23rd Jyvaskyla
Summer School
7-9 Aug.. 2013, University of Jyvaskyla, Jyvaskyla

COM8
Techno-economic Systems Institutional Innovation (2)

Chihiro Watanabe

Professor, Department of Industrial Management, Tokyo Seitoku University
Professor Emeritus, Tokyo Institute of Technology
Visiting Professor, National University of Singapore
Visiting Professor, University of Jyvaskyla, Finland
Research Scholar, International Institute for Applied Systems Analysis (IIASA)

watanabe.c.pqr@gmail.com

COM8: Techno-economic Systems, Institutional Innovation

Chihiro Watanabe (watanabe.c.pqr@gmail.com)

AM: 10-12 am   PM: 13-15pm

1. **7 Aug (W) AM   Technological innovation, growth, diffusion and consumption**
2. **PM   Productivity, technological progress, competitiveness**

3. **8 Aug (T) AM   Diffusion of technology, Effects of learning**
4. **PM   Technology spillover, Rate of return to R&D investment**

5. **9 Aug (F) AM   Basic concept of institutional innovation**
6. **PM   New Stream for institutional innovation**

Identity: **SEARCH** **S**ystems approach, **E**mpirical approach, **A**nalytical approach, challenge to **R**ationale, **C**omprehensive approach, with **H**istorical perspective

2. Productivity, Technological Progress, Competitiveness

2.1 Technological Progress

2.2 Total Factor Productivity (TFP)

2.3 Composition of TFP

2.4 Competitiveness

2.5 Substance of Innovation

2. Productivity, Technological Progress, Competitiveness

2.1 Technological Progress

(1) Solow Residual (R.M. Solow, 1956)

Growth rate = Contribution by Labor and Capita + 3rd Factor (Residual)

(2) Growth Accounting (Denison, 1962; Jorgenson and Griliches, 1966)

2.2 Total Factor Productivity: TFP

Contribution to growth by factors other than labor and capital can be attributed to **technological progress** in broad sense which is called **Total Factor Productivity (TFP)** or Multi Factor Productivity (MFP).

2.2.1 TFP (T) measured by residual

(1) $V = T \cdot f(L,K)$ (13)

$$\frac{dV/dt}{V} = \frac{dT/dt}{T} + \frac{df/dt}{f} = \frac{dT/dt}{T} + \frac{\partial V}{\partial L}\cdot\frac{L}{V}\cdot\frac{dL/L}{L} + \frac{\partial V}{\partial K}\cdot\frac{K}{V}\cdot\frac{dK/dt}{K}$$

$$\frac{dT/dt}{T} = \boxed{\frac{dV/dt}{V} - \left[\alpha\frac{dL/dt}{L} + \beta\frac{dK/dt}{K}\right]}$$

(2) $V = T \cdot L^{\alpha} K^{\beta} \equiv A \cdot e^{\lambda t} L^{\alpha} K^{\beta}$ (14)

$$\ln V = \ln A + \lambda t + \alpha L + \beta K$$

$$\frac{dV/dt}{V} = \lambda + \alpha\frac{dL/dt}{L} + \beta\frac{dK/dt}{K}$$

$$\boxed{\frac{dV/dt}{V} - \left[\alpha\frac{dL/dt}{L} + \beta\frac{dK/dt}{K}\right]} = \lambda = \frac{dT/dt}{T} = \frac{dTFP}{TFP} = \frac{\Delta TFP}{TFP} = \dot{TFP} \quad (15)$$

Schmpeter (1942)

Creative destruction ⇒ **Innovation**

Solow (1956)

Contributors to US GDP growth *(1909 – 1948)*

L, K **contribution**	**1/8**
Contribution by the 3rd Factor (Residual)	**7/8**

⇒ **TFP**

Denison (1962), **Jorgenson and Griliches** (1966)

Growth accounting

$$\sum_{i=1}^{m} q_i V_i = \sum_{j=1}^{n} p_j X_j \qquad \text{Output } (\boldsymbol{O}) = \text{Input } (\boldsymbol{I})$$

$$\sum_{i=1}^{m}(\Delta q_i \cdot V_i + q_i \cdot \Delta V_i) = \sum_{j=1}^{n}(\Delta p_j \cdot X_j + p_j \Delta X_j)$$

$$\sum_{i=1}^{m} q_i V_i(\dot{q}_i + \dot{V}_i) = \sum_{j=1}^{n} p_j X_j(\dot{p}_j + \dot{X}_j)$$

$$\sum_{i=1}^{m} \frac{q_i V_i}{\sum q_i V_i}(\dot{q}_i + \dot{V}_i) = \sum_{j=1}^{n} \frac{p_j X_j}{\sum p_j X_j}(\dot{p}_j + \dot{X}_j)$$

$$\sum_{i=1}^{m} w_i(\dot{q}_i + \dot{V}_i) = \sum_{j=1}^{n} v_j(\dot{p}_j + \dot{X}_j)$$

$$\sum_{i=1}^{m} w_i \dot{V}_i - \sum_{j=1}^{n} v_j \dot{X}_j = \sum_{j=1}^{n} v_j \dot{p}_j - \sum_{i=1}^{m} w_i \dot{q}_i$$

$$\dot{V} - \dot{X} = \sum_{j=1}^{n} v_j \dot{p}_j - \sum_{i=1}^{n} w_i \dot{q}_i$$

Balance of change rate of ***I*** and ***O*** ⟶ ***TFP***

Robert Solow

Bill Clinton awarding Solow the National Medal of Science (1999)

Birth	August 23, 1924 (1924-08-23) (age 88)
Nationality	United States
Institution	MIT
Field	Macroeconomics
Alma mater	Harvard University
Influences	Wassily Leontief William Phillips Alvin Hansen Paul Samuelson
Influenced	George Akerlof Robert J. Gordon Joseph Stiglitz Jagdish Bhagwati
Contributions	Exogenous growth model
Awards	John Bates Clark Medal (1961) Nobel Memorial Prize in Economic Sciences (1987) National Medal of Science(1999)

Joseph Schumpeter

Birth	8 February 1883(1883-02-08) Třešť, Moravia, Austria–Hungary(now Czech Republic)
Death	8 January 1950 (aged 66) Taconic, Connecticut, U.S.
Institution	Harvard University1932-50 University of Bonn1925-32 Biedermann Bank 1921-24 University of Graz 1912-14 University of Czernowitz 1909-11
Field	Economics
Alma mater	University of Vienna
Influences	Böhm-Bawerk, Wieser, Menger, Walras, Juglar
Influenced	Friedman, Samuelson, Tobin, Williams, Bergson Georgescu-Roegen, Heilbroner, Schiff
Contributions	Business cycles Economic development Entrepreneurship Evolutionary economics

2.2.2 Total Factor Productivity (TFP): *Endogenous approach*

(1) Technology Knowledge Stock

1) Measurement of technology knowledge stock

$$T_t = R_{t-m} + (1-\rho)T_{t-1} \quad (18)$$

$$T_0 = R_{1-m}/(\rho+g) \quad (19)$$

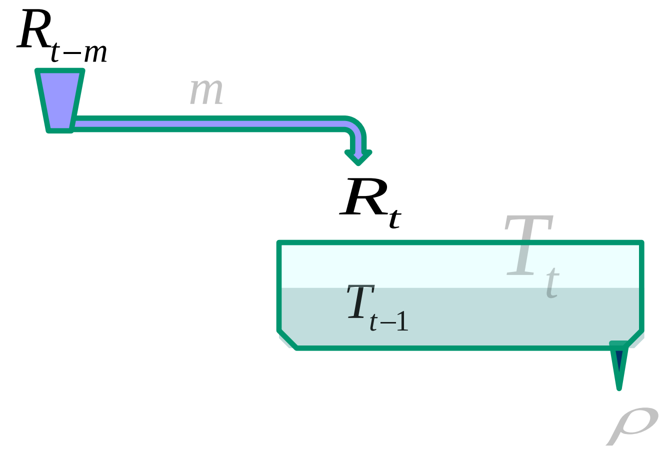
T_t: *Technology knowledge stock at time t*

R_t: (gross) *R&D investment at time t*

m: *Lead-time between R&D and commercialization*

ρ: *Rate of obsolescence of technology*

g: growth rate of R&D investment at initial period ($\Delta R/R$)



When $t=1$, $T_1 = R_{1-m} + (1-\rho)T_0$

Given the increase rate at initial period $\frac{\Delta T}{T} \approx \frac{\Delta R}{R} = g$,

$T_1 = (1+g)T_0$

$(1+g)T_0 = R_{1-m} + (1-\rho)T_0$

$(\rho+g)T_0 = R_{1-m}$, therefore, $T_0 = \frac{R_{1-m}}{(\rho+g)}$

2) Lead-time and rate of obsolescence

Table 3 Comparison of Lead-time and Rate of Obsolescence of Technology in the US and Japanese Manufacturing Industry in the 1980s

	USA	**Japan**	(Textiles, Pulp & Paper, Cement)	(Chemicals)	(Iron & Steel)	(Machinery)
m (years)	**5.1**	**3.3**	3.4	4.2	3.2	3.3
ρ (%)	**6.7**	**9.8**	16.1	9.0	6.0	10.3

(2) Dynamic Change in ρ and *m*

ρ_t : rate of obsolescence of technology at time ***t***

m: lead-time between R&D and commercialization at time ***t***

$$\rho_t = \rho(T_t), \quad m_t = m(\rho_t)$$

$$\rho_t = \rho_0 e^{aT_t}$$

ρ **increases as *T* increases**

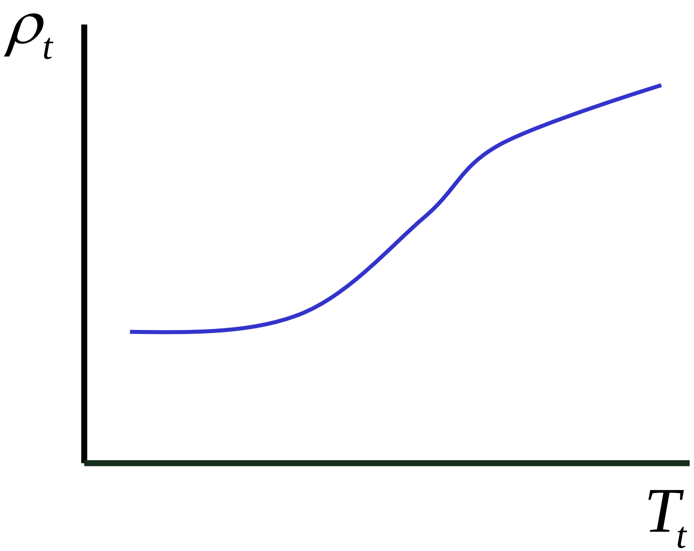
$$m_t = \frac{\ln \frac{R_0}{T_0} - \ln(\rho_t + g)}{\ln(1+g)} + 1$$

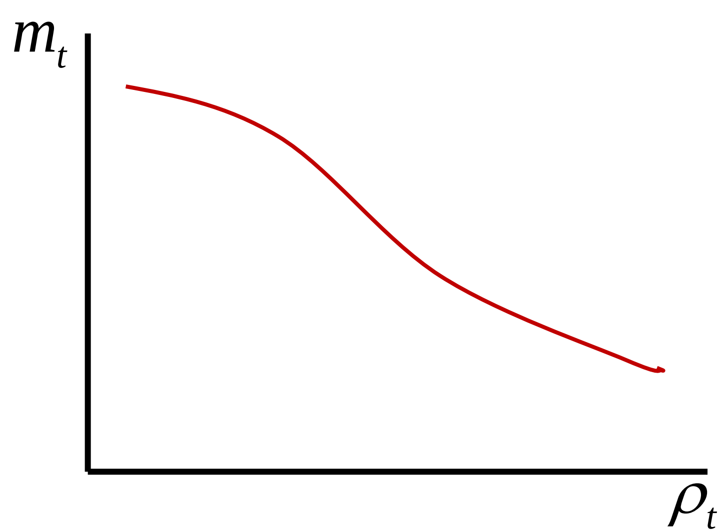
***m* decreases as ρ increases**

$$T_0 = \frac{R_{1-m_t}}{\rho_t + g} = \frac{R_0(1+g)^{1-m_t}}{\rho_t + g}$$

$$\ln T_0 = \ln R_0 + (1-m_t)\ln(1+g) - \ln(\rho_t + g)$$

$$m_t = \frac{\ln \frac{R_0}{T_0} - \ln(\rho_t + g)}{\ln(1+g)} + 1$$





Firm's crucial problem: Decrease in ρ ⟹ Urge to shorten ***m*** ⟹ ***Easy-going innovation***

(3) TFP (T) Measured by Technology Knowledge Stock

1) Measurement of technology knowledge stock

$$T_t = R_{t-m} + (1-\rho)T_{t-1} \qquad (16)$$

$$T_0 = R_{1-m}/(\rho + g)$$

(see detail 25 Aug. "Accumulation of technology knowledge")

T_t: Technology knowledge stock at time t

R_t: R&D investment at time t

m: Lead-time between R&D and commercialization

ρ: Rate of obsolescence of technology

g: growth rate of R&D investment at initial period ($\Delta R/R$)

(**See detail 28 Aug Accumulation of technology knowledge**)

2) TFP contribution to growth

$$V = F(L,K,T) \equiv F(X,T) \qquad (17)$$

$$\frac{\Delta V}{V} = \sum_{X=L,K}\left(\frac{\partial V}{\partial X}\cdot\frac{X}{V}\right)\frac{\Delta X}{X} + \left(\frac{\partial V}{\partial T}\cdot\frac{T}{V}\right)\frac{\Delta T}{T} \approx \sum_{X=L,K}\left(\frac{\partial V}{\partial X}\cdot\frac{X}{V}\right)\frac{\Delta X}{X} + \frac{\partial V}{\partial T}\cdot\frac{R}{V} \qquad (18)$$

$\Delta T \approx R$

TFP growth rate | **TFP growth rate**

V: GDP ; X: Labor (L), Capital (K) ;
T: Technology knowledge stock

$$\frac{dV}{dt} \equiv \Delta V, \frac{dX}{dt} \equiv \Delta X, \frac{dT}{dt} \equiv \Delta T \approx R \text{ (R\&D investment)}$$

TFP growth rate = MPT ($\frac{\partial V}{\partial T}$) x R&D intensity (R/V)

MPT: Marginal Productivity of Technology

$$= \frac{\partial V}{\partial T} = aV\left(1 - \frac{1}{FD}\right)$$

a: Velocity of diffusion

FD: Functionality development

(Ability to improve performance of production processes, goods and services by means of innovation)

(See detail 1 Sep Diffusion of technology)

3) TFP generation in an information society

Industrial society *(Growth oriented)*

$$\frac{\Delta V}{V} \approx \sum_{X=L,K}\left(\frac{\partial V}{\partial X}\cdot\frac{X}{V}\right)\frac{\Delta X}{X} + \frac{\partial V}{\partial T}\cdot\frac{R}{V}$$

$$\frac{\partial V}{\partial T} = aV\left(1 - \frac{1}{FD}\right)$$

Information society *(FD initiated)*

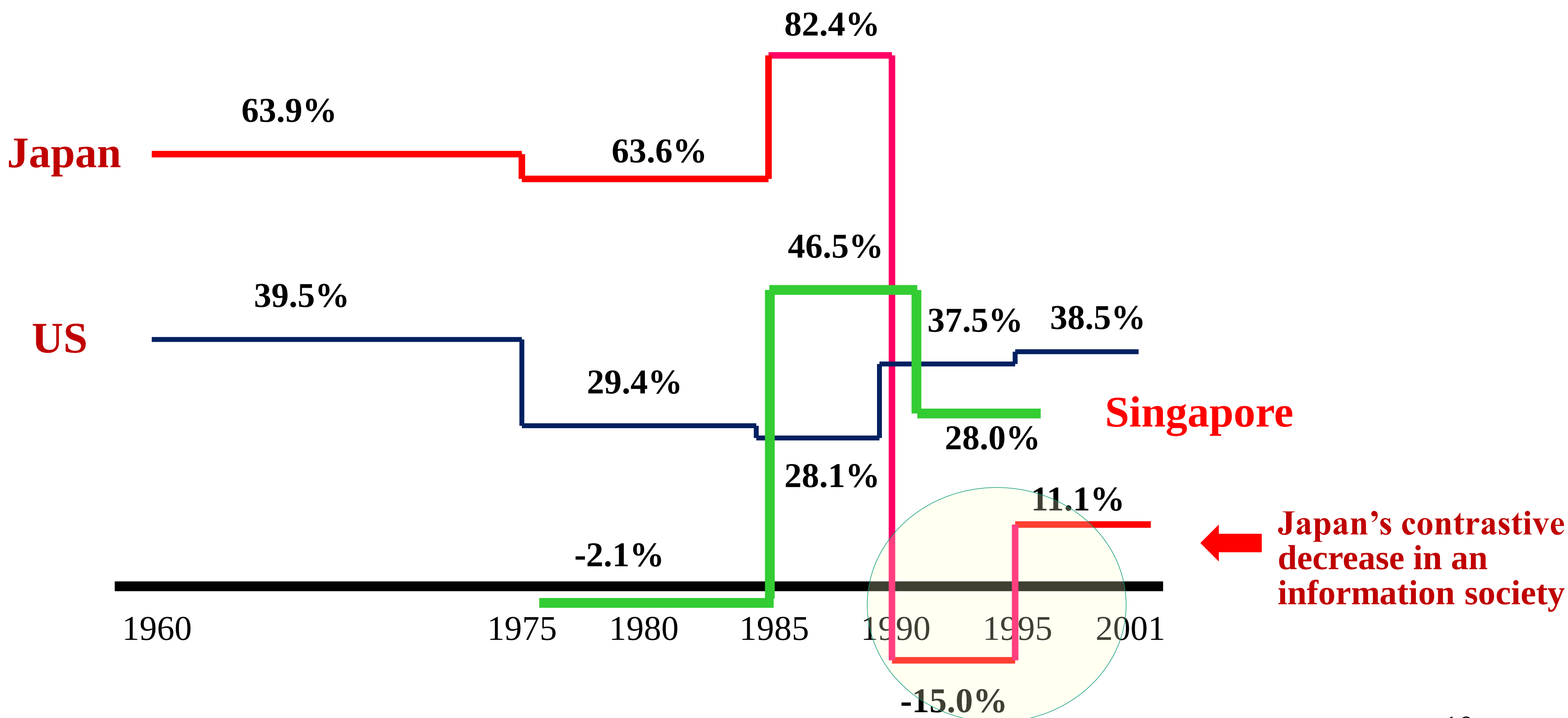
$$\frac{\Delta V}{V} \approx \sum_{X=L,K}\left(\frac{\partial V}{\partial X}\cdot\frac{X}{V}\right)\frac{\Delta X}{X} + \frac{\partial V}{\partial T}\cdot\frac{R}{V}$$

$$\frac{\partial V}{\partial T} = aV\left(1 - \frac{1}{FD}\right)$$

Contribution of TFP to Growth in Japan, US and Singapore

Fig. 1. Contribution of Innovation to GDP Growth in Japan, US and Singapore ***(1960-2001)***

Sources: OECD, EU and "Total Factor Productivity Growth in Singapore: Methodology and Trends (S.T. Wong and B.S.S. Seng, 1997).



GDP growth rate = Contribution by Innovation (TFP) + Labor and Capital

2.3 Composition of TFP

TFP
- Direct effects
  - Own efforts — R&D investment — Technology knowledge stock
  - Dependent — Spillover technology — Assimilation
  - → Technological improvement
- Indirect effects
  - Learning effects
  - Economies of scale
  - Labor quality improvement
  - Maturity of capital stock
  - Industrial structural change
  - Improvement of management
  - External economy, policy effects
  - → Productivity increase

Technological improvement + Productivity increase → Technological progress

7 Aug P Accumulation of technology knowledge
8 Aug A Diffusion of technology
8 Aug A Effects of learning
8 Aug P Technology spillover

Denison's Approach for Decomposition of Contributing Factors to Growth

Country Period	Japan 1953-71	US 1948-69	France 1950-62	W Germany 1950-62	UK 1950-62
% per annum					
Growth rate	8.81	4.00	4.70	6.27	2.38
Increase rate of prod. factors	3.95	2.09	1.24	2.78	1.11
Labor input	1.85	1.30	0.45	1.37	0.60
Number of employee	1.14	1.17	0.08	1.49	0.50
Working hours	0.21	−0.21	−0.02	−0.27	−0.15
Change in age/gender	0.14	−0.10	0.10	0.04	−0.04
Education	0.34	0.41	0.29	0.11	0.29
Others	0.02	0.03	0.00	0.00	0.00
Capital input	2.10	0.79	0.79	1.41	0.51
Residuals	4.86	1.91	3.46	3.49	1.27
Technological progress	1.97	1.19	1.51	0.87	0.79
Resources allocation	0.95	0.30	0.95	1.01	0.12
Economy of scale	1.94	0.42	1.00	1.61	0.36
% of contribution					
Growth rate	100.0	100.0	100.0	100.0	100.0
Increase rate of prod. factors	44.8	52.3	26.4	44.3	46.6
Labor input	21.0	32.5	9.6	21.9	25.2
Number of employee	12.9	29.3	1.7	23.8	21.0
Working hours	2.4	−5.3	−0.4	−4.3	−6.3
Change in age/gender	1.6	−2.5	2.1	0.6	−1.7
Education	3.9	10.3	6.2	1.8	12.2
Others	0.2	0.8	0.0	0.0	0.0
Capital input	23.8	19.8	16.8	22.5	21.4
Residuals	55.2	47.8	73.6	55.7	53.4
Technological progress	22.4	29.8	32.1	13.9	33.2
Resources allocation	10.8	7.5	20.2	16.1	5.0
Economy of scale	22.0	10.5	21.3	25.7	15.1

E. F. Denison and T. W. Schultz, Economic Growth and Its Sources, in H. Patric and H. Rosovsky edt. Asian's New Giant — How the Japanese Economy Works (The Brooking Institution, Washington DC, 1976) 98—99.

2.4 Competitiveness

2.4.1 Decrease in TFP and Consequent GDP Decline

Table 1 Trends in Growth Rates of GDP and TFP in Japan, the US, Germany and SG *(1960 -2001)* **% p.a.**

	1960 - 1973	1975 - 1985	1985 - 1990	1990 - 1995	1995 - 2001
Japan	9.7 (6.2) [63.9]	2.2 (1.4) [63.6]	3.4 (2.8) [82.4]	2.0 (-0.3) [-15.0]	1.8 (0.2) [11.1]
USA	3.8 (1.5) [39.5]	3.4 (1.0) [29.4]	3.2 (0.9) [28.1]	2.4 (0.9) [37.5]	3.9 (1.5) [38.5]
Germany	4.6 (2.8) [60.9]	3.8 (1.2) [31.6]	5.2 (1.7) [32.7]	1.5 (1.1) [73.7]	1.1 (0.7) [63.6]
Singapore		7.1 (-0.2) [-2.1]	8.1 (3.8) [46.5]	8.2 (2.3) [28.0]	

a Figures indicate GDP growth rate, while figures in parentheses indicate TFP growth rate and those in square bracket indicate TFP contribution ratio.

Sources：1960-1973：OECD Economic Studies (1988). 1975-2001：European Competitiveness Report (2001) Total Factor Productivity Growth in Singapore (1997)..

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

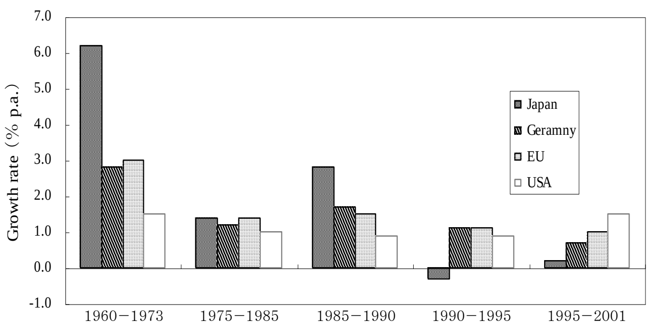


Fig. 2-1. Trends in TFP Growth Rate in Japan, the US and Germany *(1960-2001).*

a Germany in 1960-1990 is represented by FRG, EU in 1960-1973 indicates the average in FRG, France and the UK.

Sources：1960-1973：OECD Economic Studies (1988). 1975-2001：European Competitiveness Report (2001).

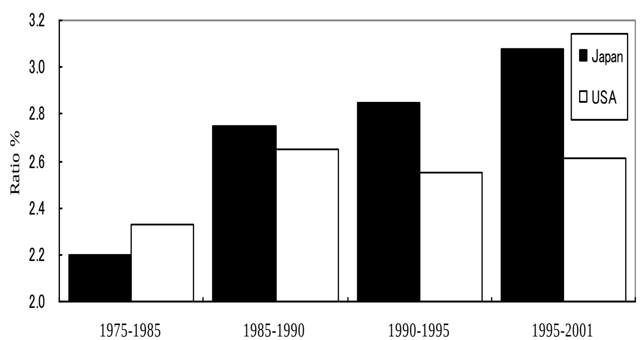


Fig. 2-2. Trends in R&D Intensity in Japan and the US *(1975-2001).*

Source: White Paper on Japan's Science and Technology (annual issue).

TFP: Total Factor Productivity (proxy of innovation)

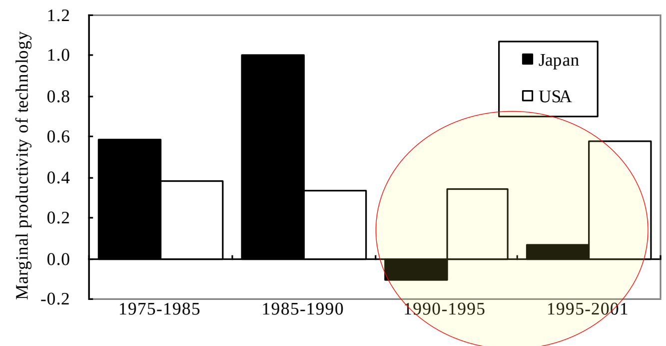


Fig. 2-3. Trends in Marginal Productivity of Technology in Japan and the US*(1960-2001).*

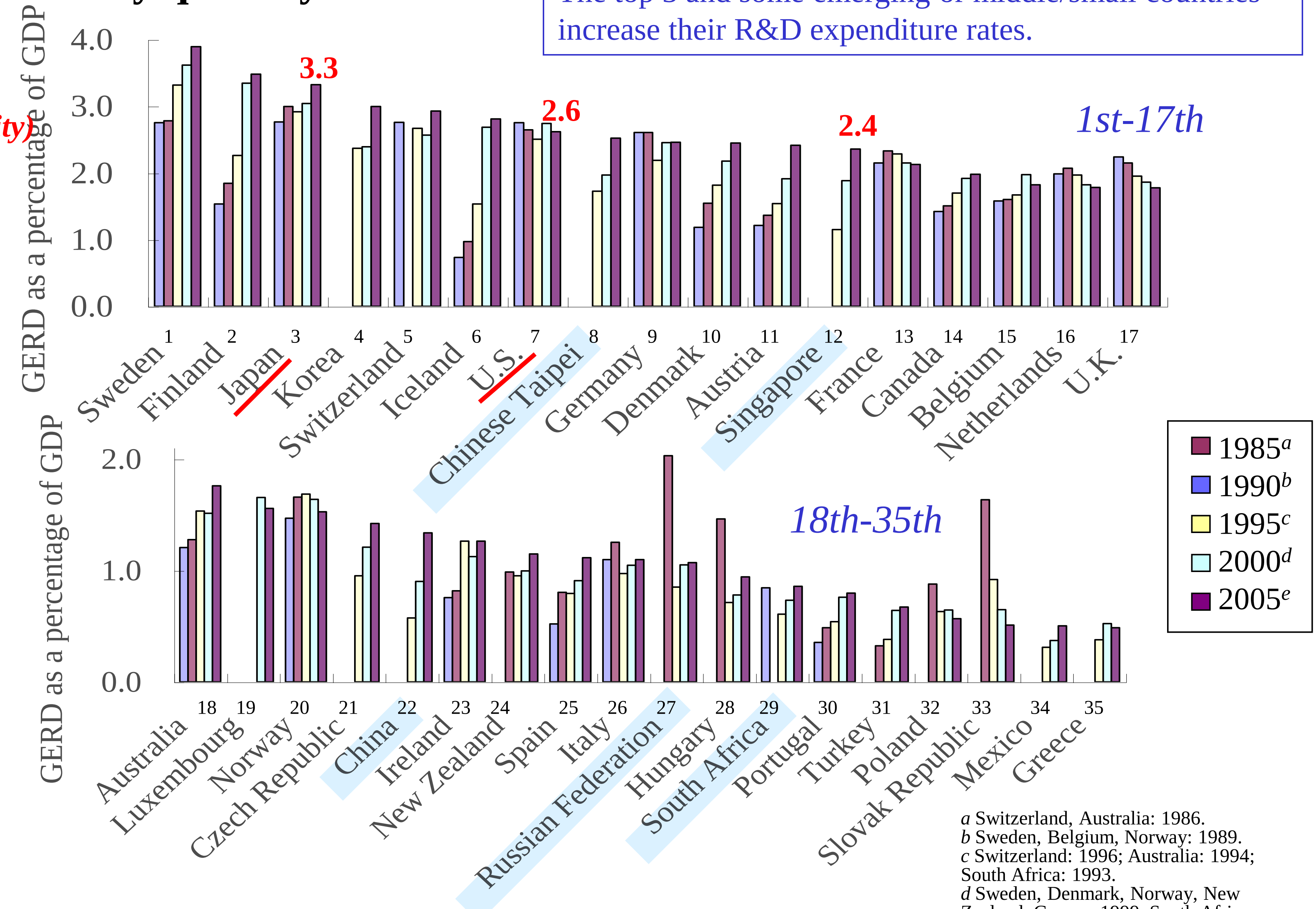
a Marginal productivity of technology = Growth rate of TFP/R&D intensity.

Sources：European Competitiveness Report (2001). White Paper on Japan's Science and Technology (annual issues).

R&D Efforts by quantity

The top 3 and some emerging or middle/small countries increase their R&D expenditure rates.

R / V
(R&D intensity)



Trends in Gross Domestic Expenditure on R&D (GERD) in 30 OECD members and 5 non-members *(1985-2005).*

a Switzerland, Australia: 1986.
b Sweden, Belgium, Norway: 1989.
c Switzerland: 1996; Australia: 1994; South Africa: 1993.
d Sweden, Denmark, Norway, New Zealand, Greece: 1999; South Africa: 2001.
e Switzerland, Netherlands, Australia, Italy, South Africa, Turkey: 2004; New Zealand: 2003

2.4.2 Sources of TFP Decrease

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

R&D intensity increased significantly

Dramatic decline in marginal productivity of technology (MPT)

2.4.3 Sources of MPT Decline: Mis-option of development trajectory

$$\textbf{MPT} = \frac{\partial V}{\partial T} = aV\left(1 - \frac{1}{FD}\right)$$

Industrial society	→	Information society
MT		IT
Productivity (*V*)		Functionality (*FD*)

(1) Features Differences between Manufacturing Technology and IT

(2) Inefficiency in IT Innovation and Its Utilization

(3) Structure of System Conflict in an Information Society

(4) System Conflict and Subsequent FD Decline

(5) Dramatic Decline in MPT and Consequent Innovation Decrease

⇨ **Vicious cycle between MPT, TFP and *V*** resulting in loosing economic competitiveness

(1) Features Differences between Manufacturing Technology and IT

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

Table 2 Comparison of Features between Manufacturing Technology and IT

	1980s	1990s
Paradigm	**Industrial society** (Materialization economy)	**Information society** (De-materializing (digital) economy)
Core technology	**Manufacturing technology**	**IT**
1. Optimization	Within firms/Organizations	In the market
2. Key features formation process	Provided by suppliers	Formed through the interacting with institutions
3. Fundamental nature	As given	Self-propagating
4. Actors forming features	Individual firms/organizations	Institutions as a whole

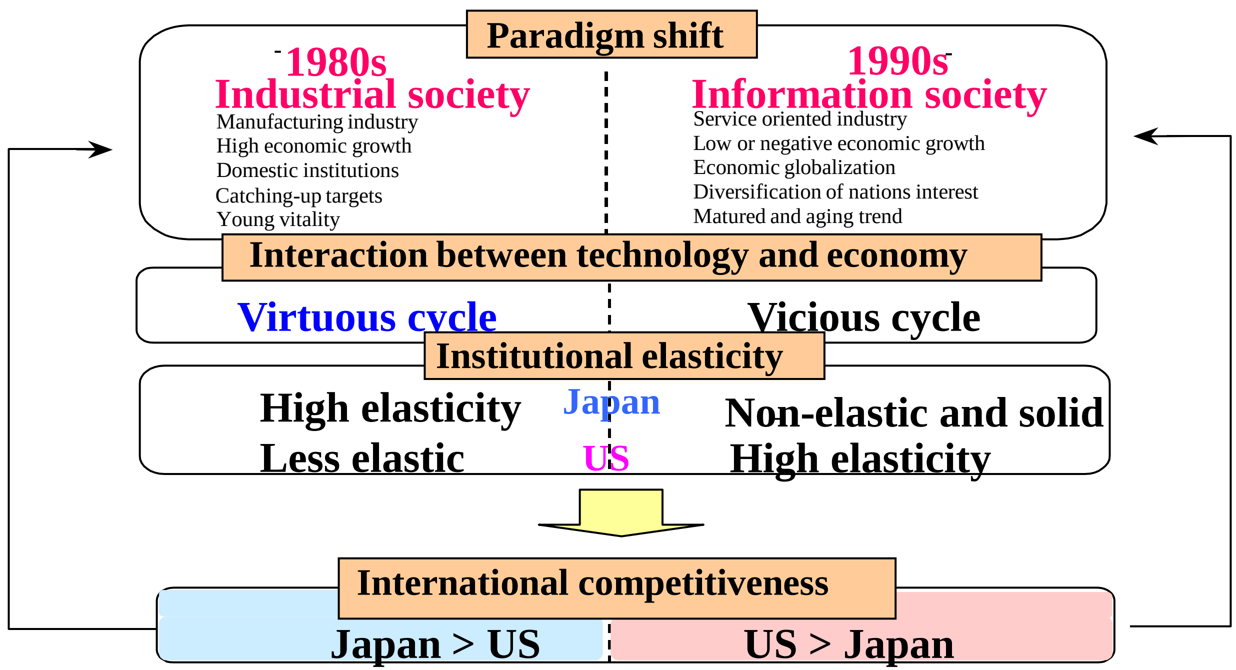


Fig. 3. Scheme Leading Japan to Lose Its Institutional Elasticity.

Source: Watanabe et al. (2003).

(2) Inefficiency in IT Innovation and Its Utilization

Consequently, Japan revealed its inefficiency in its IT innovation and utilization.

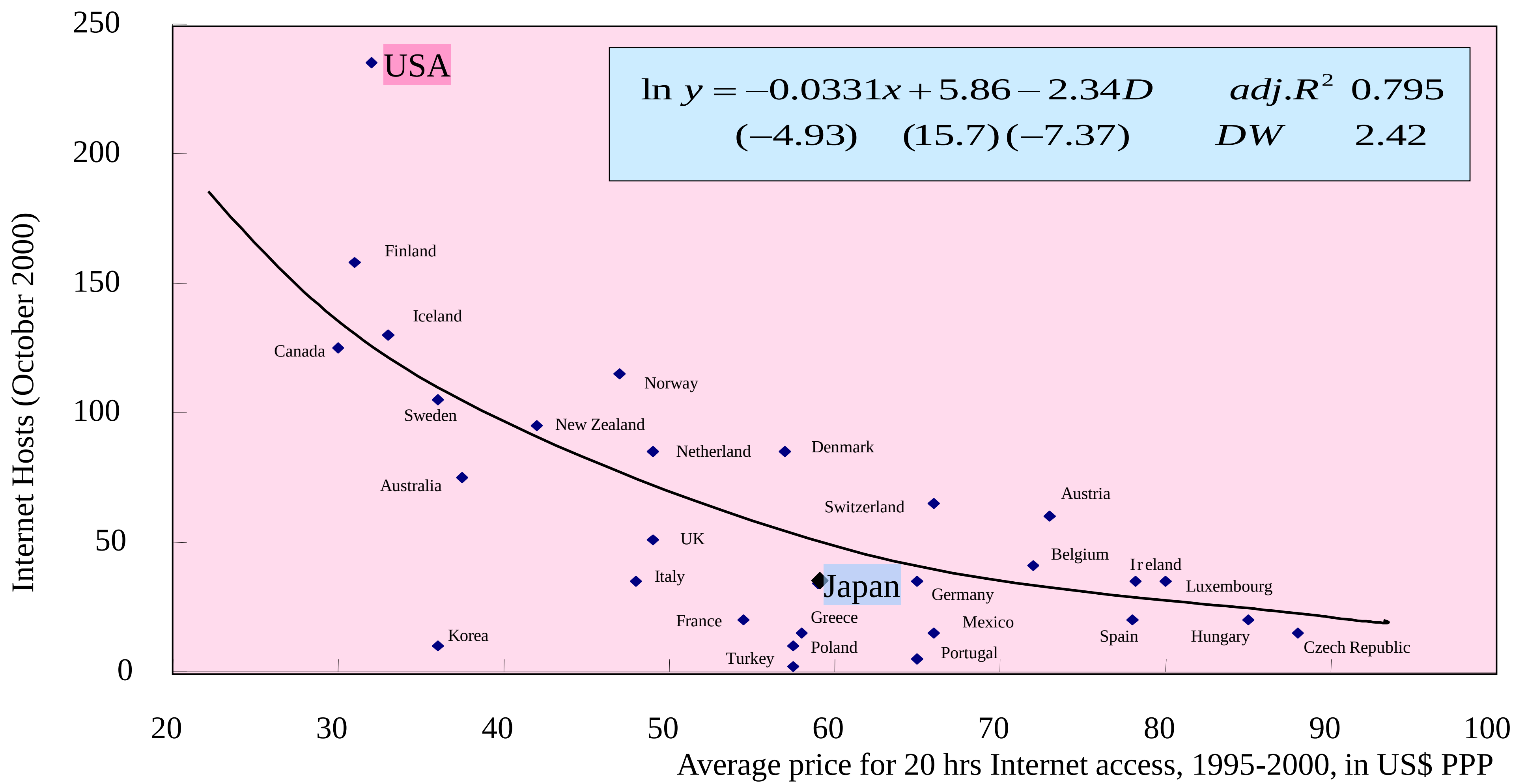


Fig. 4. Access Costs and Uptake of the Internet.

[a] Korea, Czech Republic, Hungary, Mexico, and Poland were excluded from the analysis since these countries joined OECD relatively recently.
[b] D in regression indicates dummy variables: Turkey, Greece, Portugal = 1, other countries = 0.
[c] Figures in parentheses indicate t-value.

Sources: Reproduced from OECD's report on the OECD Growth Project (OECD (2001), Kondo and Watanabe (2001)).

(3) The Networked Readiness Index 2012

1 Sweden 5.94
2 Singapore 5.86
3 Finland 5.81
4 Denmark 5.70
5 Switzerland 5.61
6 Netherlands 5.60
7 Norway 5.59
8 United States 5.56
9 Canada 5.51
10 United Kingdom 5.50
11 Taiwan, China 5.48
12 Korea, Rep. 5.47
13 Hong Kong SAR 5.46
14 New Zealand 5.36
15 Iceland 5.33
16 Germany 5.32
17 Australia 5.29
18 Japan 5.25
19 Austria 5.25
20 Israel 5.24
21 Luxembourg 5.22
22 Belgium 5.13
23 France 5.12
24 Estonia 5.09
25 Ireland 5.02

26 Malta 4.91
27 Bahrain 4.90
28 Qatar 4.81
29 Malaysia 4.80
30 United Arab Emirates 4.77
31 Lithuania 4.66
32 Cyprus 4.66
33 Portugal 4.63
34 Saudi Arabia 4.62
35 Barbados 4.61
36 Puerto Rico 4.59
37 Slovenia 4.58
38 Spain 4.54
39 Chile 4.44
40 Oman 4.35
41 Latvia 4.35
42 Czech Republic 4.33
43 Hungary 4.30
44 Uruguay 4.28
45 Croatia 4.22
46 Montenegro 4.22
47 Jordan 4.17
48 Italy 4.17
49 Poland 4.16
50 Tunisia 4.12

51 China 4.11
52 Turkey 4.07
53 Mauritius 4.06
54 Brunei Darussalam 4.04
55 Kazakhstan 4.03
56 Russian Federation 4.02
57 Panama 4.01
58 Costa Rica 4.00
59 Greece 3.99
60 Trinidad and Tobago 3.98
61 Azerbaijan 3.95
62 Kuwait 3.95
63 Mongolia 3.95
64 Slovak Republic 3.94
65 Brazil 3.92
66 Macedonia, FYR 3.91
67 Romania 3.90
68 Albania 3.89
69 India 3.89
70 Bulgaria 3.89
71 Sri Lanka 3.88
72 South Africa 3.87
73 Colombia 3.87
74 Jamaica 3.86
75 Ukraine 3.85

76 Mexico 3.82
77 Thailand 3.78
78 Moldova 3.78
79 Egypt 3.77
80 Indonesia 3.75
81 Cape Verde 3.71
82 Rwanda 3.70
83 Vietnam 3.70
84 Bosnia and Herzegovina 3.65
85 Serbia 3.64
86 Philippines 3.64
87 Dominican Republic 3.60
88 Georgia 3.60
89 Botswana 3.58
90 Guyana 3.58
91 Morocco 3.56
92 Argentina 3.52
93 Kenya 3.51
94 Armenia 3.49
95 Lebanon 3.49
96 Ecuador 3.46
97 Ghana 3.44
98 Guatemala 3.43
99 Honduras 3.43
100 Senegal 3.42

Source: The Global Information Technology Report 2012 (World Economic Forum, 2012).

The Network Readiness Index; **Environment** (Political and regulatory environment, Business and innovation environment), **Readiness** (Infrastructure and digital content, Affordability), **Usage** (Individual usage, Business usage, Government usage), **Impact** (Economic impact, Social impact)

(4) Structure of System Conflict in an Information Society

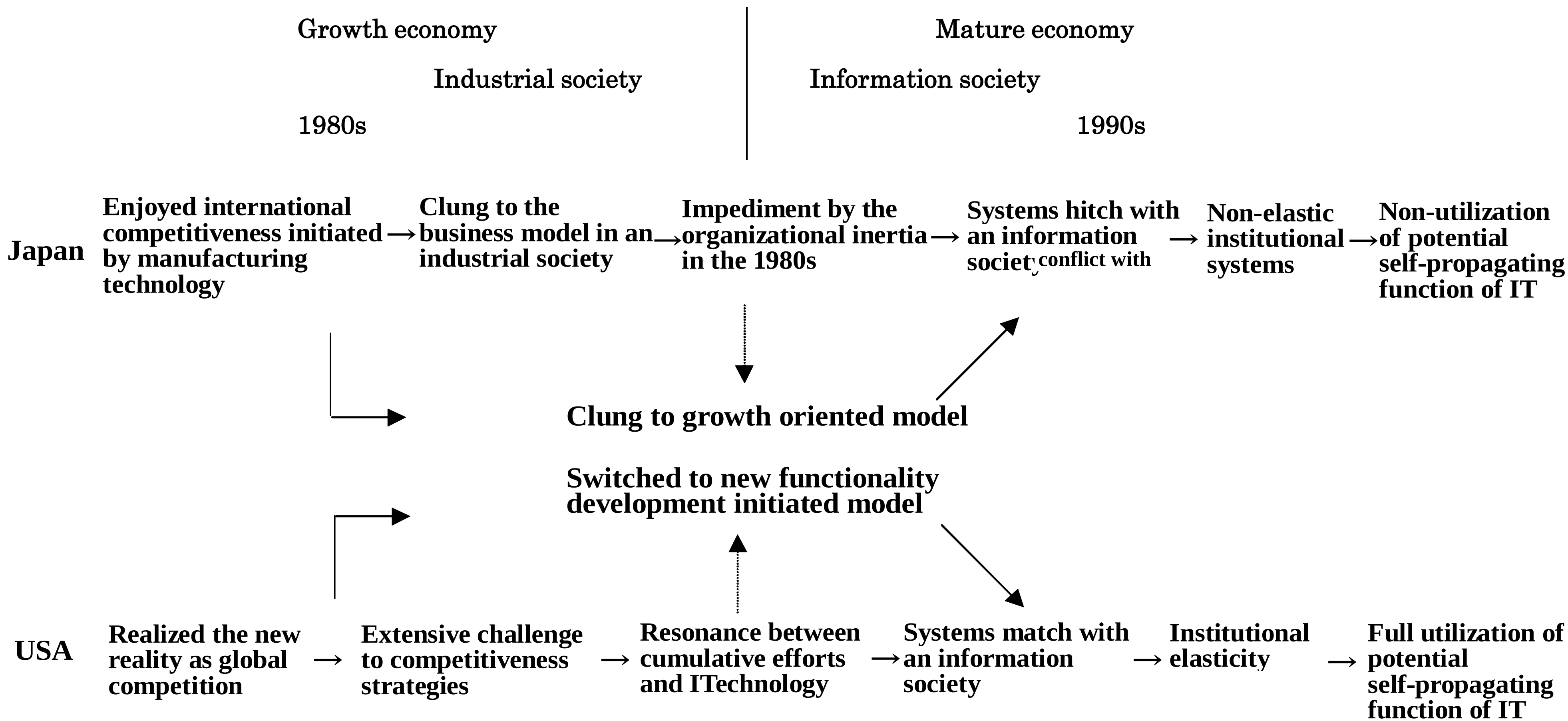


Fig. 5. Development Trajectories and Adaptability to an Information Society in Japan and the US.

(5) System Conflict and Subsequent FD Decline

1. **System conflict** led to an **institutional less-elasticity** in an information society resulting in a **dramatic decrease in Japan's FD**.
2. FD decrease led to a **MPT decline**.

FD: Ability to improve performance of production processes, goods and services by means of innovation

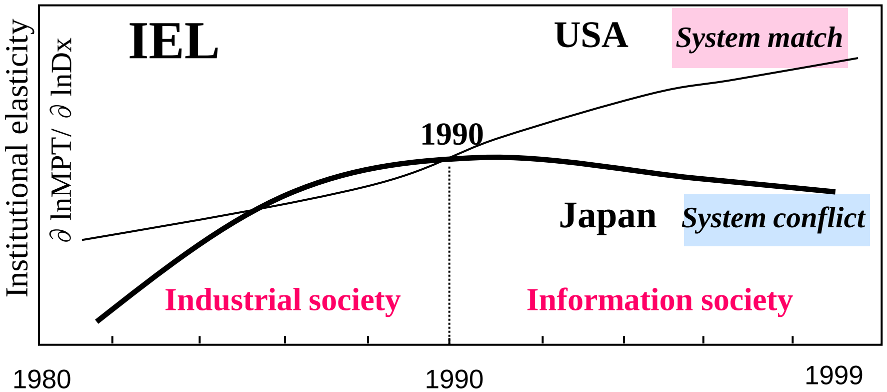


Fig. 6-1. Institutional Elasticity of Manufacturing Technology
- Elasticity of the Shift to an Information Society to Marginal Productivity of Technology *(1980-1999) - Index :1990 =100.*

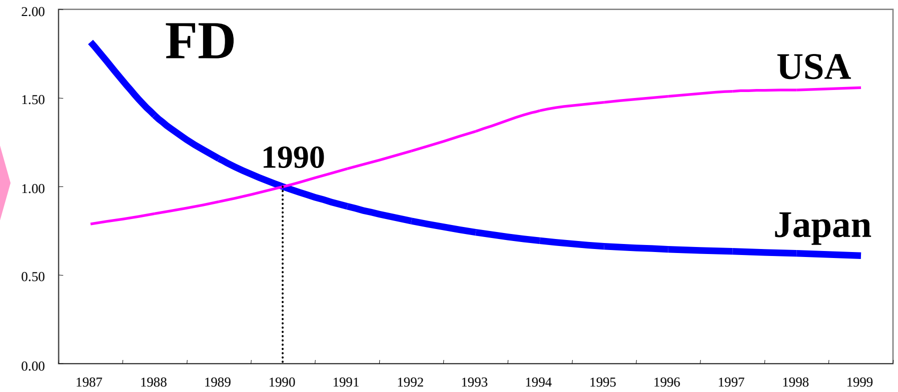


Fig. 6-2. Functionality Development *(1987-1999) - Index: 1990 =1.*

$$V = F(L, K, T)$$

$$\ln V = A + \alpha \ln L + \beta \ln K + \gamma_1 \ln T + \gamma_2 D_x \ln T$$

where A: scale factor; α, β, γ_1, and γ_2: elasticities; D_x: coefficient dummy variable representing the trend in shifting from an industrial society to an information society ($D_x = \frac{1}{1+e^{-at-b}}$, a, b: coefficients).

$$MPT = \frac{\partial V}{\partial T} = \frac{\partial \ln V}{\partial \ln T} \cdot \frac{V}{T} = (\gamma_1 + \gamma_2 D_x) \cdot \frac{V}{T}$$

$$MPT = F(V, T, D_x)$$

$$\ln MPT = B + \alpha_1 \ln V + \alpha_2 \ln T + \alpha_3 \ln D_x + \beta_1 \ln V \cdot \ln T + \beta_2 \ln V \ln D_x + \beta_3 \ln T \ln D_x$$

where B: scale factor; α_i and β_i (i = 1~3): elasticities.

$$IEL \text{ (Institutional Elasticity) } = \frac{\partial \ln MPT}{\partial \ln D_x}$$

$$MPT = aV\left(1 - \frac{1}{FD}\right), \quad FD = \frac{1}{1 - \left(MPT/aV\right)}$$

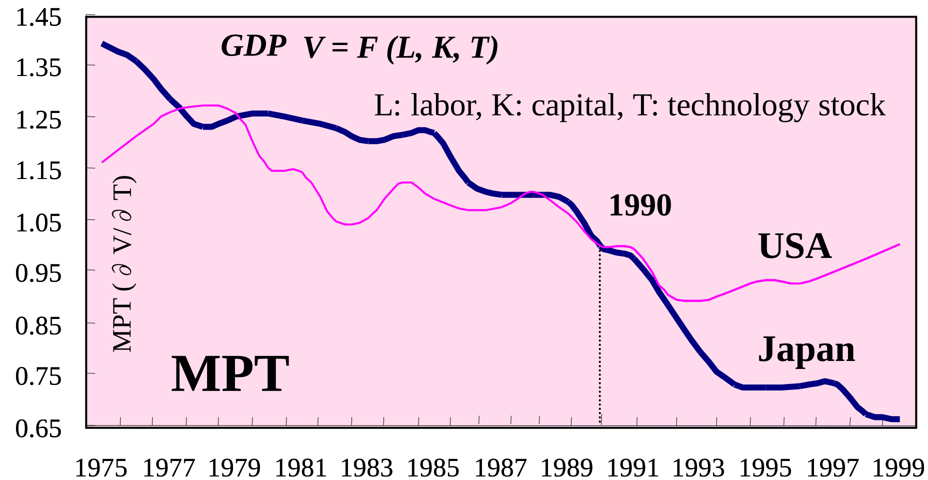


Fig. 6-3. Marginal Productivity of Manufacturing Technology
(1975-1999) - Index: 1990 =1.

(6) Dramatic Decline in MPT and Consequent Innovation Decrease

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

MPT: Marginal Productivity of Technology

TFP: Total Factor Productivity

(i) Dramatic Decline in Marginal Productivity of Technology

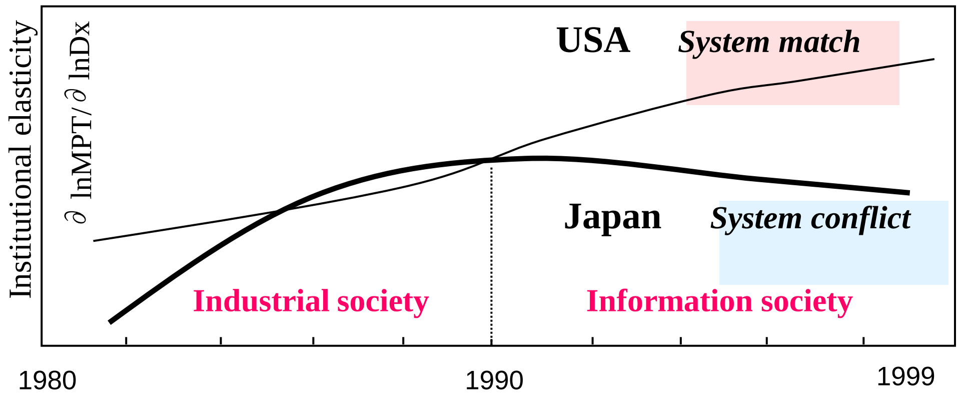


Fig. 6-1. Institutional Elasticity of Manufacturing Technology
- Elasticity of the Shift to an Information Society to Marginal Productivity of Technology *(1980-1999) - Index :1990 =100.*

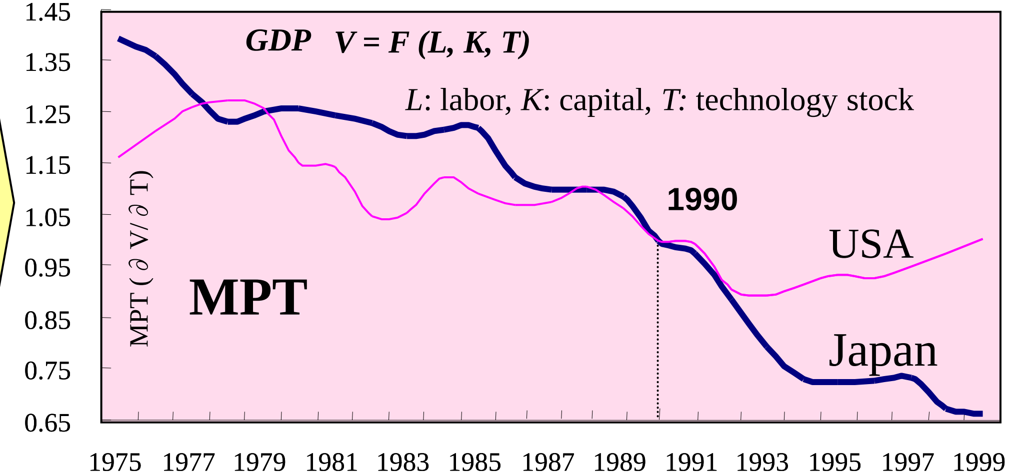


Fig. 6-3. Marginal Productivity of Manufacturing Technology
(1975-1999) - Index: 1990 =1.

(ii) Consequent Decrease in Innovation

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

Innovation to GDP growth

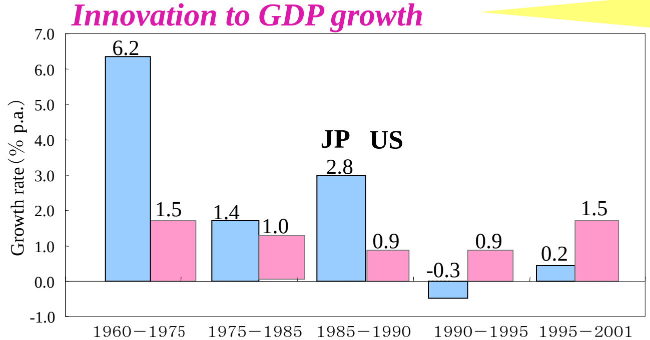


Fig. 6-4-1. TFP Growth Rate *(1960-2001).*

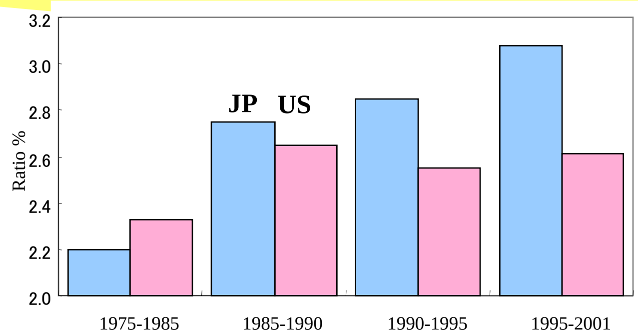


Fig. 6--4-2. R&D Intensity *(1975-2001).*

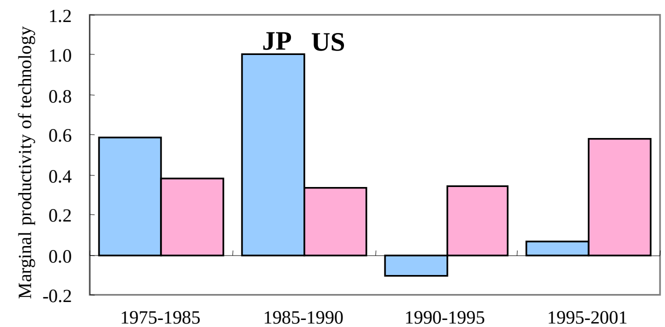


Fig. 6-4-3. Marginal Productivity of Technology
(1960-2001).

21

(7) Technology Substitution for Constraints

$$V = F(L, K) \quad \Rightarrow \quad Y = F(X, T)$$

$$GC = C(V, p_l, p_k) \quad \Rightarrow \quad GC = C(Y, p_x, p_t)$$

X*: *L, K, M, E

$p_x : p_l, p_k, p_m, p_e$

Under profit maximum conditions

Elasticity of substitution

$$\sigma = \frac{\left(\dfrac{d(T/X)}{T/X}\right)}{\left(\dfrac{d(P_x/P_t)}{P_x/P_t}\right)} = \frac{d \ln \frac{T}{X}}{d \ln \frac{P_x}{P_t}} = \frac{d \ln \frac{T}{X}}{d \ln \frac{\partial Y / \partial X}{\partial Y / \partial T}}$$

$$\ln \frac{T}{X} = c + \sigma \ln \frac{P_x}{P_t} = c + \sigma \ln \frac{\frac{\partial Y}{\partial X}}{\frac{\partial Y}{\partial T}}$$

c: constant term.

Elasticity of *T* substitution for *X*

$$\sigma = \frac{\ln \frac{T}{X} - c}{\ln \frac{\partial Y}{\partial X} - \ln \frac{\partial Y}{\partial T}}$$

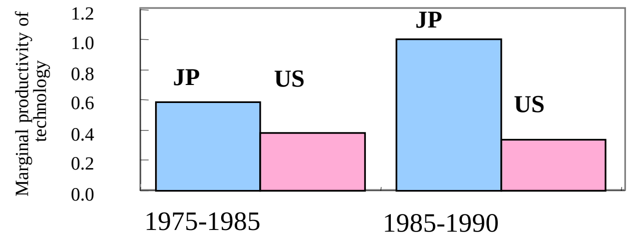
V, Y: Quantity of output (e.g., GDP sales, volume of PC production)
L: Labor (e.g., employees, workers)
K: Capital stock (e.g., machines, robots)

M: Materials
E: Energy
T: Technology knowledge stock

P_l: Prices of labor
P_k: Prices of capital
P_m: Prices of materials
P_e: Prices of energy
P_t: Prices of technology

(8) Substitution Mechanism

Japan's high level of Marginal Productivity of Technology: MPT



1960s Labor	Labor saving, automation
1970s Energy	Energy saving, oil-alternative
1980s Trade	High-technology

$$Y = F(X, T) \Rightarrow \frac{\Delta Y}{Y} = \sum\left(\frac{\partial Y}{\partial X}\cdot\frac{X}{Y}\right)\frac{\Delta X}{X} + \frac{\partial Y}{\partial T}\cdot\frac{R}{Y}$$

Production

Labor
Capital
Energy
Materials

Technology stock

Sustain Y

Diffusion trajectory $\frac{\partial Y}{\partial T} = aY\left(1-\frac{1}{FD}\right)$

MPT $\frac{\partial Y}{\partial T}$

IRR (Internal Rate of Return to R&D) $\uparrow \rightarrow R\uparrow \rightarrow T\uparrow \rightarrow T/X\uparrow$

Elasticity of technology substitution (ETC) for X

c: coefficient

$$\left[\ln\frac{\partial Y}{\partial X} - \ln\frac{\partial Y}{\partial T}\right]\downarrow \longrightarrow \frac{\ln\frac{T}{X} - c}{\ln\frac{\partial Y}{\partial X} - \ln\frac{\partial Y}{\partial T}} = \sigma_{TX} \rightarrow \frac{T}{X}\uparrow$$

Technology productivity $\frac{Y}{T}\uparrow$

Y/X increase

$$\frac{T}{X}\cdot\frac{Y}{T} = \frac{Y}{X}\uparrow$$

T substitutes for X

Constraint of X supply

Y/X increase

Induce R (R&D investment)

External crises

Abundant curiosity, assimilation proficiency, and thoroughness in learning and absorption

Xenophobia and Uncertainty avoidance

Growth dependent trajectory in an industrial society

Japan constructed a sophisticated co-evolutionary dynamism between innovation and institutional systems by transforming external crises into a springboard for new innovation.

This transformation ability can largely be attributed to Japan's unique features of the nation such as having

(i) a strong motivation for overcoming fear based on xenophobia and uncertainty avoidance,
(ii) while abundant curiosity, assimilation proficiency, and thoroughness in learning and absorption.

Such a unique institutional system led to a high level of MPT leveraging a conspicuously high level of

(i) elasticity of technology substitution for energy leading to a shift from energy to technology (T/E), and
(ii) increased technology productivity (Y/T) which generated
(iii) a notable energy productivity as a multiplier effect of these accomplishments ($\frac{Y}{E} = \frac{T}{E}\cdot\frac{Y}{T}$).

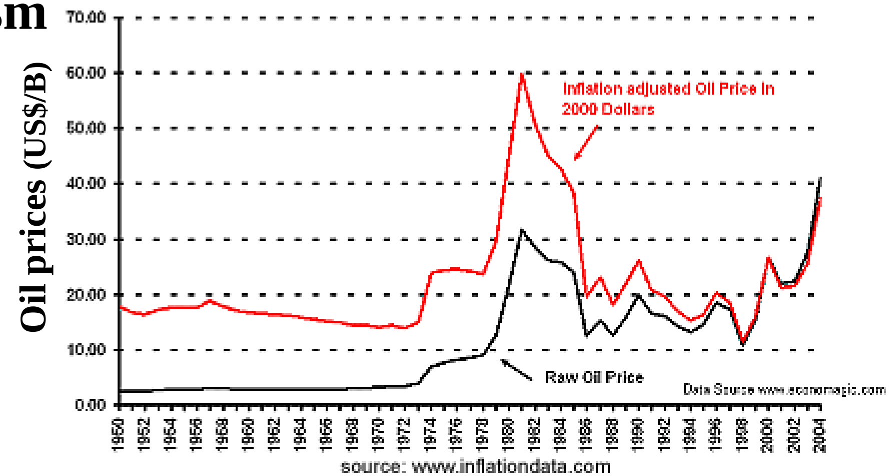
leading to sophisticated substitution mechanism.

Fig. 7. Japan's System in Transforming Crises into a Springboard for New Innovation.

(9) Technology Substitution for Energy

Japan's explicit co-evolutionary dynamism between innovation and institutional systems by transforming external crises into a springboard for new innovation was typically demonstrated by technology substitution for energy in the 1970s.

1) Dynamism



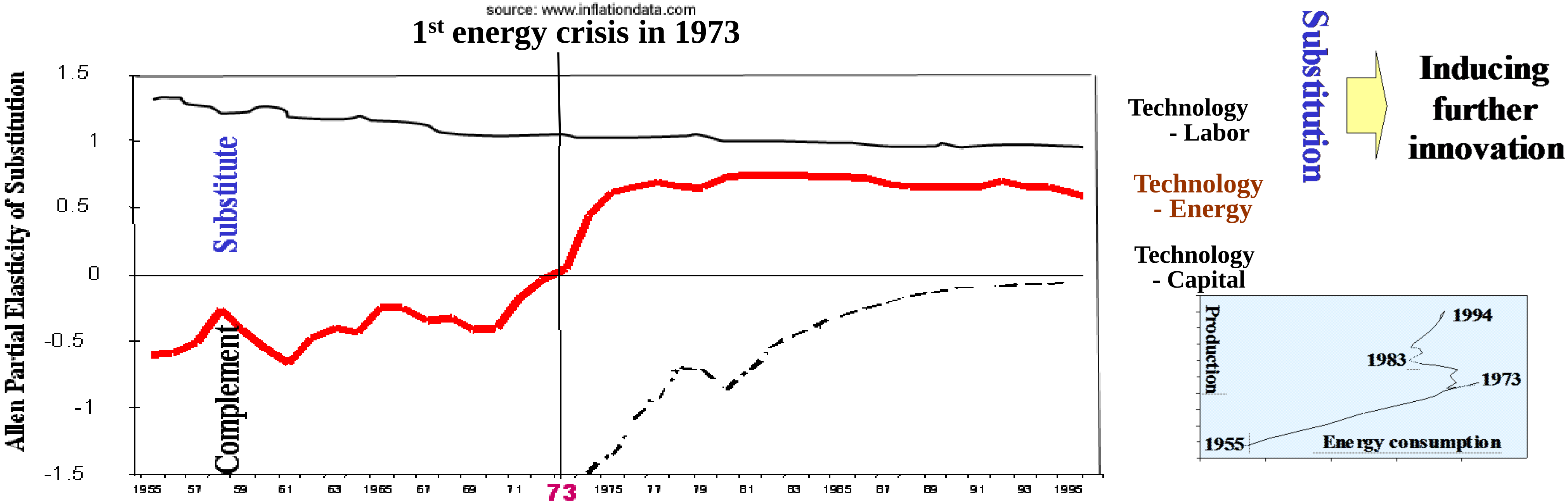


Fig. 8. Trends in Technology Substitution for Production Factors in the Japanese Manufacturing Industry
(1955-1997) - Allen Partial Elasticity of Substitution. Source: Watanabe (1999).

2) Conspicuous energy efficiency

1. Japan accomplished the highest GDP growth in a decade after the 2nd energy crisis in 1979.
2. This can be attributed to its conspicuous energy efficiency enabled by technology substitution for energy.
3. Consequently, Japan demonstrates the world's highest energy efficiency.

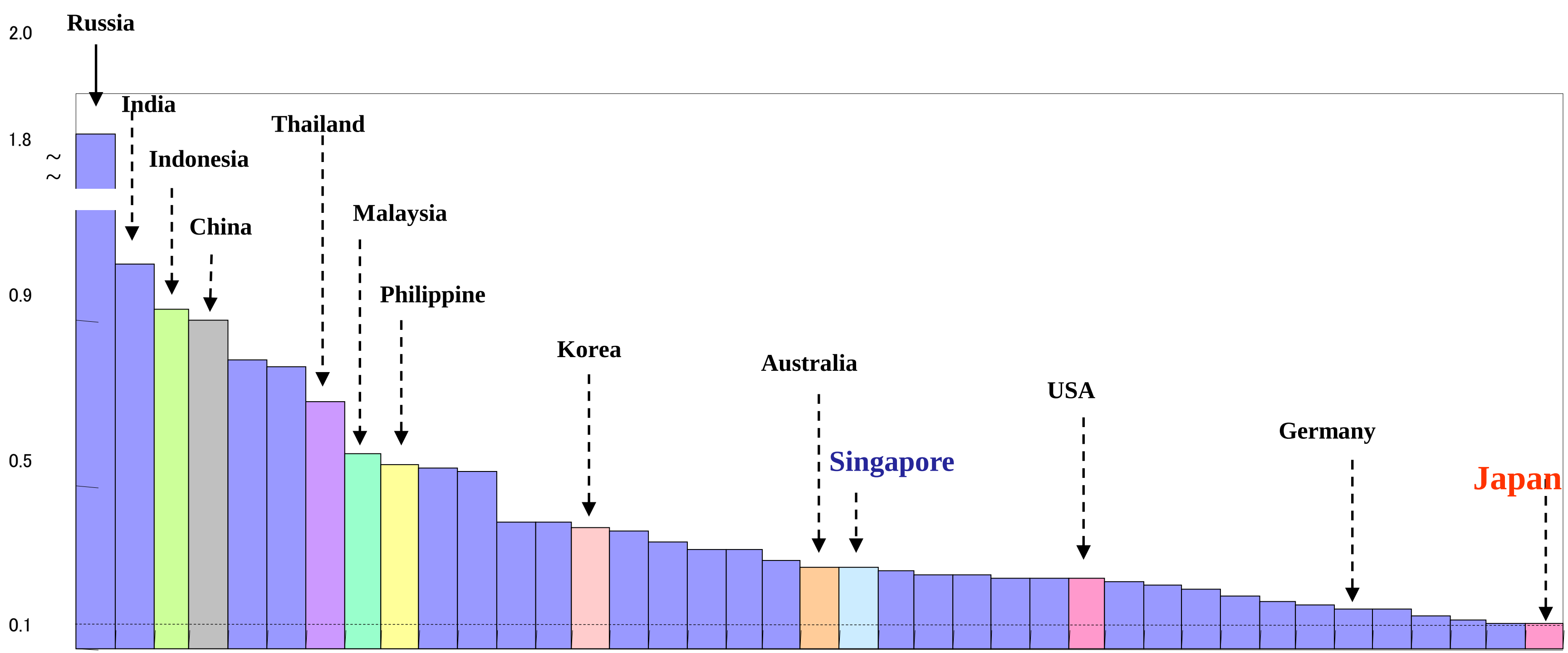
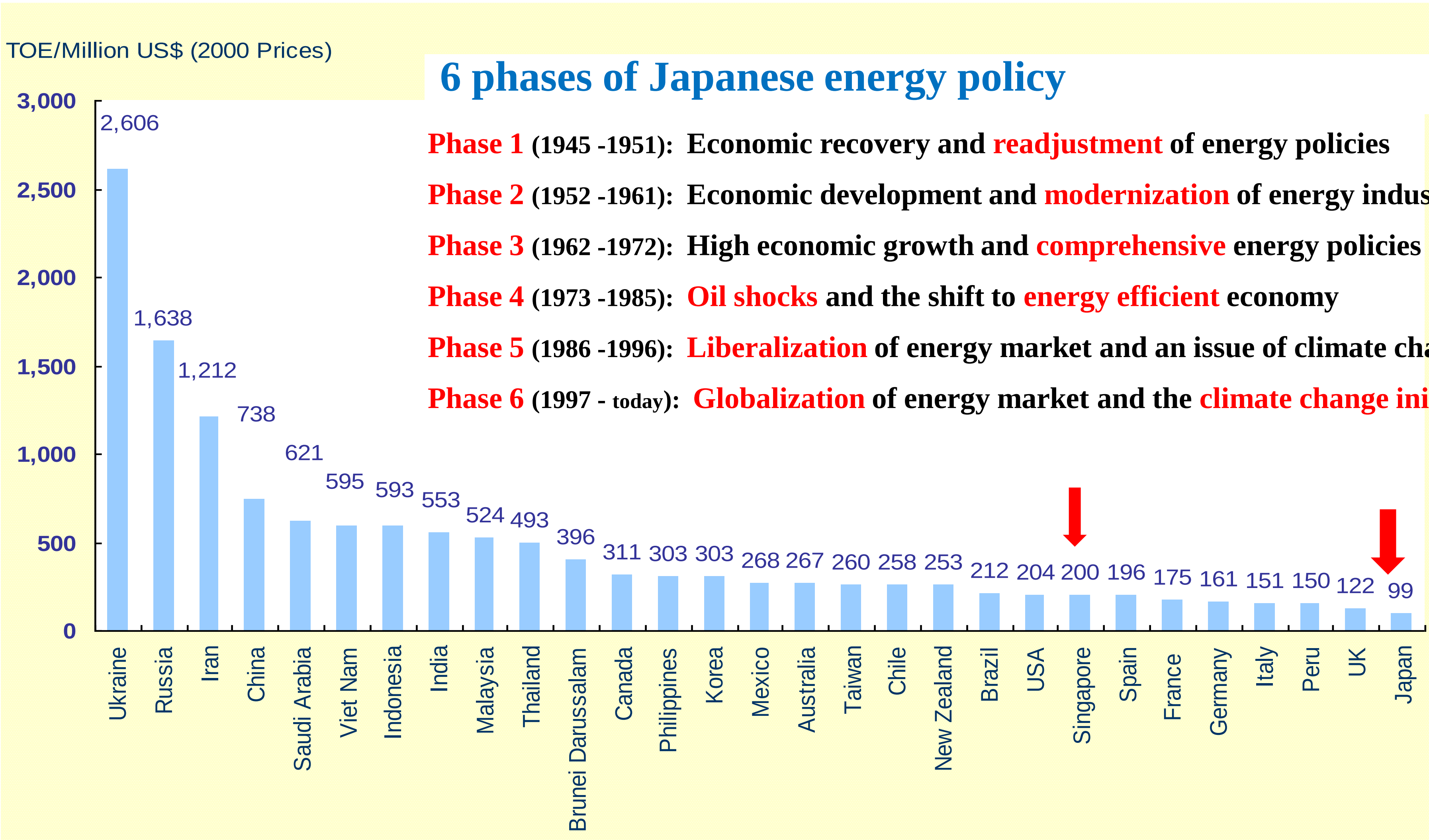


Fig. 9. Energy Consumption per GDP in 40 Countries ***(2004).***

3) Conspicuous energy efficiency *(2007)*
- Japan by far leads the world in energy efficiency



6 phases of Japanese energy policy

Phase 1 (1945 -1951): **Economic recovery and readjustment of energy policies**

Phase 2 (1952 -1961): **Economic development and modernization of energy industry**

Phase 3 (1962 -1972): **High economic growth and comprehensive energy policies**

Phase 4 (1973 -1985): **Oil shocks and the shift to energy efficient economy**

Phase 5 (1986 -1996): **Liberalization of energy market and an issue of climate change**

Phase 6 (1997 - today): **Globalization of energy market and the climate change initiative**

Sources: GDP: World Bank (2009), World Development Indicators, and Total Primary Energy: IEA(2009), Energy Balances of OECD and Non-OECD Countries

(10) Decisive role of MPT in Inducing Co-evolution between Innovation and Institutional Systems

$$\therefore \frac{\Delta TFP}{TFP} = F\left(\frac{\partial V}{\partial T}, \frac{R}{V}\right) = \frac{\partial V}{\partial T} \times \frac{R}{V} \qquad (18)$$

MPT **R&D intensity** *MPT: Marginal Productivity of Technology*

13 Oct Rate of return to R&D investment

1. MPT plays a decisive role in inducing R&D leading to creation of technology knowledge stock (T) and its effective utilization.
2. T induces effective utilization of external resources in innovation (learning and spillover effects as well as indirect effect of R&D investment)
3. Thus, MPT represents a state of institutional systems with which co-evolutionary dynamism of innovation can be expected.

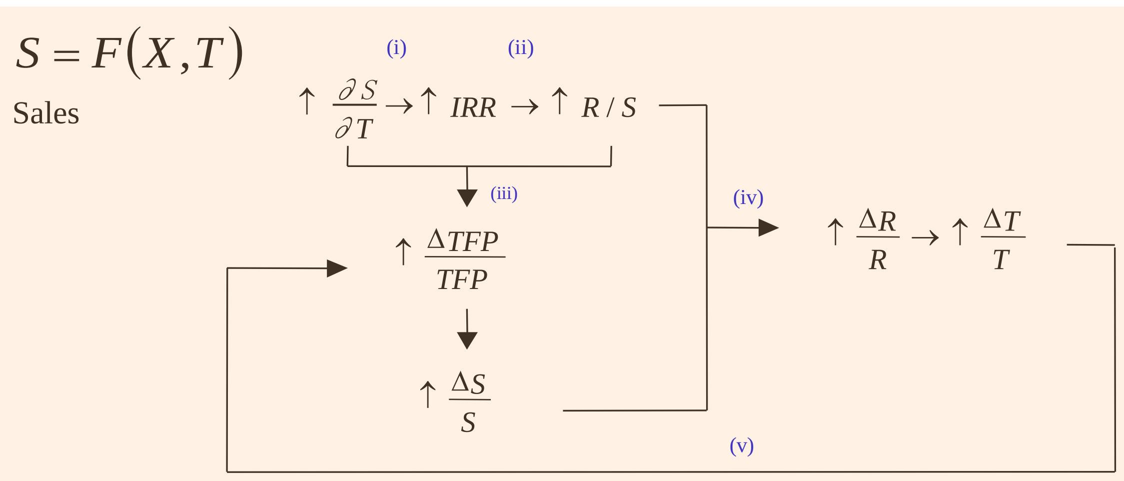


Fig. 10. Organic Cycle between MPT and R&D Intensity.

a $\frac{\partial S}{\partial T}$: marginal productivity of technology; IRR : internal rate of return to R&D investment;

R/S : R&D intensity; $\frac{\Delta TFP}{TFP}$: change rate of total factor productivity; $\frac{\Delta S}{S}$: change rate of sales;

$\frac{\Delta R}{R}$: change rate of R&D investment; and $\frac{\Delta T}{T}$: change rate of technology stock

(i) Increase in marginal productivity of technology (MPT) leads to increase in internal rate of return to R&D investment (IRR) as explicitly depicted by the following equation:

$$r \equiv IRR = \left[\sqrt{4m\frac{\partial S}{\partial T} + (1+m\rho)^2 - 4m\rho} - (1+m\rho)\right] \Big/ 2m \qquad (3)$$

(ii) As demonstrated by the preceding work (Watanabe and Wakabayashi, 1996) increase in IRR induces higher R&D intensity.

(iii) These increases in both MPT and R&D intensity result in increase in TFP as its increasing rate can be approximated by the product of these factors as follows:

$$\frac{\Delta TFP}{TFP} = \frac{\partial S}{\partial T} \cdot \frac{T}{S} \cdot \frac{\Delta T}{T} \approx \frac{\partial S}{\partial T} \cdot \frac{R}{S}$$

(iv) TFP increase contributes to increase in production which together with the foregoing increase in R&D intensity induces R&D investment as simply depicted as follows:.

$$\frac{\Delta R}{R} = \frac{\Delta (R/S)}{R/S} + \frac{\Delta S}{S} \qquad (4)$$

(v) Induced R&D investment contributes to increase in technology stock, which further accelerates TFP increase, thus a virtuous cycle between technology stock and production increase is expected.

(11) Firm's Technopreneurial Strategy in Enhancing MPT (Marginal Productivity of Technology)

Increase prices of technology

Increase production

$$\frac{\partial V}{\partial T} = \frac{p_t}{p_v} = aV\left(1 - \frac{1}{FD}\right)$$

Decrease prices of product

Increase functionality

a: Velocity of diffusion

FD: Functionality development

(Ability to improve performance of production processes, goods and services by means of innovation)

Learning exercise
Economy of scale

High-functional mobile phone is expensive than simple one.
Wages (prices of labor) university graduates are higher than high school graduates.

Substance of innovation
Function of innovation

2.5 Substance of Innovation

2.5.1 Innovation and Entrepreneurship

(1) Function of Innovation

Change in production, cost and demand functions depending on the stage of innovation as (i) Invention, (ii) Development, and (iii) Commercialization

(2)Substance of Innovation and Technology

1) Substance of innovation

Innovation incorporates three dimensional features as (i) Input, (ii) Process, and (iii) Impacts .

2) Substance of technology

Technology incorporates such unique nature as small in (i) non-simultaneous use, and (ii) exclusive use, while large in (iii) externality

(3) Inducing Factor of Innovation

Co-evolution between innovation and institutional systems plays a decisive role in inducing innovation.

(4)Prerequisite of Innovation

(i) Accumulation of information, (ii) Risk capital, and (iii) Entrepreneurship.

2.5.2 Explicit and Tacit Knowledge

(1) Composition of Knowledge

(i) Explicit knowledge

(ii) Tacit knowledge

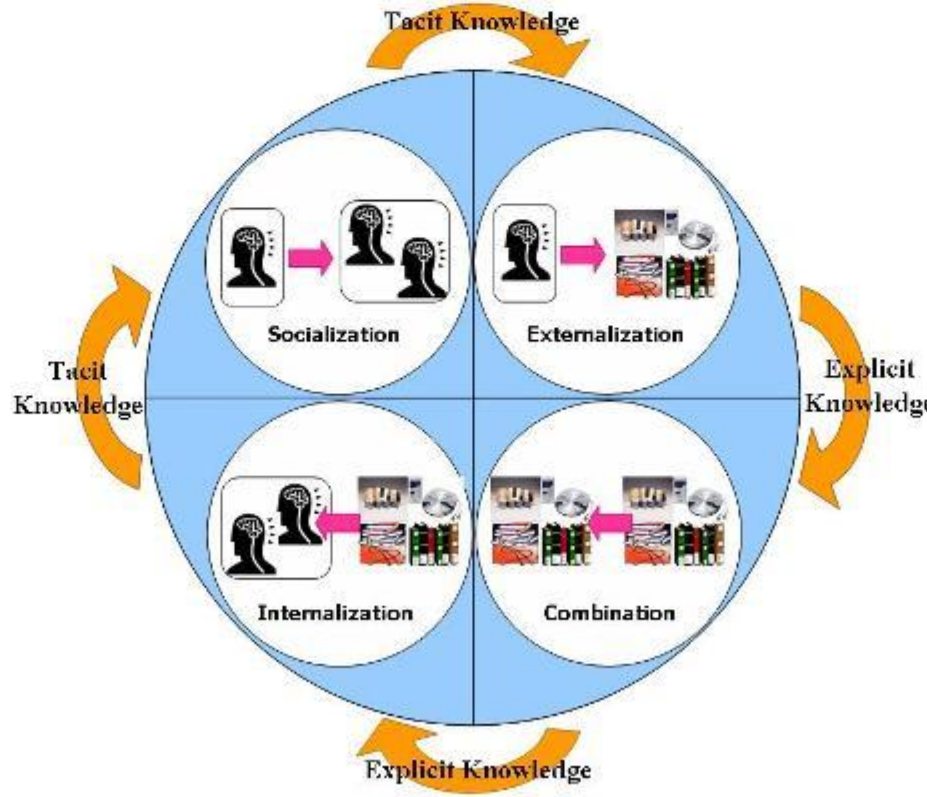
(2) Transforming Process of Tacit Knowledge to Explicit Knowledge (*SECI* model)

(i) Socialization,

(ii) Externalization,

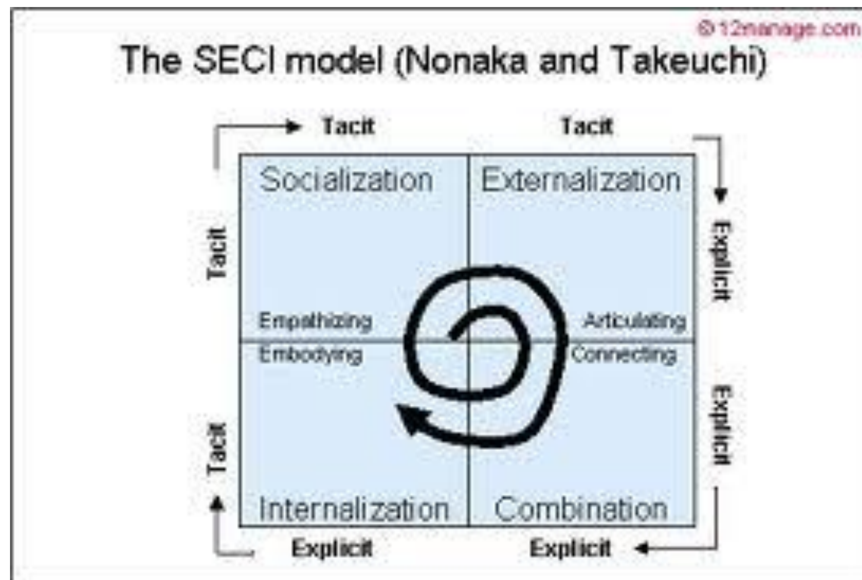
(iii) Combination,

(iv) Internalization



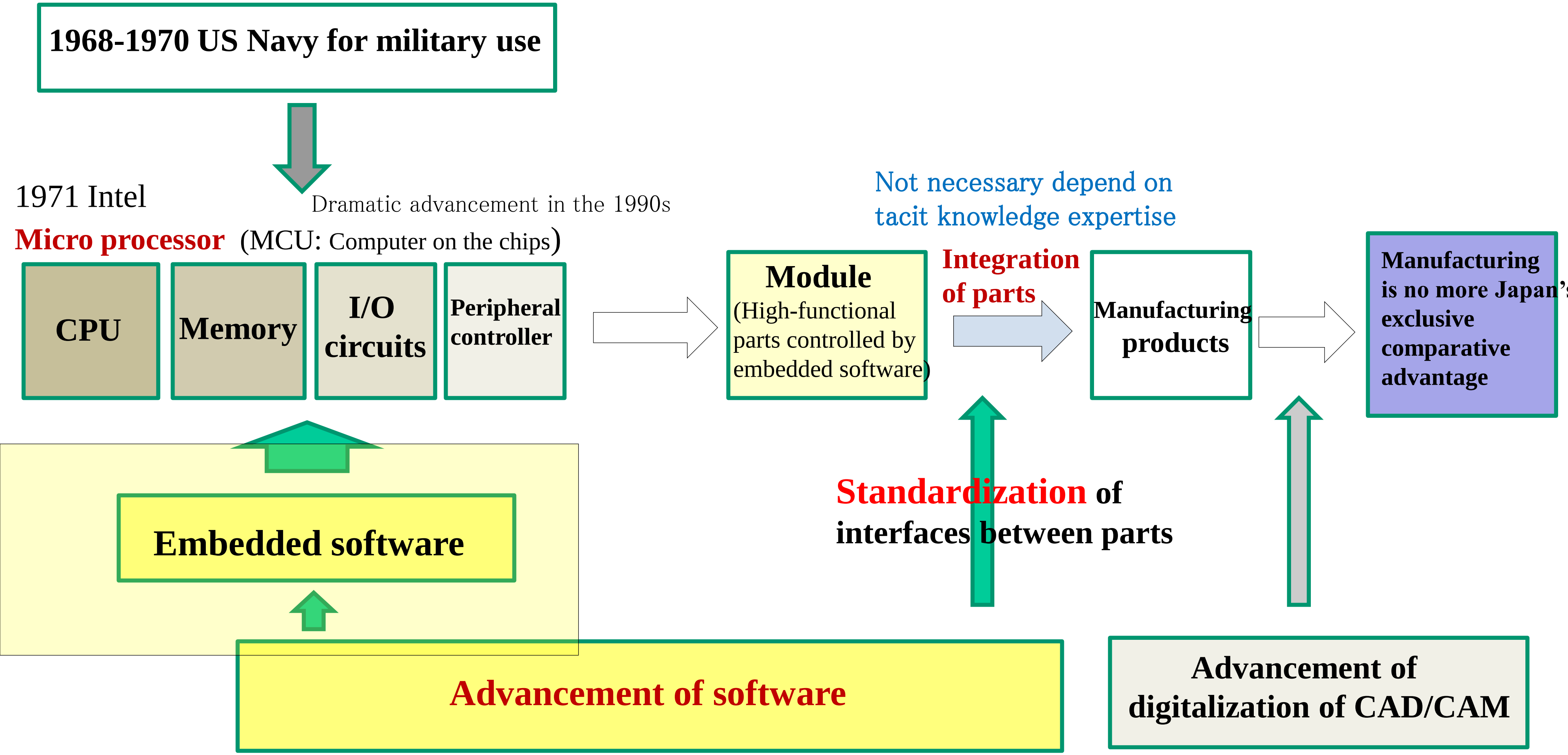
(3) Paradigm Shift to an Information Society and Its Impacts on Explicit and Tacit Knowledge Dynamism

(4) Digitalization of Manufacturing Knowhow



2.5.3 Digitalization of manufacturing

(1) Mechanism



(2) Bi-polarization of Technopreneurial Trajectory (Phase 2: *Early 2010s*)

IT driven business environment change

1.Digitalization of manufacturing process

No more Japan's indigenous knowhow

↓

Unable to disseminate
No substantial differences in quality

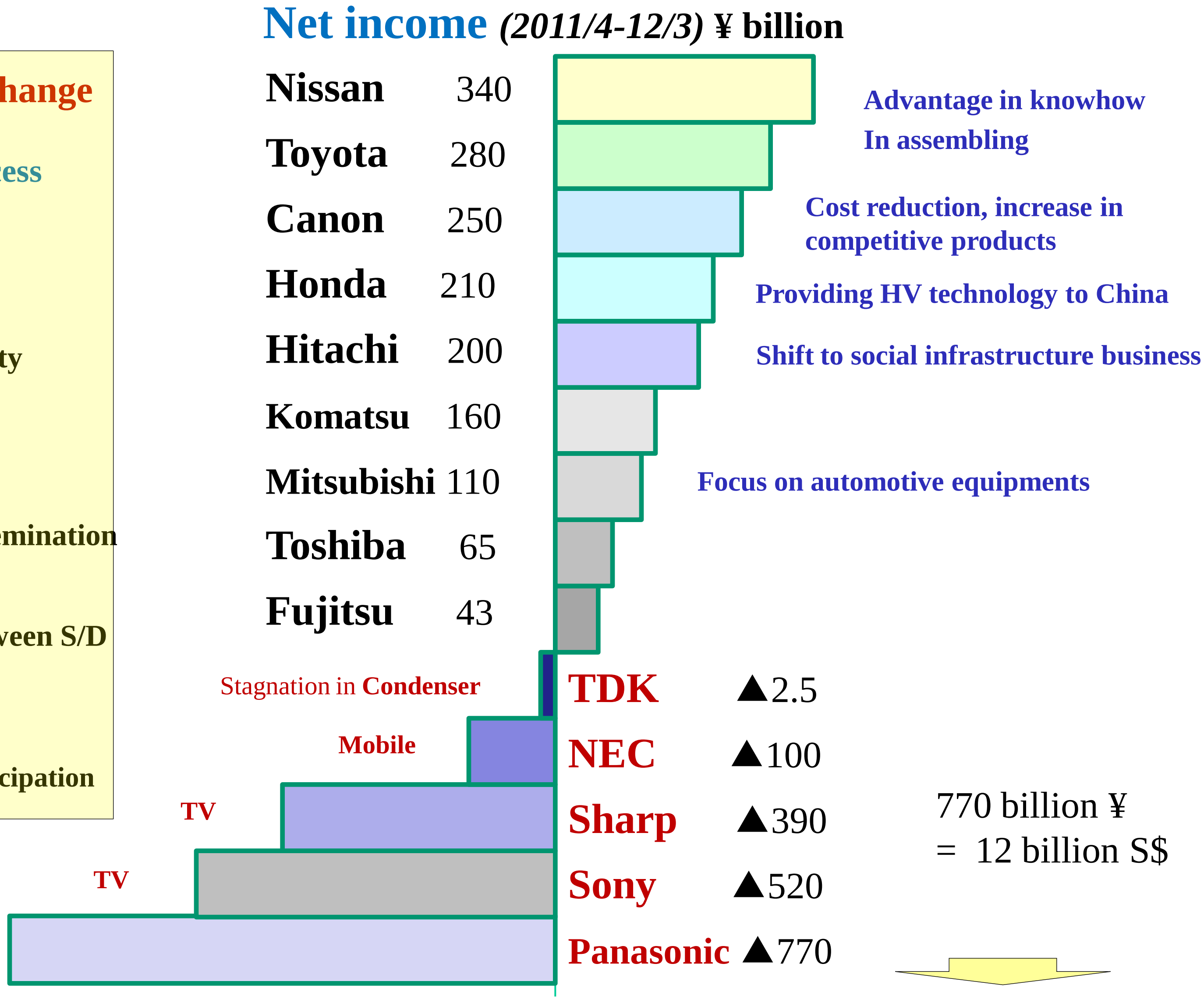
2. Advancement of Internet beyond anticipation

No time differences in information dissemination
(Global simultaneous start-up)

Reverse in asymetory of information between S/D

3. Rapid networking speed

Integration of multifunction faster than anticipation



As a consequence of efficiency oriented BM (business model)

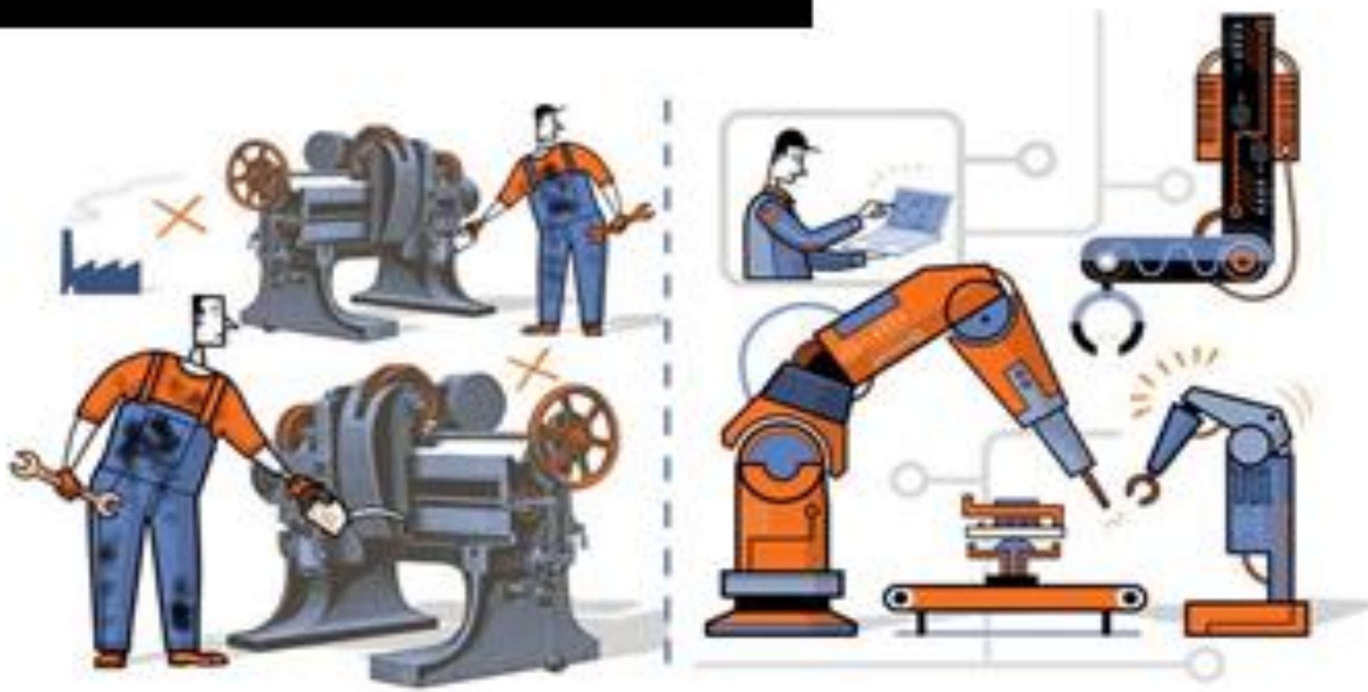
1. Misunderstand new stream
2. Non adaptive to env. change
3. Cling to traditional BM
4. Delay in structural change

Reorganization of electronic machinery industry

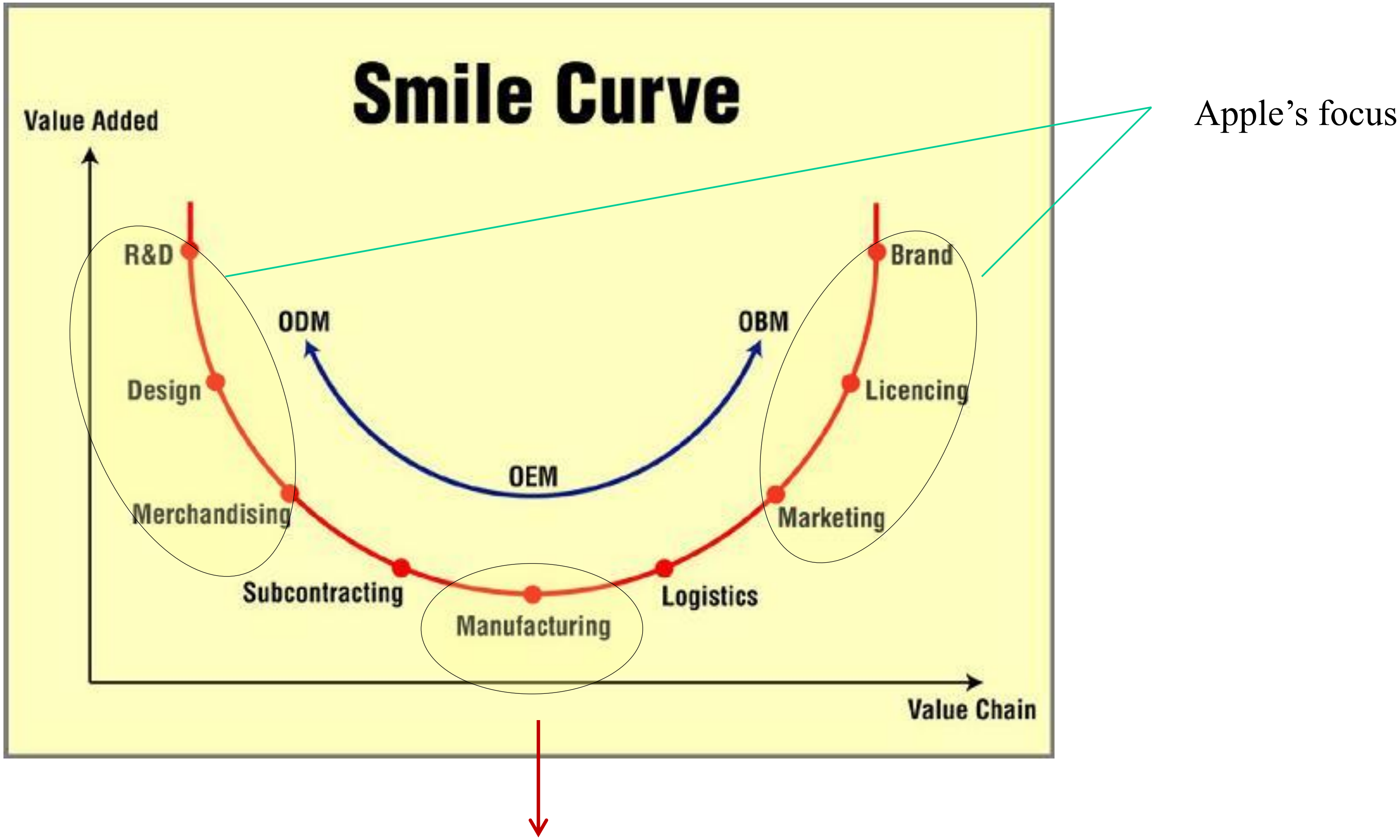
Constructing new mechanism for profit creation by transforming own business resources into strength in the new environment

(3) Shift to New Trajectory

As manufacturing goes digital, it will change out of all recognition, and some of the business of making things will return to rich countries



(4) New Focus



Japan clings to this focus
Should transfer to EMS
(Electronics Manufacturing Service)