2C02　イノベーションとインスティテューションの共進化ダイナミズム
—主要国製造技術・ＩＴの共進ダイナミズムと競争力の比較実証分析

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1. Introduction

Contrary to its long-lasting economic stagnation during the "lost decade" in the 1990s, Japan is expected to "flying again." This anticipation can largely be attributed to the activation of Japan's indigenous virtuous cycle between technological innovation and economic development.

Despite many handicaps, Japan achieved a conspicuous technological advancement and subsequent productivity increase by devoting a sophisticated combination of industry efforts and government stimulation. Industry made every effort for technology substitution for constrained production factors while government stimulation was focused on constructing a socio-economic system in which technology could maximize its potential performance.

Such efforts enabled Japan to improve its institutional systems essential for its technological innovation, which in turn induced further innovation. Thus, Japan constructed a sophisticated co-evolutionary dynamism between innovation and institutional systems. However, its economic stagnation in the 1990s demonstrates that this dynamism may stagnate if institutional systems can not adapt to innovations.

Noteworthy surge in new innovation in recent years in leading edge activities of Japan's certain high-technology firms can be attributed to the co-evolution between indigenous strength developed in an in industrial society and effects of the cumulative learning from their competitors in an information society.

This co-evolution emerges hybrid management by fusing "east" (indigenous strength) and "west" (learning from and corresponding to digital economy) leading Japan's firms more resilient against ubiquitous economy where seamless, on demand and open-sourcing are essential requirements.

Empirical analysis is focused on the elucidation of the dynamism fusing the transformation of the characterization of technology.

2. Japan's Development Trajectory

2.1 Historical Perspectives

Rise and fall of the Japanese economy can be attributed to the **co-evolution** (virtuous cycle) and **disengagement** (vicious cycle) between innovation and institutional systems. **Successful co-evolution in an industrial society** by manufacturing technology substitution for materialized production factors changed to **disengagement in an information society**. Noteworthy surge in new innovation in recent years in leading edge activities of Japan's leading high-technology firms can be attributed to the **co-evolution between indigenous strength developed in an in industrial society and effects of the cumulative learning in an information society.** This surge suggests a possibility of reactivation of Japan indigenous co-evolutionary dynamism leading to revitalizing its economy

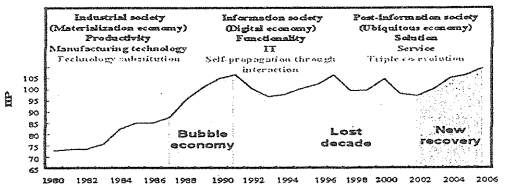


Fig. 1. Trend in Japan's Index of Industrial Production (1980-2006) –IIP:1990=100.

2.2 Japan Indigenous Institutional Systems for Innovation

Emerged innovation improves institutional systems such as *economic environment*, *natural environment* and *social/cultural environment*, which in turn induces further innovation (**co-evolution**) Innovation generation cycle leads to emerging innovations to market by means of effective utilization of resources in innovation. This inducement may stagnate if institutional systems cannot adapt to evolving innovation (**disengagement**).

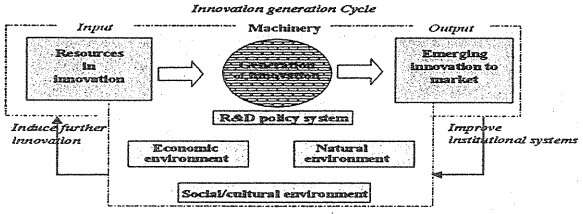


Fig. 2. Scheme of Institutional Systems for Innovation.

2.3 Technology Substitution for Constrained Production Factors

Supported by institutional systems for innovation, **technology substitution for constrained production factors** functioned well in Japan typically observed in technology substituted for energy started from 1973. This substitution not only enabled Japan overcoming energy constraints while maintaining sustainable growth but also induced further innovation leading to constructing a **co-evolution between innovation and institutional systems**. Thus, Japan enjoyed high-technology miracle in the 1980s based on **technology substitution for materialized production factors in an industrial society**.

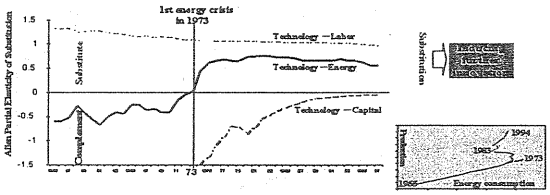


Fig. 3. Trends in Substitution and Complement among Labor, Capital, Energy and Technology in the Japanese Manufacturing Industry *(1955-1997) Allen Partial Elasticity of Substitution.*

2.4 Features Differences between Manufacturing Technology and IT

Disengagement in an information society is due to a **system conflict** toward **de-materializing society**. Japan's conspicuous technology substitution for constrained production factors functioned well for materialized production factors. However, as paradigm shifts to an information society, its subsequent shift from manf. tech. to IT led to de-materializing society. Organizational inertia in an industrial society impeded Japan's institutions correspond to an information society.

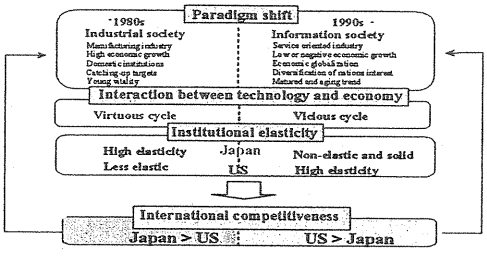


Fig. 4. Scheme Leading Japan to Lose Its Institutional Elasticity.

2.5 System Conflict in an Information Society

System conflict led to an **institutional less-elasticity** in an information society resulting in a **dramatic decrease in MPT**. MPT decrease led to **TFP decrease** resulting in a **decrease in innovation contribution to growth**. Thus, **co-evolution changed to disengagement** in an information society

(1) Dramatic Decrease in Marginal Productivity of Technology

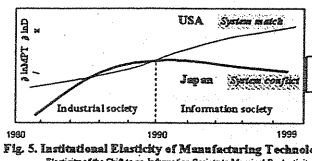


Fig. 5. Institutional Elasticity of Manufacturing Technology - Elasticity of the Shift to an Information Society to Marginal Productivity of Technology (1980-1999) - Index: 1990=100.

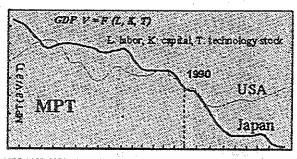


Fig. 6. Marginal Productivity of Manufacturing Technology (1975-1999) - Index: 1990 = 1.

(2) Consequent Decrease in Innovation

TFP change rate (ΔTFP/TFP) = R&D intensity (R/V) × Marginal productivity of technology (MPT)

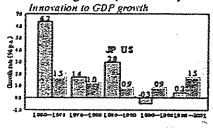


Fig. 7-1. TFP Growth Rate (1960-2001).

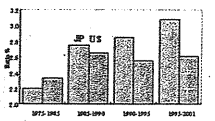


Fig. 7-2. R&D Intensity (1975-2001).

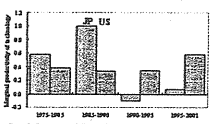


Fig. 7-3. Marginal Productivity of Technology (1960-2001).

3. Surge of the Reactivation of Co-evolutionary Dynamism

3.1 Shifting Trajectory from MT (manf. technology) to IT (inform. technology)

Mobile phone driven innovation triggered a surge in co-evolution. Dramatic increase in mobile phone exceeded fixed phones in 1998. i-mode service from Feb. 1999 accelerated IP mobile diffusion. Intensive interaction with institutions increased the learning coefficient from the mid. 2002. Similar increase has been observed also in leading high-tech. firms.

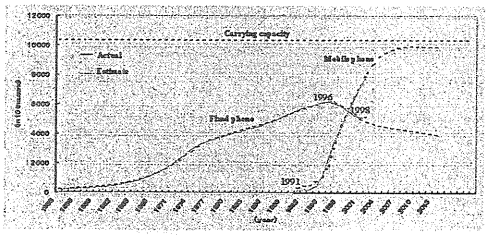


Fig. 8 Trend in the Substitution of Mobile Subscribers for Fixed Line in Japan (1953-2004: actual; 2005-2015: estimate).

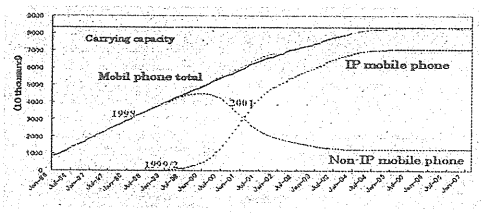
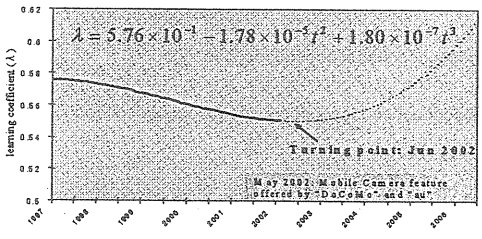


Fig. 9. Trend in Mobile Phone Diffusion in Japan (Jan. 1996-Dec. 2003: actual, and Jan. 2004-Jan. 2007: estimate).

3.2 Increase in Market Learning Effects

Correlation between mobile phone subscribers and their prices in Japan (Jan. 1997- Feb. 2002)

$$\ln P = 10.03 - (5.76\times10^{-1} - 1.78\times10^{-5}t^2 + 1.80\times10^{-7}t^3)\ln N \qquad adj.R^2 = 0.986$$
(42.66) (24.74) (7.97) (6.07)



P: price index,
N: cumulative number,
t: time trend

Fig. 10. Trend in Learning Coefficient in Mobile Phone (1997–2006).

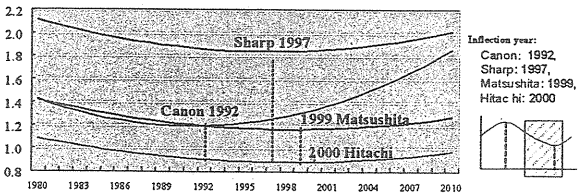


Fig. 11. Learning Coefficients in 4 Electrical Machinery Firms (1980-2003).

3.3 Co-evolutionary Dynamism Leading to New Innovation

(1) Dual Co-evolution in Japan's Mobile Phone Development

Thus, dual co-evolution through (i) market learning, and (ii) operators-vendors interaction has been constructed in Japan's mobile phone development.

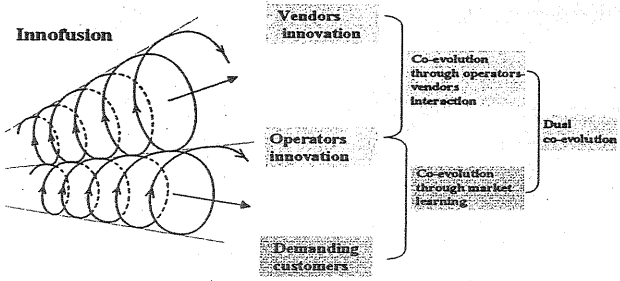


Fig. 12. Dual Co-evolution in Japan's Mobile Phone Development.

(2) Reactivation of the Co-evolutionary Dynamism – *Mobile Phone Driven Innovation*

This dual co-evolution has induced Japan's mobile phone driven innovation that emerged in the beginning of the 2000s. While this innovation has stimulated the reactivation of Japan's indigenous co-evolution between innovation and institutions, there remains the limit of the global deployment as it depends on closed suppliers chain.

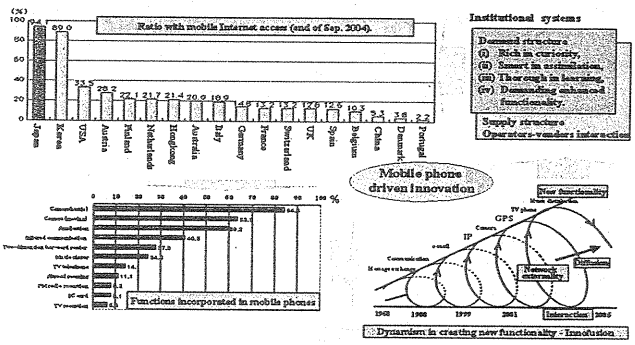


Fig. 13. Co-evolution of Mobile Phone Driven Innovation.

(3) Triple Co-evolution Corresponding to Web 2.0 Trend

In line with the increasing demand on services toward a post-information society, dependency on external services such as outsourcing to Chinese software has dramatically increased. Such an increase leads to open-sourcing enabling a breakthrough of the limit of global deployment of the dual co-evolution based on a closed suppliers chain. Thus, triple co-evolution more resilient than dual-co-evolution consists of **(i) internal market learning, (ii) internal suppliers interaction,** and **(iii) external outsourcing** has been emerging corresponding to Web 2.0 trend in leading edge activities in certain high-tech. firms.

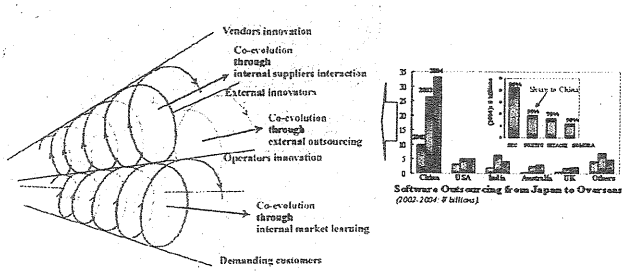


Fig. 14. Triple Co-evolution Corresponding to Web 2.0 Trend.

3.4 Swell of Japan's Institutional MOT toward a Post-information Society

Noteworthy surge in new innovation in leading edge activities in certain high-tech firms in recent years corresponds to essential requirements in a ubiquitous economy characterized by "on demand", "all actors participation and cooperation," "open-sourcing" and "seamless" community. This can be attributed to the **co-evolution between indigenous strength developed in an industrial society** and **the effects of learning in an information society**

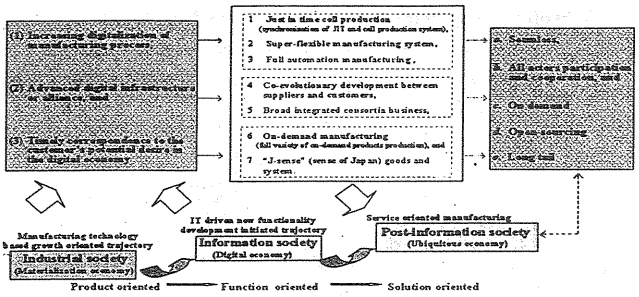


Fig. 15. Swell of Japan's New Innovation.

4. Fusing Process of East and West

4.1 Hybrid Management - *Fuses East and West*

Japan is emerging from years of sluggish growth. Its firms appear to have produced something. Management method that incorporates lessons from US firms while preserving the practices that once made Japanese firms famous.

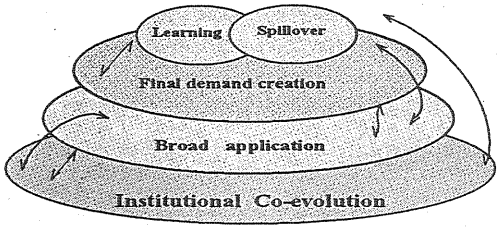


Fig. 16. Scheme of Co-evolutional 5 Dimensions.

4.2 Institutional Co-evolution

(1) Internalization Process of the Features Formation Process of IT

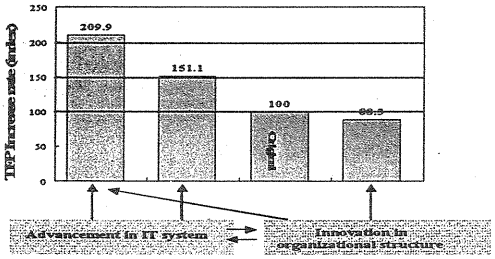


Fig. 17. Comparison of the Contraction of ICT Advancement to TFP Growth Depending on the Innovation in Organizational Structure in Japan's Firms (2005) - Index: original size = 100.

(2) Identification of the Competitive Position in Leading Technologies

1) Level of Manufacturing Technology (*MT*)

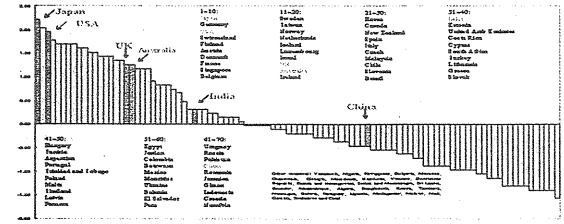


Fig. 18. Level of MT in 100 Countries *(2004)*.

2) Level of ICT Development/Utilization (*I*)

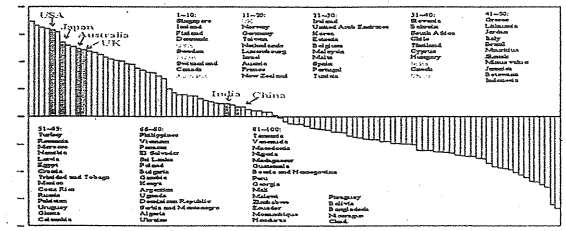


Fig. 19. Level of ICT in 100 Countries *(2004)*.

3) Level of SW *(Potential of Software Development)*

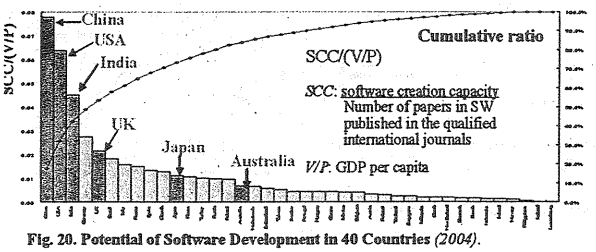


Fig. 20. Potential of Software Development in 40 Countries *(2004)*.

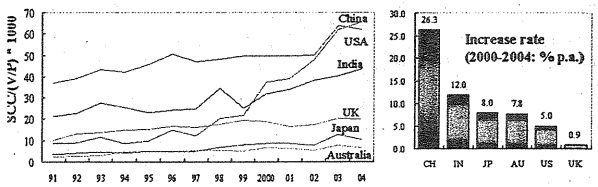


Fig. 21. Trends in the Potential of Software Development in 6 Countries *(1991-2004)*.

(3) Institutional Structure

1) Factors Constituting the Institutional Systems

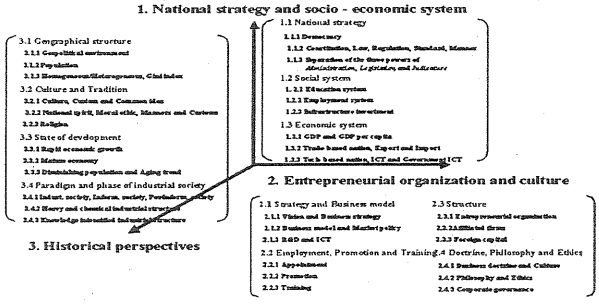


Fig. 22. Constitution of Three Dimensions of Institutional Systems.

2) Structure of Institutional Systems in 40 Countries - *Principal Component Analysis*

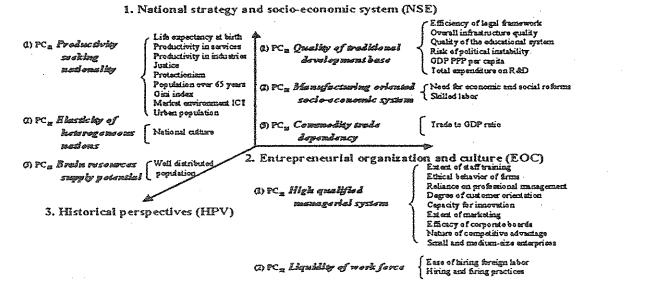


Fig. 23. Structure of Institutional Systems in 40 Countries *(2004)*.

(4) Global Co-evolution between MT, IT, SW and Institutional Systems

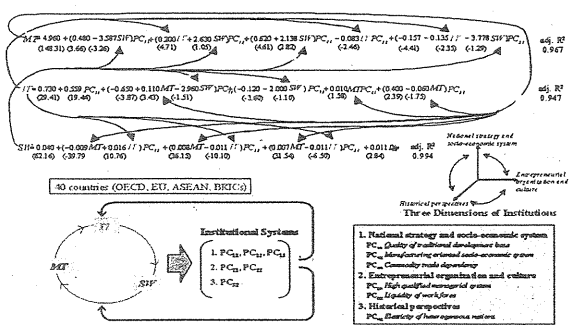


Fig. 24. Co-evolution between Leading Technologies and Institutional Systems in 40 Countries *(2004)*.

(5) Identification of the Competitive Position in Institutional Innovation – *Global Complements for Global Co-evolution*

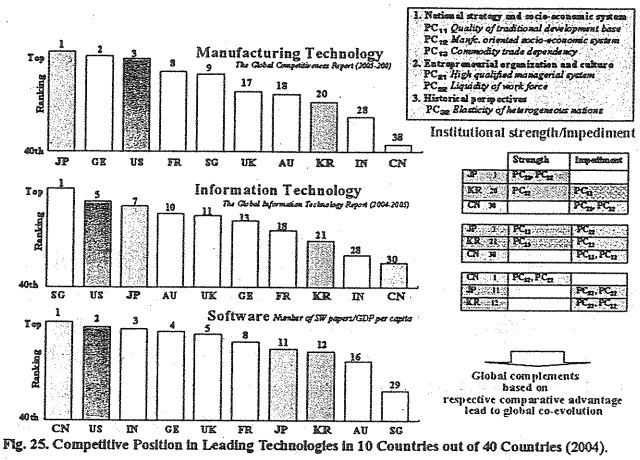


Fig. 25. Competitive Position in Leading Technologies in 10 Countries out of 40 Countries (2004).

(6) Contribution of Institutional Factors to MT, IT and SW- *Japan-USA Comparison (2004)*

1) Governing Institutional Structure

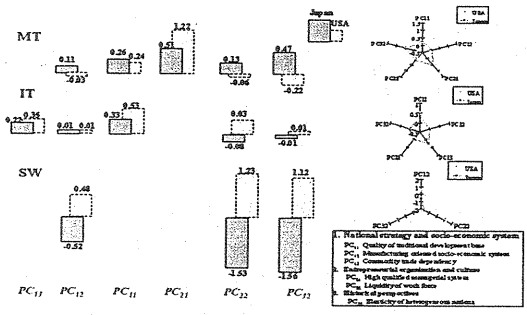


Fig. 26. Contribution of Institutional Factors to MT, IT and SW in Japan and USA (2004).

5. Conclusion

5.1 Rise and Fall of the Japanese Economy

Rise and fall of the Japanese economy over the last 3 decades can be attributed to the consequence of the co-evolution and disengagement between innovation and institutional systems.

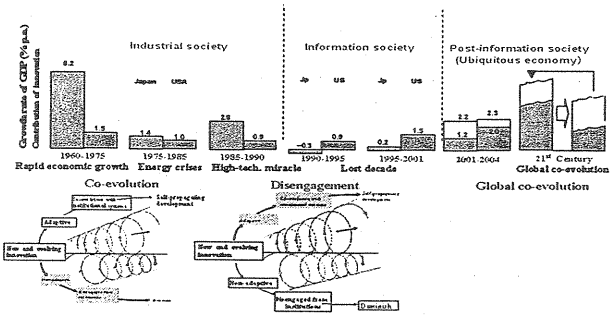


Fig. 27. Rise and Fall of the Japanese Economy as a Consequence of Co-evolution and Disengagement between Innovation and Institutional Systems.

5.2 Accruing Japan's System of MOT to Global Knowledge Assets

The co-evolutionary dynamism between innovation and institutional systems is decisive for an innovation-driven economy. Noteworthy surge in new innovation in leading edge activities in certain high-tech. firms can be attributed to the **co-evolution between indigenous strength** developed in an industrial society and the **effects of learning in an information society**. This surge suggests a possibility of **reactivation of its system of MOT** leading to revitalizing Japan's economy. This can be enabled by constructing a virtuous cycle with vitalized world economy. Accruing Japan's System of MOT to global knowledge assets is thus important.

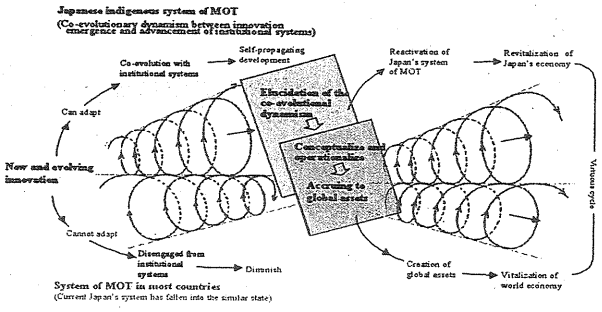


Fig. 28. Global Co-Evolution between Innovation and Institutional Systems.

5.3 What Found, Elucidated and What Remains Blackbox – *Focus of the Next Step*

1. An elucidation of the role of institutional systems in characterizing technology development trajectory – a global comparative analysis of manufacturing technology and information technology in the enhancement of business practice.
2. Elucidation of the role through Mobile driven innovation process: Dual co-evolution consists of (i) Co-evolution through market learning, and (ii) Co-evolution through operators-vendors interaction.
3. Breakthrough of the limit of Japan's closed system against global deployment strategy: Triple co-evolution corresponding to Web 2.0 trend that corresponds to a ubiquitous society.
4. Noteworthy surge in new innovation in leading edge activities in certain high-tech. firms can be attributed to the **co-evolution between indigenous strength** developed in an industrial society and the **effects of learning in an information society**.
5. Hybrid management by fusing "East" and "West"

   Management method that incorporates lessons from US while preserving indigenous practices.
6. Bi-polarization of Japan's leading firms which previously homogeneous.
7. Therefore,

   (i) Elucidation of the endogenous process of the characterization of technology,

   (ii) Impacts of the endogenous process on firms features formation leading to bi-polarization, and

   (iii) Co-evolution between heterogeneous firms.

References

[1] C. Chen and C. Watanabe, "Diffusion, Substitution and Competition Dynamism Inside the ICT Market: A Case of Japan," Technology Forecasting and Social Change 73, No .6 (2006) 731-759.

[2] C. Chen, "Institutional Structure Governing the Dissemination Process of Mobile Phone Driven Innovation," Ph. D. Dissertation (Tokyo Institute of Technology, Tokyo, 2006).

[3] D.C. North, "Understanding the Process of Economic Change," Princeton University Press (Princeton and Oxford, 2005).

[4] A. Ohmura and C. Watanabe, "Cross-products Technology Spillover in Inducing a Self-propagating Dynamism for the Shift to a Service-oriented Economy: Lessons from High-performance Fine Ceramics," Journal of Services Research (2006) in print.

[5] C. Watanabe, "Systems Option for Sustainable Development," Research Policy 28, No.7 (1999) 719-749.

[6] C. Watanabe and B. Asgari, "Impacts of Functionality Development on the Dynamism between Learning and Diffusion of Technology," Technovation 24, No. 8 (2004) 651-664.

[7] C. Watanabe, R. Kondo, N. Ouchi, H. Wei and C. Griffy-Brown, "Institutional Elasticity as a Significant Driver of IT Functionality Development," Technological Forecasting and Social Change 71, No. 7 (2004) 723-750.

[8] C. Watanabe, K. Matsumoto and J.Y. Hur, "Technological Diversification and Assimilation of Spillover Technology: Cannon's Scenario for Sustainable Growth," Technological Forecasting and Social Change 71, No. 9 (2004) 941-959.

[9] C. Watanabe and K. Fukuda, "National Innovation Ecosystem: The Similarity and Disparity of Japan- US Technology Policy Systems toward a Service-oriented Economy," Journal of Services Research 6, No. 1 (2006) 159-186.

[10] C. Watanabe and S. Lei, "The Role of Techno-countervailing Power in Inducing the Development and Dissemination of New Functionality: An Analysis of Canon Printers and Japan's Personal Computers," International Journal of Technology Management (2006) in print.

[11] W. Zhao, "Co-evolution between Software Innovation and Institutions: Elucidation of Co-evolutionary Dynamism between Japan and China through Outsourcing," Master Thesis (Tokyo Institute of Technology, Tokyo, 2006).