2H15 Co-evolution between Software Innovation and Institutions

—Empirical Analysis of China's Software Development

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Abstract

Since the middle of the 1990s, China's software industry has achieved rapid development. With the background of high growth in economic development and the diffusion of PC and Internet, conspicuous advancement in China's software development typically in its world highest increase rate of (i) number of papers in the field of software published in the qualified international journals, and also (ii) IT software spending has drawn world attention. It can be concluded that the advancement of software is subject to the institutional structure of the nation. Then, institutional structure governing the potential of software development in China was analyzed; thereby institutional factors essential for the software development were identified. Furthermore, co-evolution between software innovation and institutions was elucidated.

1. Introduction

1.1 Background

As a strategic industry in information industry, rapid development and potentiality of software have been focused. In China, software industry has been accelerating its growth with high priority expecting to be the core industry.

Behind the remarkable development of Chinese software industry, "IT software spending" (expenditure for ICT development/utilization including *the purchase of all software products, external customization of computer programs, systems software/utilities, application tools and application solutions*) is playing an important role to promote the development of software industry. Compound Annual Growth Rate in IT software spending in 38 countries is illustrated in **Figure 1-1**. It is noted that China ranked the top position followed by India.

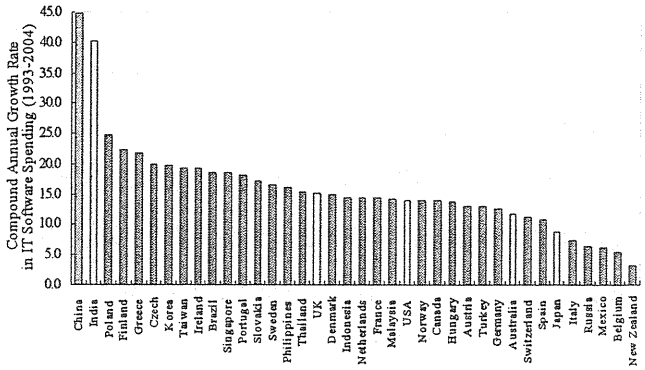


Figure 1-1. Compound Annual Growth Rate (CAGR) in IT Software Spending in 38 Countries *(1993-2004).*
Source: Digital Planet 2002

Not only IT software spending, but also number of papers in the field of software has been focused. **Figure 1-2** demonstrates the trends in the number of papers published in the qualified international journals by 6 countries over the period 1991-2004. The average increase was 31% that ranks the first.

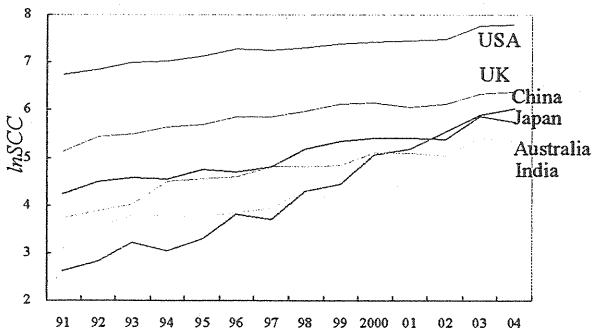


Figure 1-2. Trends in Number of Papers Published in the Qualified International Journals in 6 Countries *(1991-2004)*

1.2 Hypothesis

China's advancement of software is subject to the institutional structure of the nation. High functionalities based on its institutional systems that incorporate

conspicuous resources lead to software development innovation.

2. Analytical Framework

2.1 Measurement of the Potential of Software Development

Since *the potential of software development* in the nation (*SW*) which can be defined as *nation's resources potential in software innovation* is considered as a product of the quality of software development (*SWL*) and number of the contributor of the software development (*SWN*) in the nation, it can be simply depicted as follows:

$$SW = SWL \times SWN \qquad (2\text{-}1)$$

Differentiation by time leads to the following equation:

$$\frac{\Delta SW}{SW} = \frac{\Delta SWL}{SWL} + \frac{\Delta SWN}{SWN} \qquad (2\text{-}2) \text{ where } \Delta SW = \frac{dSW}{dt}$$

In order to evaluate *SWL* and *SWN* by their trend, the change rate not by their absolute values is used for measurement.

The first term of the right hand side of the equation demonstrates the increase rate of the quality of software development of the nation which can be represented by the change rate of the productivity of the software corresponding to the economic growth of the nation as follows:

$$\frac{\Delta SWL}{SWL} = \frac{\Delta(SCC\ /\ V)}{SCC\ /\ V} \qquad (2\text{-}3)$$

where *SCC*: software creation capacity; and

V: GDP of the nation.

SCC is defined as *nation's capacity to create innovative high-qualified software* that can be represented by *the creativity of the software* such as the *number of the novel academic papers* in the software field.

The second term of the right hand side of the equation (2-2) can be proportional to the increase rate of the population of the nation under certain developed states as follows:

$$\frac{\Delta SWN}{SWN} = \frac{\Delta P}{P} \qquad (2\text{-}4)$$ where *P*: population.

Substitution of equations (2-3) and (2-4) for the right hand side of the equation (2-2) leads to the following equation:

$$\frac{\Delta SW}{SW} = \frac{\Delta(SCC\ /\ V)}{SCC\ /\ V} + \frac{\Delta P}{P} = \frac{\Delta(\frac{SCC}{V\ /\ P})}{(\frac{SCC}{V\ /\ P})} \qquad (2\text{-}5)$$

Equation (2-5) implies that the change rate of *the potential of software development* in the nation can be depicted by the change rate of the ratio of the creativity of the software and GDP per capita.

Thus, *the potential of the software development* in the nation can be represented by the index of the ratio of the creativity of the software and GDP per capita as follows:

$$SW = (\frac{SCC}{V\ /\ P})^* \qquad (2\text{-}6)$$ where $(\frac{SCC}{V\ /\ P})^*$ indicates the index.

2.2 Governing Factors of Institutions Emerging the Potential of Software Development

(1) Constitution of Institutional Systems

Institutional systems (IS) are constituted by the following three dimensions as illustrated in **Figure 2-1** (SIMOT, 2004):

(i) National strategy and socio-economic system,

(ii) Entrepreneurial organization and culture, and

(iii) Historical perspectives.

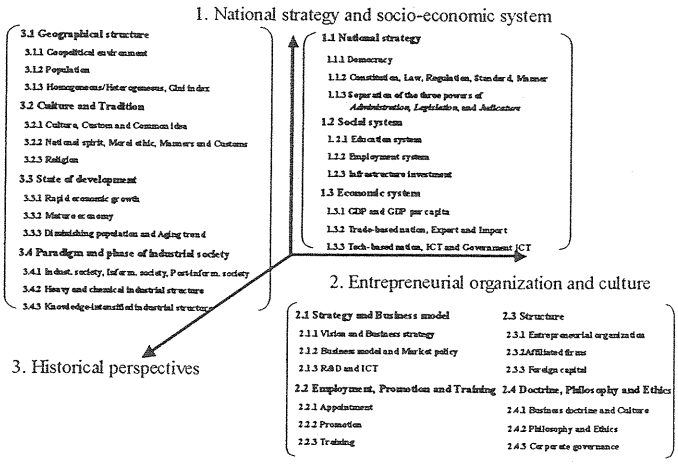


Figure 2-1. Constitution of Three Dimensions of Institutional Systems.

(2) Identification of the Governing Factors

Institutional systems (IS) can be depicted by the following equation:

$$IS = F(X, Y, Z) \quad (2\text{-}7)$$

where $X = X(X_1, X_2, \ldots X_n)$, $Y = Y(Y_1, Y_2, \ldots Y_n)$, and $Z = Z(Z_1, Z_2, \ldots Z_n)$ which demonstrate (i) national strategy and socio-economic system, (ii) entrepreneurial organization and culture, and (iii) historical perspectives constituting X_i, Y_i, and Z_i (i = 1-n), respectively. X_i, Y_i, and Z_i can be identified by means of Principal Component Analysis (PCA) as follows:

$$\begin{aligned} X &= X(PCx_1, PCx_2, PCx_3, \cdots PCx_n) \\ Y &= Y(PCy_1, PCy_2, PCy_3, \cdots PCy_n) \quad (2\text{-}8) \\ Z &= Z(PCz_1, PCz_2, PCz_3, \cdots PCz_n) \end{aligned}$$

where PCx_i, PCy_i, and PCz_i (i = 1-n) are principal components of X, Y and Z, respectively.

3. Empirical Analysis

3.1 Potential of Software Development

Based on the equation (2-5), first, a proxy representing the software creation capacity (*SCC*) that can be defined as nation's capacity to create innovative high-qualified software is identified. In order to evaluate the eligibility of *SCC/(V/P)* as a proxy of the potential of software development of the nation, a cross-country regression analysis in 40 countries tabulated was conducted. These 40 countries share 94.83% and 77.13% of world GDP and population in 2004, respectively. The result of the analysis is summarized as follows:

$$I = -5.70 + 0.69 \ln V/P + 0.06 \ln \frac{SCC}{V/P} - 1.00D \qquad adj.\ R^2 \quad 0.688$$

$$(-7.55)\ (8.69) \qquad (1.39) \qquad (-3.70)$$

where D: dummy variable (Italy and Poland = 1; other countries = 0).

Other regression analyses were conducted to confirm that the significance of *SCC/(V/P)* using *number of papers published in the qualified international journals in the field of software* for *SCC* and *GDP PPP per capita* for *V/P* as a reliable proxy of *the potential of software development.*

3.2 Policy Inducement in Software Development

Aiming at identifying the effect of "IT software spending" (*SWS*: expenditure for ICT development/utilization including *the purchase of all software products, external customization of computer programs, systems software/utilities, application tools and application solution*) in inducing the software development (*SW*), correlation analysis between *SWS* and *SW* was conducted as follows:

$$\ln SW = a + b_1 D_1 \ln SWS_{-1} + b_2 D_2 \ln SWS_{-1}$$

where D_1 and D_2: dummy variables (D_1: 1993-2001 = 1, other years = 0; and D_2: 2002-2003 = 1, other years = 0); and SWS_{-1}: *SWS* in the preceding year.

The result of the analysis is summarized in **Table 3-1**.

Table 3-1 Correlation between IT Software Spending and the Potential of Software Development in 6 Countries *(1993-2004)*

	a	b_1	b_2	$adj.\ R^2$	DW
China	-0.480	0.580	0.592	0.887	1.93
	(-0.90)	(6.61)	(8.29)		
USA	2.736	0.104	0.121	0.872	1.67
	(6.37)	(2.65)	(3.27)		
India	2.259	0.217	0.127	0.739	2.69
	(7.28)	(3.57)	(4.61)		
UK	1.540	0.144	0.152	0.572	1.45
	(2.65)	(2.24)	(2.53)		
Japan	-8.996	1.173	1.186	0.752	1.58
	(-3.06)	(3.70)	(3.90)		
Australia	-0.853	0.338	0.354	0.781	2.63
	(-1.16)	(3.44)	(3.87)		

Looking at the table, we note that "IT software spending"(SWS) has provided a significant impact in inducing the software development in all countries examined.

3.3 The Role of IS in Inducing SW Development

In line with the three dimensional institutional systems and their constitution as demonstrated in Figure 2-1, proxies representing 33 institutional factors were constructed. Utilizing the selected 33 institutional factors, principal component analysis (PCA) was attempted for each respective dimension. Three principal components for *National Strategy and Socio-economic System*, two principal components for *Entrepreneurial Organization and Culture*, and three principal components for *Historical Perspectives* were demonstrated high level of eigenvalue over 1. On the basis of the foregoing PCA, structure of institutional system in 40 countries were identified as demonstrated in **Figure 3-1**.

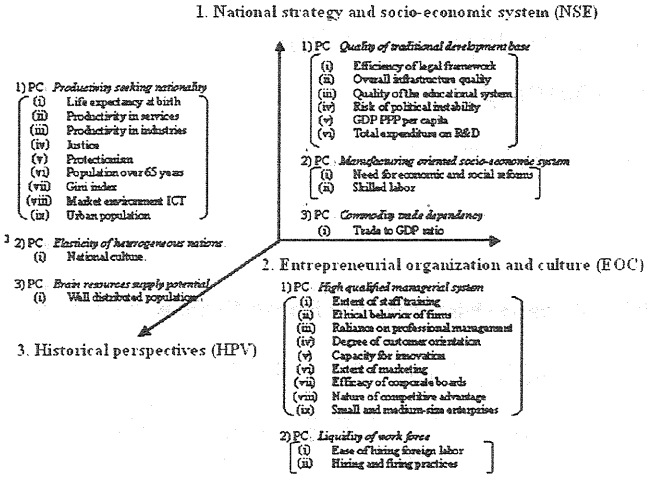


Figure 3-1. Structure of Institutional Systems *(2004)*.

Multi-regression analysis between principal components of institutional factors and SW development was conducted. Institutional factors governing SW was examined that "*Manufacturing oriented socio-economic system*" (PC_{12}), "*Liquidity of work force*" (PC_{22}) and "*Elasticity of heterogeneous nations*" (PC_{32}) play a significant role in SW development. The following relationship was also obtained:

$$SW = 0.038 - 0.036PC_{12} + 0.031PC_{22} + 0.028PC_{32}$$

Table 3-2 compares contribution of institutional factors to SW in 6 countries.

Table 3-2 Contribution of Institutional Factors to Potential Software Development in 6 Countries (2004)-SW/GDPPPPpercapita × 100

	SW/V/P	Constant[b]	PC_{12}	PC_{22}	PC_{32}
China	7.8	3.8	-0.6	1.8	2.8
USA	6.4	3.8	0.3	1.3	1.0
India	4.5	4.3	0.3	0.1	-0.2
UK	2.1	2.4	-0.2	-0.1	0
Japan	1.1	0.6	0.1	0.2	0.2
Australia	0.7	0.4	0.1	0.1	0.1

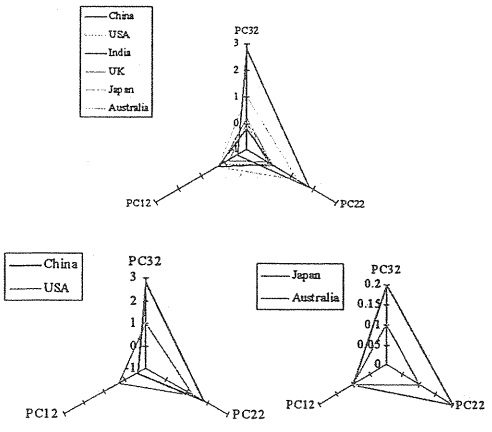
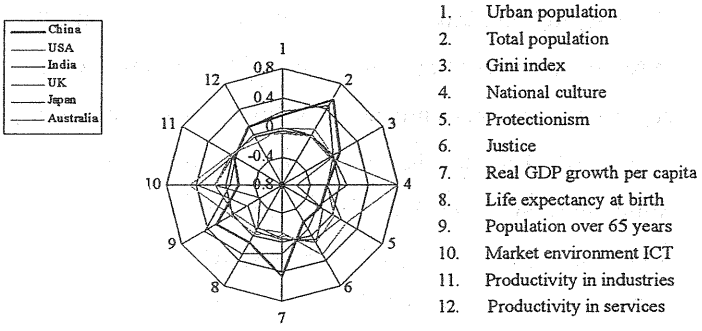


Figure 3-2. Radar Chart of Contribution of Institutional Factors to SW.

Inspired by this comparison, **Figure 3-2** demonstrates the institutional characteristics in inducing potential software development in 6 countries. In light of the conspicuous score of China's "*Elasticity of heterogeneous nations*" (PC_{32}), **Figure 3-3** compares the constitution of this component by illustrating the score of 12 variables constituting this component.



4. Conclusion

Since the middle of the 1990s, China's software industry has achieved rapid development. It can be concluded that the advancement of software is subject to the institutional structure of the nation. Then, institutional structure governing the potential of software development in China was analyzed; thereby institutional factors essential for the software development were identified. Similarly, co-evolution between software innovation and institutions was elucidated.

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