary	3.98	-1.10	19764
Iceland	5.20	0.77	37595
India	4.09	-0.93	3275
Indonesia	3.72	-1.50	4205
Ireland	4.82	0.18	41278
Italy[c]	4.77	0.11	31909
Japan	4.89	0.29	32443
Korea	5.14	0.67	27168
Luxembourg	5.02	0.49	84003
Malaysia	4.65	-0.08	13982
Mexico	3.61	-1.67	14337
Netherlands	5.32	0.95	40715
New Zealand	4.94	0.37	28723
Norway	5.22	0.80	55672
Philippines	3.51	-1.82	3546
Poland	3.74	-1.47	19059
Portugal	4.41	-0.44	24021
Russia	3.58	-1.71	18945
Singapore	5.64	1.44	50705
Slovak	3.86	-1.29	22446
Spain[c]	4.81	0.17	32545
Sweden	5.65	1.46	37905
Switzerland	5.48	1.20	44725
Taiwan	5.20	0.77	32000
Thailand	3.97	-1.12	8004
Turkey	3.68	-1.56	13905
United Kingdom	5.17	0.72	36496
United States	5.46	1.16	46436

[a]Original source: Global Information Technology Report (GITR) 2009-2010 (World Economic Forum: WEF, 2010).
[b]Original source: IMD World Competitiveness Yearbook 2010 (IMD, 2010).
[c]Adjusted by cross evaluation with OECD IT Statistics (OECD, 2010) and Technology Competitiveness Report (WEF, 2010).

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Printed by: Mr. Deepak Gupta, Savitar Press and published by Dr. Madhu Chitkara on behalf of Chitkara University, Saraswati Kendra, SCO 160-161, Sector-9-C, Madhya Marg, Chandigarh-160009 and printed at: Savitar Press, Plot No.: 820, Industrial Area, Phase-2, Chandigarh and published at Chandigrah.Editor Dr. Vinnie Jauhari