1L11 Interaction between ICT Development and Institutional Systems in China

— Comparative Analysis on the Development Trajectory

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Abstract

This research is focusing on China's conspicuous ICT diffusion: rapid increase of absolute user and high growth rate. China is successful to co-evolve with productivity and resilience because of its strong relationship among three ICT fields (PC, internet and mobile) and special structure and institutional sources. Principal Component Analysis (PCA) with forward selection method was introduced to analyze the comprehensive effect both interrelation within ICT industry and institutional factors. In the same time, Mutual Interdependency of PCs, Internet, and Mobile phones (MIPIM) was introduced to quantify interrelation.

1. Introduction

1.1 Background

High growth rate illustrating high productivity in diffusion of ICT industry in China absorbs the attention of the world. From 1993 to 2002, rank of PC users shifted from 16th to 4th, internet users from 45th to 2nd, and mobile users from 9th to 1st in the world. PCs and mobile phones are used as terminal of Internet. Many PC makers entered other ICT areas. Even these 3 ICT areas are directly supervised by the same administrative organ – Ministry of Information Industry. In China, these three ICT areas have strong relationships. Meanwhile, PCs elasticity to GDP is much higher than those of Internet and mobiles. Therefore, PC industry has become the dynamic factor of whole ICT industry. It accelerates GDP growth in China significantly.

1.2 Hypothesis

Based on aforesaid characters of China's ICT industry, we attempts to demonstrate the following hypothetical views:

(i) High productivity growth depends on development trajectory of ICT industry defined by institutional structure and internal relation within ICT in China. Relation between n Institutional Factors (INF) and ICT Interrelation can be developed as the following functions:
INF = F (V1, V2 ・・・Vn)　Vi is the different dimension of institutional system,
ICTi = F (V1, V2 ・・・Vn, ICTj) j = 1 or 2, j≠i.
Interrelation =α・β・γ. It is possible to identify the development trajectory of ICT diffusions through INF and α・β・γ.

(ii) Sophisticated ICT structure co-evolving high productivity and resilience.

(iii) Conspicuous PCs development and strong inter-firm, inter-industry coordination activities could satisfy co-evolution between productivity and resilience.

2 Analytical Frameworks

2.1 Principal Component Analysis (PCA)

PCA is used to analyze the ICT institutional structures. In this research, 15 institutional factors are selected to relegate 3 dimensions of institutional system (**Fig. 1**).

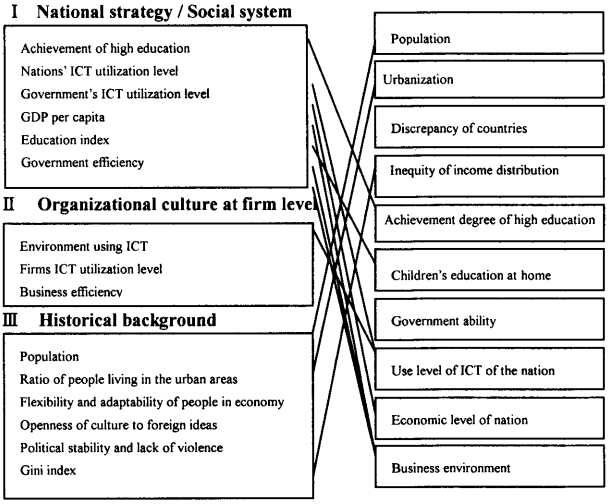

Fig. 1. Index to Characterize China's Institutional Systems.

2.2Measure Interrelation within ICT Industry

Interrelation of 3 ICT areas could be computed with the following functions.

$$\ln Inter = a_1 + \alpha \ln PC_{-1}$$
$$\ln MP = a_2 + \beta \ln Inter_{-1}$$
$$\ln PC = a_3 + \gamma \ln MP_{-1}$$

New variable - MIPIM is introduced to quantitatively express interrelation within ICT industry. (MIPIM: Mutual Interdependency between PC, Internet and Mobile Phone):

$$MIPIM = \alpha \cdot \beta \cdot \gamma = \frac{\partial \ln Inter}{\partial \ln PC_{-1}} \cdot \frac{\partial \ln MP}{\partial \ln Inter_{-1}} \cdot \frac{\partial \ln PC}{\partial \ln MP_{-1}}$$
$$= \frac{\partial \ln PC}{\partial \ln PC_{-1}} \cdot \frac{\partial \ln Inter}{\partial \ln Inter_{-1}} \cdot \frac{\partial \ln MP}{\partial \ln MP_{-1}} = \bar{\eta}_1 \cdot \bar{\eta}_2 \cdot \bar{\eta}_3 = \eta$$

$$\bar{\eta}_1 = Average \frac{\partial \ln ICT}{\partial \ln ICT_{-1}}, \quad ICT = ICT_{-1}^{\bar{\eta}_1}$$

$$\bar{\eta}_1 = \sqrt[n]{\prod_{t=1}^{n} \eta_{1t}} = \sqrt[n]{\prod_{t=1}^{n} \frac{\ln PC_t}{\ln PC_{t-1}}} = \sqrt[n]{\frac{\ln PC_n}{\ln PC_0}} = \sqrt[n]{\frac{\ln (1+g_1)^n PC_0}{\ln PC_0}} = \sqrt[n]{1 + \frac{g_1 \cdot n}{\ln PC_0}}$$

PC_0: PCs at initial period; n: period examined; and g_1: average growth rate.

By the same method, η can be computed, which indicates the average growth speed of ICTs. Based on the data from World Development Indicator (WDI), the value of MIPIM in 28 selected

countries is computed as the following **Fig. 2.**

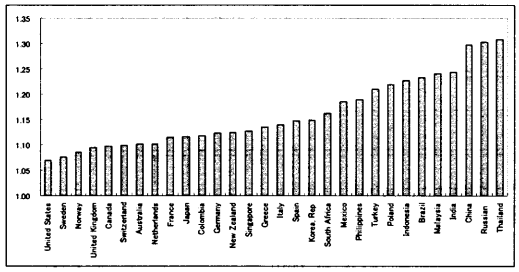

Fig. 2. Comparison of MIPIM in Selected 28 Countries.

High score of China reflects its high interrelation within ICT industry and rapid growth of ICT from initial time.

2.3 Measure Convergence with Entropy

MIPIM is introduced to measure interrelation and average of ICT diffusion in different countries. However, MIPIM could not indicate whether ICT 3 areas are developing in balance, if only one or two areas are developing rapidly but others are in stagnation, the system would be fragile. Based on the value of MIPIM, new variable – entropy is defined as following:

$$\varepsilon = \sum_{j=1}^{n} P_j \ln \frac{1}{P_j}$$

Entropy (ε) is often utilized as a diversification index. When Pj is equal to 1, ε has minimum value 0; when $p_i = p_j = \ldots p_n$, ε has maximum value ln n. **Fig. 3** is the ranking of entropy in 28 countries. Developing countries and developed countries are clearly in 2 different groups. China's scores are relatively low which implies China has relative convergence structure. Why China could maintain its robust ICT development on a relatively fragile structure? To find the answer we have to deeply look into China's ICT industry focusing on China's special institutional systems which could stimulate inter-firm technology spillover.

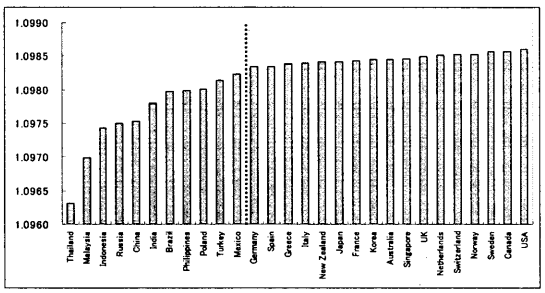

Fig. 3. Comparison of ε in Selected 28 Countries.

3. Empirical Analysis

3.1 Result of PCA

The result of principal component analysis is placed on **Table 1**. The first 3 principal components share almost 77% contribution ratio and eigen value of the fourth principal component is under 1. For these reasons only the first 3 principal components (PC_1, PC_2, PC_3) are selected as representation of the original factors. With this method the number of variables is reduced greatly, which could make regression analysis simple to find the key factors affect ICT diffusion in China.

Table 1 Descriptive Statistics of Selected Principal Components

Principal Component	Eigen value	Variance proportion (%)	Cumulative variance proportion (%)
PC_1	7.095	47.30%	47.30%
PC_2	2.933	19.56%	66.86%
PC_3	1.500	10.00%	76.86%
PC_4	0.894	5.96%	82.82%

Table 2 Weight of Variables in Selected principal Components

	PC_1	PC_2	PC_3
Achievement degree of high education (%)	0.197	-0.210	-0.209
Use level of ICT of the nation	0.282	-0.149	0.143
Use level of ICT of the government	0.241	0.269	0.205
GDP per capita (US$ PPPs)	0.339	-0.160	0.063
Education index	0.262	-0.268	-0.250
Government efficiency	0.260	0.268	0.208
Environment that can use ICT	0.359	0.022	0.097
Use level of ICT of the firm	0.353	0.077	0.058
Business efficiency	0.277	0.359	0.099
Population (1000)	-0.165	0.194	0.560
Ratio of the people living in the urban areas (%)	0.263	-0.078	-0.373
Flexibility and adaptability of people in economy	0.076	0.447	-0.320
Openness of culture to foreign ideas	0.056	0.484	-0.252
Political stability and lack of violence	0.330	-0.077	0.078
Gini Index	-0.166	0.269	-0.371

3.2 Result of Principal Component Regression and Interpretation

To find the correlation between institutional systems and ICT diffusion, stepwise multiple regression analysis with forward selection method is applied. Explained variable is penetration (per 1000 people) of one ICT area; explanatory variables are scores of PC_1, PC_2 , and PC_3 in 28 countries and other ICT penetration. It can be developed as follows:

$$\ln ICT_n = A + aV_1 + bV_2 + cV_3 + d \ln ICT_i + e \ln ICT_j + fD$$

D: Dummy variable.

Result is summarized in **Table 3**. By forward selection method, variables that are not statistically significant would be deleted automatically. The result clearly demonstrates factors that affect ICT diffusion.

Table 3 Result of Multiple Regressions

ln PC = 2.673 + 0.288 PC_1 - 0.111PC_2 - 0.104PC_3 + 0.474ln Inter-1+ 0.744D *adj.* R^2 = 0.980
(5.03) (6.14) (-3.54) (-3.43) (6.04) (5.61)
D: Dummy variable for China, Mexico and Russia =1 other countries = 0.

ln Inter = 2.072 + 0.145PC_1 + 0.314ln PC-1+ 0.275ln MP-1+ 0.675D *adj.* R^2= 0.957
(4.71) (3.77) (2.65) (3.77) (4.69)
D: Dummy variable for Poland, Malaysia and Indonesia =1 other countries = 0.

ln MP = 1.256 - 0.204PC_1+ 0.965 ln Inter-1- 1.117D *adj.* R^2 = 0.906
(2.13) (-3.78) (8.30) (-5.44)
D: Dummy variable for India, Indonesia and Malaysia =1 other countries = 0.

For PCs, three dimensions of institutional systems would affect its diffusion. PC_1 has active effect, however, PC_2 which is represent social and business flexibility and PC_3 which implies influence of population have negative effects. It is easy to understand trade off relation between population and PC diffusion, however, why social and business flexibility has negative effect to diffusion? It needs to be interpreted by other evidence. Also the greater weight variable of Internet demonstrates the strong interrelation of Internet and PCs diffusion. "Network is Computer" is a famous wisdom from the founder of SUN system. The result can improve it is correct.

For Internet, PC_1 still has active effect. In the same time PCs and MPs diffusion also have conspicuous active effect. It could prove that as the terminal of Internet, PCs and MPs have strong interrelation to Internet.

For MPs, the greatest coefficient of Internet demonstrates

strongest correlation of Internet and MPs comparing to others, however, PC_1 which implies national ICT environment and socio-economic development level become negative. It seems paradox. It is greeted that high ICT and economic level should have active effect to MPs diffusion. Why the result demonstrates the contrary? It also needs to be interpreted.

As we discussed before, 2nd principal component (PC_2) implicates social and business efficiency and flexibility. For firms or government to increase business efficiency, not only IT investment but also intangible asset investment is required (Erik Brynjolfsson.2003). The quantity of these two investments can be demonstrated as following **Fig. 4.** The same research also indicates that compare to hardware investment, investment to construct digital organization is much more important to increase efficiency or flexibility. These investments are including training expenditure, and etc. The relation of hardware investment, digital organization investment, and efficiency can be demonstrated as Fig. 4.

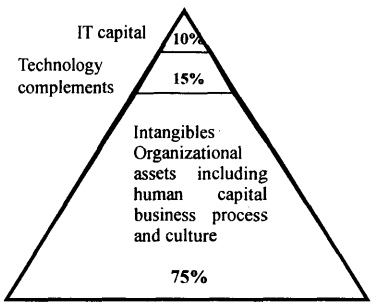

Fig. 4. Quantities of Intangible Investment and Hardware Investment.

The latter "paradox" is that ICT environment and socio-economic development level have active effect to PCs and Internet diffusion but negative effect to MPs diffusion. Before explaining that, we find the fact that weight variable of $\ln INT_{-1}$ in the regression function is conspicuous, which means Internet diffusion has strong active impact on MPs' diffusion. PC_1 has negative value in the regression function, which means nation's ICT environment does not have direct influence to mobile phone diffusion. However, because PC_1 has active impact to Internet diffusion and Internet diffusion has strong active effect to mobile phone diffusion, PC_1 should have indirect influence to mobile phones diffusion via the cycle like **Fig. 5.**

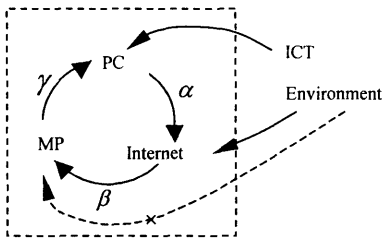

Fig. 5. Relation of ICT Environment and ICT Diffusion.

3.3 ICT Development Trajectory Depicted by PC_1 and MIPIM

Through the foregoing multiple regression, we discovered the factors which could influence ICT diffusion. PC_1 has significant effect to the diffusion process in all 3 ICT areas; therefore PC_1 could be appropriate variable which could represent institutional system influencing ICT diffusion.

Meanwhile, results of statistical calculation improved the observation that not only in China, but also in other countries, Interrelation of within ICT industry is significant.

Based on this fact, we could define the ICT development trajectory by PC_1 and MIPIM. The plot of PC_1 and MIPIM are illustrated in **Fig. 6.** This figure suggested that China's ICT industry still have conspicuous potential to grow, via high productive development (high MIPIM), it will evolve to high level in the near future.

$$\text{Ln } \alpha\beta\gamma = 0.144 - 0.018D_1PC_1 - 0.069(1-D_1)PC_1 \quad adj.\ R^2 = 0.799$$
$$(27.12)\ (-9.17)\qquad (-4.94)$$

D_1: Dummy variable, Thailand and Malaysia = 0, other countries = 1.

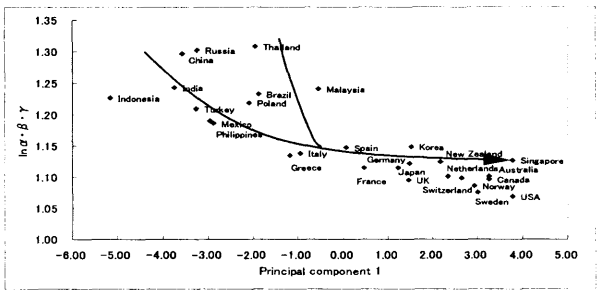

Fig. 6. Development Trajectory of ICT.

3.3 China's Productive and Resilient Structure

Single regression analysis is applied to find correlation between MIPIM and productivity. Growth rate of 3 ICT fields from 1998 to 2002 are averaged to represent total image of ICT productivity, we call it GR_ICT. MIPIM is explanatory variable to predict it. The result is displayed on the **Fig.7.** It demonstrates that for almost countries, MIPIM contributes to their ICT development. Therefore China's astonishing growth among PCs, Internet, and mobile phones attributes to its tight link within ICT industry.

$$\ln GR\_ICT = -2.093 + 8.183\ln MIPIM - 0.578D \quad adj.\ R^2 = 0.792$$
$$(-14.25)\quad (8.09)\qquad (-2.94)$$

D: Dummy variable for Russia, Thailand, and Malaysia.

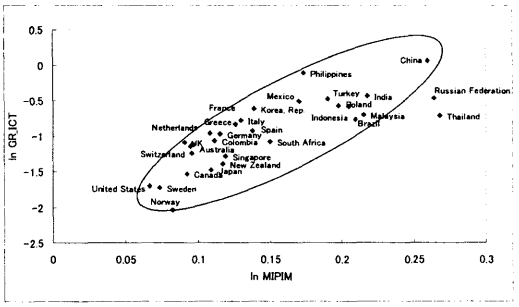

Fig. 7. Relation between MIPIM and ICT Growth.

The relation of convergence (entropy) and productivity (MIPIM) can be illustrated by the **Fig. 8,** which is based on the single regression analysis of MIPIM and ε.

$$\varepsilon = 1.0963 + X = 1.0963\left(1 + \frac{X}{1.0963}\right)$$

$$\ln\varepsilon \approx \ln 1.0963 + \frac{X}{1.0963}$$

$$\text{Ln } \alpha\beta\gamma = 0.312 - 142.155D1X - 92.013(1-D1)X + 0.058D \quad adj.\ R^2 = 0.840$$
$$(15.39)\ (-3.03)\ (-9.05)\ (3.61)$$

D1, D: Dummy variables, Thailand and Malaysia =1 for D1; Brazil, China, Russia = 1 For D; other countries = 0.

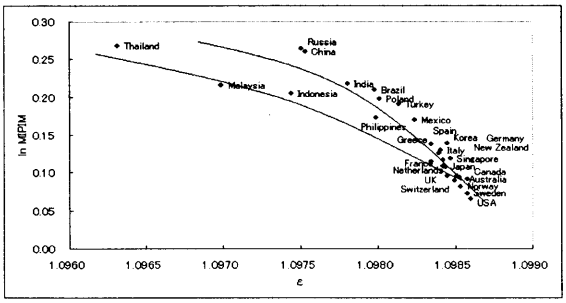

Fig. 8. Relation between ε and MIPIM in 28 Selected Countries.

In the both two routes MIPIM which imply high productivity has clear trade off relation to entropy which suggests convergence of structure. Therefore in China's case, it is secure to say China's high productivity in ICT diffusion determined by the high interrelation within ICT and its convergent ICT structure.

3.4 China's Resilience to External Changes

The foregoing analysis clearly demonstrates the convergent structure would have active effect to ICT development. However, there will be another question of convergent structure which suggests the unbalance. All the developed countries whose resilience to external changes is relatively strong are all in the group of high entropy. Focusing on China's case, one can have a question, would China will be resilient to external changes? Index of Political stability and lack of violence (POL) is selected to represent ability to social crises, and regression analysis is applied. The result is shown on the **Fig. 9**.

$$POL = 2.576 + 1677.432X + 1.819D \qquad adj.\ R^2 = 0.782$$
$$(4.71) \quad (6.13) \quad (3.85)$$

D: Dummy variable, China, Malaysia and Thailand = 1 other countries = 0.

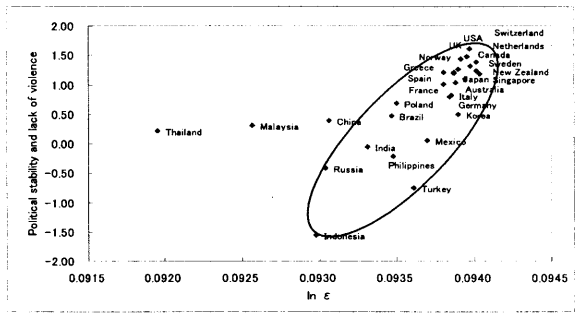

Fig. 9. Relation between ε and External Social Changes in 28 Selected Countries.

Convergent structure (low entropy) will bring relatively fragile ability against social changes. However in this analysis, China is the exception. Although it has relatively low score of entropy it still displays robust resilience against political crisis.

There is actual evidence that can also demonstrate China's ICT resilience against social changes. A critical political crisis happened in China 1989, China's GDP growth rate decreased from 1989-1991, unexpectedly, its ICT industry was still developing rapidly in these years just like nothing had happened.

3.5 Institutional Sources of China's Sustainable ICT Growth

In China, the government is not only the policy maker but also a player in ICT industry because government holds stock of many firms and there are so many large state owned enterprises in this Industry. Government combines the 3 fields of ICT into a whole, and influences the firms in these two ways. From the facts of China's ICT development, it seems successful to reduce the negative effect of convergence and promote productivity. By doing so, the channels of information exchanges, co-ordinations, technology spillovers are broadened. Therefore, powerful government could be one of important for high interrelation and resilience of China's ICT diffusion.

The environment surrounding ICT firms could be demonstrated like **Fig. 10**.

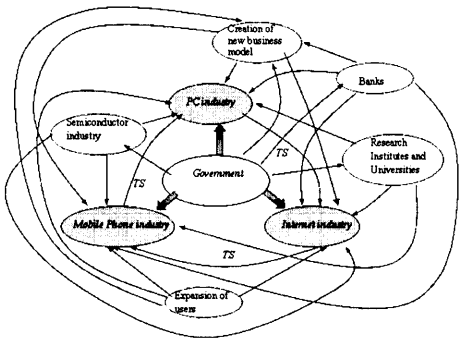

Fig. 10. Complex Technological Web Suspending China's Interdependent ICT Development.

4. Conclusion

In this research, both internal interrelation and external institutional factors were analyzed as the governing factors which have impact on ICT diffusion. The following findings are obtained:

(i) High MIPIM Contributes to High Productivity;

(ii) PCs Based Inter-firm Technology Spillovers Contribute to High Resilience;

(iii) China's Sustainable ICT Growth Attributes Its Unique Institutional Structure.

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