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Institutional elasticity towards IT waves for Japan's survival—the significant role of an IT testbed

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Abstract

While the dramatic advances in information technology (IT) in recent years has provided all nations with a large number of potential benefits, effective utilization of these benefits greatly depends on institutional elasticity.

Notwithstanding a high institutional elasticity towards "catching-up," Japan's institutional system lost its elasticity under a new paradigm that emerged in the 1990s, and remediation of this problem has become crucial as advances in IT and subsequent economic globalization has highlighted global, invisible, interactive, disseminative and coevolutional features, leading to an increased significance of institutional elasticity.

A testbed can play a significant role in inducing and diffusing new technology, and given the unique features of IT, an IT testbed is particularly important. With such systems functions as predictability, observability and triability, an IT testbed can provide services to demonstrate hidden benefits, instill confidence by providing visuality, and stimulate learning exercises leading to construction of a virtuous cycle between IT inducement and diffusion. These services correspond to requirements for complementing the constraints of Japan's institutions. Thus, an IT testbed can unexpectedly play a significant role in the remediation of Japan's lost institutional elasticity.

This paper analyzes the significant role of institutional elasticity, and on the basis of a case evaluation of the Japan Gigabit Network, demonstrates the hypothesis that an IT testbed can contribute to the remediation of Japan's institutional elasticity.

Keywords: IT; Institutions; Institutional elasticity; IT testbed

1. Introduction

The dramatic advances in information technology (IT) in recent years has provided all nations of the world with a large number of potential benefits, and effective utilization of these benefits has become one of the most crucial aspects of competitive strategy for a nation. However, it should be noted that effective utilization of these potential benefits greatly depends on the flexibility of the institutions relevant to the inducement and diffusion of IT, or institutional elasticity.

Notwithstanding a high institutional elasticity towards "catching-up" up at the end of the 1980s, Japan's institutional system has lost its elasticity and shifted to a non-elastic and solid correspondence to the dramatic advancement of IT under a new paradigm that emerged in the 1990s, including low or negative economic growth and a conspicuous aging trend. Remediation of this problem has become crucial as the advancement of IT and subsequent economic globalization has highlighted global, invisible, interactive, disseminative and coevolutional features with respect to the interaction between technology and institutions, leading to the increasing significance of institutional elasticity.

A testbed can play a significant role in inducing and diffusing new technology. Given the particular features of IT mentioned above, an IT testbed is particularly important, and it is expected to incorporate such systems functions as predictability, observability and triability. With these functions, an IT testbed can provide services to demonstrate hidden benefits, instill confidence by pro-

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viding visuality, and stimulate learning exercises leading to the construction of a virtuous cycle between IT inducement and diffusion. These services correspond exactly to the requirements necessary for complementing the constraints of Japan's institutions. Thus, an IT testbed can unexpectedly play a significant role in the remediation of Japan's lost institutional elasticity.

To date, a number of studies have identified the impact of technological innovation and its diffusion process (e.g. Romer, 1986; Grossman and Helpman, 1991; Rogers, 1962). In addition, analyses of the impacts of IT on socioeconomic development and firm strategy have become popular works for economists (e.g. Morrison, 1988; Brynjolfsson, 1993; US DOC, 2000a; OECD, 2000). In the light of the significance of the interrelationship between innovation and external circumstances, a number of works have focused on the identification of this interaction mechanism. Baranson (1967) postulated a concept of interaction between internal technology and external technology. Internal technology means qualification of the R&D environment and consists of quality and quantity of resources for R&D. External technology consists of the "economic environment," "physical and natural environment" (such as energy resources and geographical conditions), "social and cultural environment" (such as informatization, education, ethics of labor and entrepreneurs, customs and tradition, and preferences of consumers) and "policy system" (Watanabe 1995, 1997). These components are collectively designated as "institutions." North (1994) defined institutions as: "The humanly devised constraints that structure human interaction. They are made up of formal constraints (e.g. rules, laws, constitutions), informal constraints (e.g. norms of behavior, conventions, self-imposed codes of conduct), and their enforcement characteristics. Together they define the incentive structure of societies and specifically economies." Thus, institutions play a significant role in inducing and diffusing technological innovation.

While a number of works have conducted broad-ranging theoretical and empirical analyses on the behavior of institutions (e.g. North 1990, 1994; Knight, 1992; Milner, 1997; see also Hodgson, 1993), their focus is not necessarily the identification of the role of institutions as a core inducing factor of innovation and stimulator for broad diffusion. An exceptional pioneer work can be found in Binswanger and Ruttan's *Induced Innovation: Technology, Institutions, and Development* (1978). This work paid special attention to the role of institutions in inducing innovation. Over the two decades since Binswanger and Ruttan's postulate was demonstrated, intensive work has been conducted on the identification of the behavior of institutions. Orihata and Watanabe (2000), by synchronizing Baranson's postulate of the interaction between internal and external technologies, Binswanger's postulate of the inducing role of institutions, and advancement of studies on institutions, attempted to construct a new framework explaining a driving mechanism for product innovation.

In line with the dramatic advancement of IT and subsequent economic globalization, significant aspects of the interaction between technological innovation and institutions have been structurally changed. The advancement of IT and economic globalization inevitably highlights "global," "invisible," "interactive," "disseminative," and "coevolutional" features with respect to the interaction between technology and institutions, leading to the increasing significance of institutional elasticity (Watanabe, 2000a,b; Griffy-Brown et al., 2001).

As noted above, while a number of studies have been conducted on the impact of innovation with respect to socioeconomics, interaction between innovation and institutions, and the behavior of institutions, no attempts have been made to analyze the specific feature of interaction between IT and institutions, particularly the significant role of institutional elasticity or flexibility. This paper first focuses on an analysis of this particular feature.

Provided that institutional elasticity plays a significant role in the inducement and diffusion of IT, and that nations have comparative advantages and disadvantages (e.g. Watanabe, 1999), the question of how to complement disadvantageous aspects of institutional elasticity is crucial for improving international competitiveness. This complement is of particular importance for Japan as, contrary to its high level of institutional elasticity in the 1980s, under a new paradigm of the 1990s including low or negative economic growth and a conspicuous aging trend, it has been suffering from a loss of institutional elasticity. An IT testbed is expected to play a significant role in complementing the shortage of institutional elasticity, and it is thus crucially important to Japan for a smooth inducement and diffusion of IT.

While a number of studies have reviewed the role of testing and evaluation for sound development and diffusion of technology for sustainability (e.g. Watanabe, 1996; Tenckhoff, 1996), no works have undertaken an analysis of such facilities from the viewpoint of the complement of institutional elasticity. The second focus of this paper is to analyze the expected structural role of an IT testbed as a complement to Japan's lost institutional elasticity.

First, this paper analyzes the specific features of interaction between IT and institutions, particularly the significant role of institutional elasticity, and, second, on the basis of a case evaluation of the Japan Gigabit Network (JGN), demonstrates a hypothesis with respect to an IT testbed's contribution to remedy Japan's institutional elasticity.

Section 2 analyzes the essential role of institutional elasticity for IT inducement and diffusion. Section 3 demonstrates the significance of an IT testbed as a complement to institutional elasticity. Section 4 summarizes implications for full utilization of the potential benefits of IT.

2. Institutional elasticity for IT inducement and diffusion

2.1. IT waves and the essential role of institutional elasticity

2.1.1. Emergence of IT waves

IT waves, most recently exemplified by the growing popularity of the Internet, are changing the structure of business and impacting on the daily life of people. According to *Nua Internet Surveys*, there were approximately 248.7 million Internet users worldwide at the beginning of the year 2000, which reached an estimated 407.1 million users as of November 2000.

From a market point of view, the leading player of the IT industry is shifting from personal computers to network equipment.[1] OECD (2000) describes the main trends in OECD trade of IT products and services by categorizing IT goods into four main segments: computer equipment, communication equipment, electronic components and software goods. It notes that the fastest growing segment is communication equipment, and both imports and exports more than tripled between 1990 and 1998, growing more than twice as fast as total trade. For the past two decades, enhancing the speed of microprocessors and developing personal computers which provide an efficient work environment for individuals was one of the most important subjects for IT engineers. Now, they are focusing more on providing high-speed networks to connect well-developed personal computers.

To make the best use of the benefits of IT and urgently establish international competitiveness, each government of the world is aggressively developing its own IT policy. In the United States, the House of Representatives passed the Networking and Information Research and Development Act (NITRD) in February 2000. The bill would nearly double Federal IT research over the next five years, refocuses Federal IT resources towards fundamental basic research and establishes the National Science Foundation (NSF) as the leading agency for Federal civilian IT programs.

The European Commission launched the eEurope initiative in December 1999 with the adoption of the Communication "eEurope—An Information Society for all". The initiative aims at (i) bringing all Europeans into the digital age and online, (ii) creating a digitally literate Europe supported by an entrepreneurial culture, and (iii) ensuring the process is socially inclusive and builds consumer trust.[2] The Feira European Council adopted the eEurope 2002 Action Plan in June 2000, which detailed the policy actions that are required to meet these objectives by 2002.

The Japanese government enacted the Basic Law on Formation of an Advanced Information and Telecommunications Network Society (*IT Kihon-hou*)[3] in January 2001. Based on the Law, the Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society (IT Strategic Headquarters) was established. The IT Strategic Headquarters approved the e-Japan Strategy in January 2001 by specifying four important policy areas aiming to make Japan the world's most advanced IT nation within five years: (i) establishment of an ultrahigh-speed network infrastructure and competition policies, (ii) facilitation of electronic commerce, (iii) realization of electronic government, and (iv) nurturing high-quality human resources. In March 2001, the IT Strategic Headquarters approved the e-Japan Priority Policy Program, a specific blueprint for achieving the national goal specified in the e-Japan Strategy.

Rapidly surging IT waves over the world are inevitably forcing traditional society to reform its socioeconomic structure. As the Telecommunications Council (2000) describes, IT waves are hastening the paradigm shift from an industrial society to an information society. IT enhances efficiency of the society as a whole and realizes dramatically cheaper and faster transactions. Release from the restriction of time and distance promotes borderless information exchange and also provides socially disadvantaged people with more opportunities to participate in social activities. With minimal first-stage investment, IT gives opportunities to venture firms to compete with established firms equally.

Cairncross (1997) analyzes the impact of the death of distance, which has been brought about by such IT revolution due to the paradigm shift from an industrial society to an information society, on our lives. She examines the effects of IT revolution in such broad-ranging fields as designated "institutions" (North, 1994) encompassing (i) commerce and the shape of the company, (ii) the economy, (iii) society and culture, and (iv) government and the political process, and concludes that the death of distance is a revolution about opportunity and about increasing human contact.

[1] In the 1998 IBM Annual Report, L.V. Gerstner, CEO, comments: "This is not to say that PCs are going to die off, any more than mainframes vanished when the IBM PC debuted in 1981. . . . But the PC's reign as the driver of customer buying decisions and the primary platform for application development is over. In all those respects, it has been supplanted by the network."

[2] http://europa.eu.int/comm/information_society/eeurope/

[3] http://www.kantei.co.jp/

Thus, interdependency on institutions greatly increases as the IT revolution emerges, and, as reviewed in Section 1, institutions play a significant role in inducing and diffusing technological innovation, and the role of institutions has become dramatically significant.

2.1.2. Significance of institutional elasticity

Although IT has a huge potential to realize the efficiency of business and greatly enhance the daily life of people, whether the benefits of IT can be fully applied to reforming business style and daily life greatly depends on the situation of the institution, that is institutional elasticity which is peculiar to each nation. US DOC (2000a) pointed out that "Although IT is generally available in world markets, the US economy to date has achieved greater gains from IT than other countries at least partly because of favorable monetary and fiscal policies, a pro-competitive regime of regulation, and a financial system and business culture prepared to take risks." This suggests that the US's success in the IT revolution and subsequent new economy in the 1990s to the beginning of this century can be attributed to such institutional elasticity enabling a flexible labor market, stimulating activated competition in the market-place, and inducing risk-taking business challenges as well as broad utilization of IT products.

The United States is the leading Internet nation, with 153.8 million users and 55.8% penetration rate as of November 2000.[4] The share of US households with Internet access in August 2000 was 41.5% (US DOC, 2000b), while that of Japan was 34.0% in 2000 (MPHPT, 2000). The US Internet commerce market is also expanding. The US Internet commerce final consumption goods market was worth US$34 billion in 1999 and is expected to reach US$177.4 billion in the year 2003, while that of Japan was 350 billion yen (about US$3.1 billion) in 1999 (MPHPT, 2000).[5]

This high penetration rate of IT in the US derives not only from the nation's excellence in technology but also from its pioneering spirit and its flexibility to accept heterogeneous cultures. MacRae (1995) considers the flexibility and creativity in thought as one of the greatest sustainable advantages of the US. He argues that the melting pot of the US makes it a great generator of new ideas and much of its immigrant population will enable the economy as a whole to continue growing more rapidly than either Europe or Japan. Similarly, the melting pot of the US makes the nation more generous in accepting newly emerging technology and services than other nations.

These all support DOC's postulate that institutional elasticity plays a significant role in maximizing the benefits of IT and also in inducing further advancement of IT. Thus, we can conclude that the US's success in an IT-initiated new economy can be attributed to a virtuous cycle between institutional elasticity and advance of IT innovation and diffusion.

IT waves are also gaining power in Japan. There were estimated some 47.08 million Internet users in Japan with a penetration rate of 37.1% as of the end of 2000, an increase of 74% year over year. The number is forecast as expanding to 76.7 million in 2005 as illustrated in Fig. 1.

However, Japan does not seem to fully utilize the potential benefits of IT. Notwithstanding its high institutional elasticity towards "catching-up" up to the end of the 1980s, under a new paradigm emerged with a dramatic advancement of IT in the 1990s, Japan's institutional system lost its elasticity and shifted to a non-elastic and solid correspondence to the dramatic advancement of IT (Watanabe, 2000a; Griffy-Brown et al., 2001).

During the "catching-up" period up at the end of the 1980s, human resource management and the business style of Japanese firms such as lifetime employment, seniority system, and *keiretsu* well matched the nation's institutions. Japanese people feel comfortable with "being the same" as others (neighbors), and with this nature, the above Japanese economic system established well the feeling of "family ties" which successfully led the nation to a leader in the industrial society.

By contrast, IT enables global information exchange, thus inducing global procurement of goods and mobility of human resources. Facing this new emerging paradigm, Japan's institutional system has lost its elasticity and even hinders the full utilization of IT.

Fig. 2 compares the percentage of managers by country who are familiar with the Internet.[6] As it shows, only 15% of Japanese managers responded that they feel

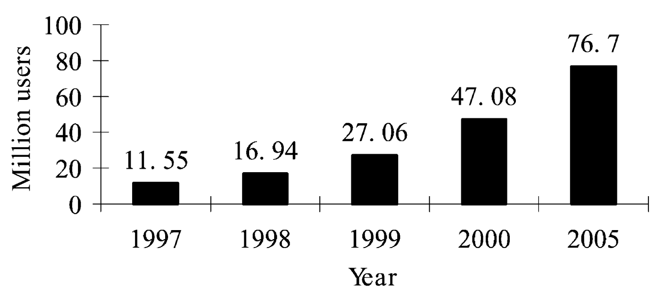


Fig. 1. Trends in internet penetration in Japan (1997–2005). *Source*: MPT, 2000.

[4] NielsenNetRatings.

[5] The Ministry of Posts and Telecommunications (MPT) was renamed the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT) on 6 January 2001 under the structural reform of the Japanese government.

[6] Fig. 2 is given in the March 2000 Report of the Telecommunications Council which refers to "Internet usage by managers" by Andersen Consulting, May 1999 as its source.

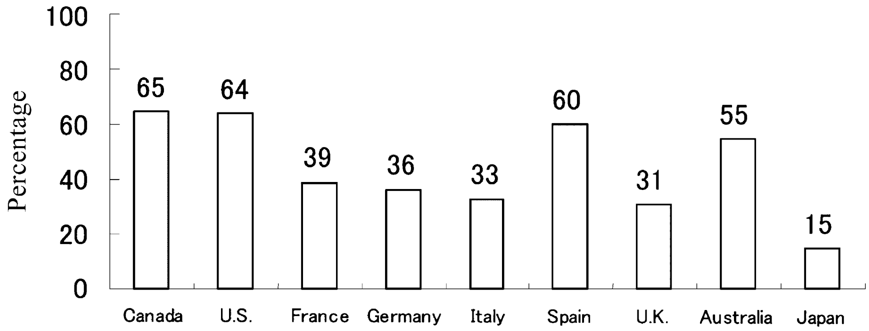


Fig. 2. Percentage of managers who responded that they feel comfortable using the internet. *Source*: Internet usage by managers, Andersen Consulting, May 1999.

comfortable to utilize the Internet while more than 60% of managers from Canada, the US, and Spain responded in the same way.

The low utilization rate of the Internet by Japanese managers should be attributed to the nation's seniority system. In general, only seniors can occupy high positions in Japan. However, Internet usage rate by senior people is quite low as revealed by Fig. 3. Furthermore, the hierarchical structure of Japanese firms hinders senior managers in communicating with younger employees who generally recognize the importance of IT. Since senior managers are not aware of the benefits of IT, they have no incentive to utilize IT and, accordingly, the effectiveness of IT would not be fully utilized.

Fig. 4 illustrates a scheme leading to Japan losing its institutional elasticity by comparing the US system which indicates that, contrary to the dual virtuous cycle up to the end of the 1980s, Japan has been suffering from a dual vicious cycle.

In order to identify factors compelling Japan to lose its institutional elasticity, a numerical analysis was attempted taking Japan's manufacturing industry over the period 1975–96.

Provided that technology incorporates in production factors (such as labor, L, and capital stock, K), a technology-incorporated production function is generally seen as follows:

$$V=F(t,L(t),K(t)) \quad (1)$$

where V is GDP, T is technology stock, and t time trend.

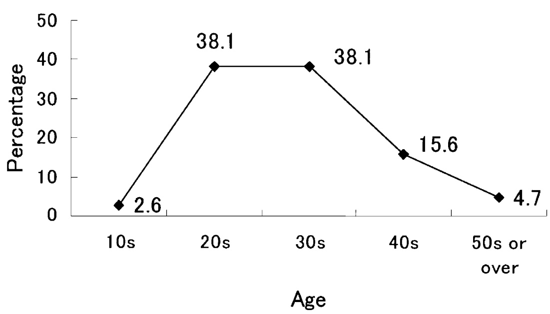


Fig. 3. Internet usage by age in Japan in 1999. *Source*: MPT, 2000.

Since institutional elasticity can be typically observed in behaviors of labor and also of labor productivity versus changes in fundamental factors such as wages, identification of optimal labor input and elasticity of wages to labor by solving a cost minimization equation using Lagrange coefficient was attempted first as follows:

$$Z=GC+\Gamma(V(L(T),K(T),t)-\bar{V}) \quad (2)$$

where Z is total expenditures and GC is gross cost.

Cost minimization under $V=\bar{V}$ in a CES-type production function can be obtained by solving the following simultaneous equations:

$$\begin{cases} \frac{\partial Z}{\partial L}=P_l+\Gamma A\,e^{\lambda t}\left(-\frac{1}{\mu}\right)[\delta K(T)^{-\mu}+(1-\delta)L(T)^{-\mu}]^{-\frac{1+\mu}{\mu}}\times(-\mu)(1-\delta)L^{-\mu-1}=0 \\ \frac{\partial Z}{\partial K}=P_k+\Gamma A\,e^{\lambda t}\left(-\frac{1}{\mu}\right)[\delta K(T)^{-\mu}+(1-\delta)L(T)^{-\mu}]^{-\frac{1+\mu}{\mu}}\times(-\mu)\delta K^{-\mu-1}=0 \\ \frac{\partial Z}{\partial \Gamma}=A\,e^{\lambda t}[\delta K(T)^{-\mu}+(1-\delta)L(T)^{-\mu}]^{-\frac{1}{\mu}}-\bar{V}=0 \end{cases}$$

where P_l is labor price (wages), P_k capital price, A scale factor, λ coefficient for time trend, μ substitution parameter, and δ capital distribution.

By solving the simultaneous equations, optimal labor input can be obtained as follows:

$$L(T)=\frac{\bar{V}}{A\,e^{\lambda t}}\left[\delta\left(\frac{1-\delta}{\delta}\right)^{\frac{\mu}{1+\mu}}\times\left(\frac{P_k}{P_l}\right)^{\frac{\mu}{1+\mu}}+(1-\delta)\right]^{\frac{1}{\mu}} \quad (3)$$

Eq. (3) indicates optimal labor input under certain production. Differentiating $L(T)$ by P_l, the elasticity of wages to labor under the same condition can be obtained as follows:

$$\frac{\partial L}{\partial P_l}\frac{P_l}{L(T)}=-\frac{1}{1+\mu}\frac{1}{\left(\frac{1-\delta}{\delta}\right)^{\frac{1}{1+\mu}}\cdot\left(\frac{P_l}{P_k}\right)^{\frac{\mu}{1+\mu}}+1} \quad (4)$$

Based on this result, the following "institutional elasticity indicator" in terms of wage elasticity to labor productivity under the optimal labor input condition

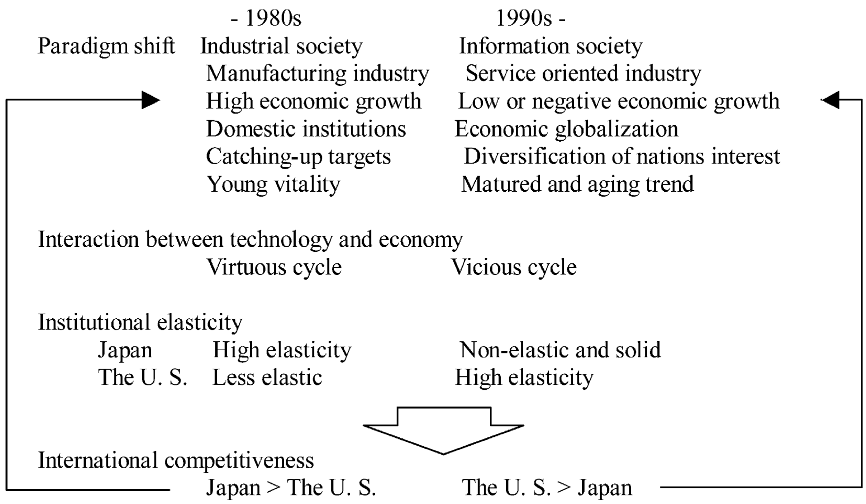


Fig. 4. Scheme leading Japan to lose its institutional elasticity.

$\Phi_{P_l(V/L)}$ can be obtained by differentiating labor productivity ($V/L(T)$) by P_l in the same condition:

$$\Phi_{P_l(V/L)} = \frac{\partial(V/L(T))}{\partial P_l}\frac{P_l}{V/L(T)} = \frac{\partial \ln(V/L(T))}{\partial \ln P_l} = \frac{\partial \ln V}{\partial \ln P_l} \tag{5}$$

$$= \frac{\partial \ln L(T)}{\partial \ln P_l} - \sigma \frac{1}{\left(\frac{1-\delta}{\delta}\right)^{\sigma}\left(\frac{P_l}{P_k}\right)^{1-\sigma}+1}$$

where $\delta=1/(1+\mu)$: elasticity of $K(T)$ substitution for $L(T)$.

As summarized in Table 1, Eq. (5) suggests that institutional elasticity (as far as measuring in terms of wage elasticity to labor productivity under the optimal labor input condition) is influenced greatly by the extent of technology substitution for labor followed by capital distribution ratio and ratio of capital and labor prices (Tou, 2001).

Table 2 and Fig. 5 demonstrate trends in institutional elasticity in the Japanese manufacturing industry as a whole and also in electrical machinery. Looking at the table and the figure we note that since the bursting of the bubble economy in 1991, (i) a decrease in technology substitution for labor due to the imbalance of technology incorporation in labor and capital, (ii) a decrease in the capital distribution ratio, and (iii) an increase in relative prices of labor to capital prices reacted to a dramatic decrease in institutional elasticity both manufacturing industry as a whole and electrical machinery.

Since the analysis in Table 2 and Fig. 5 suggests that a decrease in technology substitution for labor due to the imbalance of technology incorporation in labor and capital was the major source of the Japanese manufacturing industry losing its institutional elasticity, the next analysis is used to elucidate the sources of such imbalance in relation to the rapid advancement of IT and the subsequent paradigm change emerged in the 1990s.

The imbalance of technology in labor and capital can be attributed to the imbalance of the lead time in technology, particularly IT incorporation into labor and capital. Contrary to a smooth incorporation of IT into capital, due to institutional constraints such as traditional system, custom, education/training, and aging trends, IT's incorporation into labor is rather complicated and not necessarily as easy as incorporation into capital. Figs. 2 and 3 demonstrate this situation.

Fig. 6 illustrates a scheme for measuring institutional elasticity by means of trends in imbalance of technology incorporation in labor and capital and indicates that, under the competitive circumstances, this imbalance can be measured by the discounted ratio of gross labor cost and gross capital cost.

Fig. 7 illustrates the results of the analysis of trends

Table 1
Factors governing institutional elasticity in Japan's manufacturing industry (1975–96)

				Impact on elasticity			Magnitude
Elasticity of substitution	σ	↓	⇒	Φ	↓		Direct impact
Capital distribution	δ	↓	⇒	Φ	↓		Relatively weak
Ratio of labor to capital prices	P_l/P_k	↑	⇒	Φ	↓	(σ<1)	Generally weak

Table 2
Trends in institutional elasticity by measuring wages elasticity to labor productivity in Japan's manufacturing industry (1975–96)

	δ	P_l/P_k	Elasticity of substitution σ	Capital distribution factor $[(1-\delta)/\delta]^{\sigma}$	Relative price factor $(P_l/P_k)^{1-\sigma}$	Elasticity $\Phi_{P_l}(V/L)$
Manufacturing as a whole						
1975–86	0.41	0.68	1.01	1.44	1.00	0.41
1987–90	0.43	0.92	0.71	1.22	0.98	0.32
1991–96	0.39	1.28	0.42	1.21	1.15	0.18
Electrical machinery						
1975–86	0.43	0.72	1.69	1.65	1.26	0.55
1987–90	0.46	0.88	0.65	1.33	1.08	0.67
1991–96	0.38	1.89	0.57	1.32	1.32	0.21

δ, capital distribution; P_l/P_k, ratio of labor to capital prices.

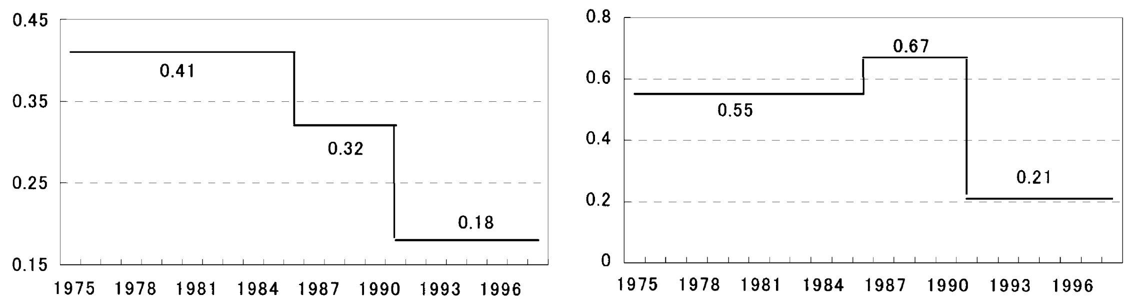
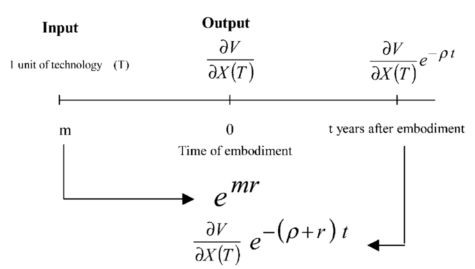


Fig. 5. Trends in institutional elasticity by measuring wages elasticity to labor productivity in Japan's manufacturing industry (1975–96).



$$e^{mr} = \frac{\partial V / \partial X(T)}{\rho + r}$$: Present discounted value where m : lead time for embodiment; ρ : rate of obsolescence of technology; and r: discount rate (interest rate).

$$\frac{\partial V}{\partial X(T)} = e^{mr}(\rho + r) = \frac{P_x}{P_v}$$

$$\therefore\ m_l - m_k = \left(ln\frac{Pl}{Pk}\right)\Big/ r = \left(ln\frac{GLC}{GCC}\right)\Big/ r \qquad \text{as 1 unit of input}\left(\frac{Pl}{Pk} = \frac{GLC}{GCC}\right)$$

where *Px*: prices of production factor X; *Pv*: prices of GDP (GDP deflator); *ml*: lead time for technology embodiment in labor; *mk*: lead time for technology embodiment in capital; *GLC*: gross labor cost; and *GCC*: gross capital cost.

Fig. 6. Scheme of measuring institutional elasticity by means of trends in imbalance of technology incorporation in labor and capital.

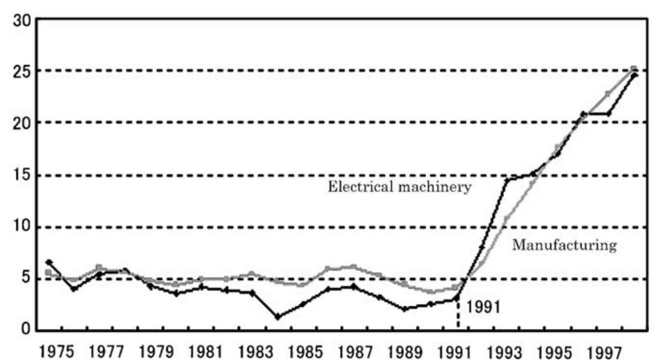


Fig. 7. Trends in imbalance of technology incorporation in labor and capital in Japan's manufacturing industry (1975–98).

in imbalance of technology incorporation in labor and capital in both Japan's manufacturing industry as a whole and electrical machinery over the period 1975–98 (Tou, 2001). Looking at Fig. 7 we note the following.

1. The lead time for technology incorporation (embodiment) in labor and capital (m_l and m_k, respectively) has been in harmony up until the end of the 1980s.
2. However, the lead time for labor has changed to a much greater lead time than capital from 1991 resulting in a dramatic increase in the imbalance of technology incorporation in labor and capital.

These results demonstrate our hypothesis that the imbalance of the lead time in technology, particularly IT incorporation in labor and capital (see Figs. 2 and 3) led to the dramatic increase in the imbalance of technology incorporation in labor and capital resulting in the decrease in technology substitution for labor (see elasticity of substitution σ in Table 2) and loss of institutional elasticity. In addition, the sources of such imbalance can be attributed to institutional constraints such as traditional system, custom, education/training, and aging trends, thus falling into a vicious cycle (see Fig. 4).

The "World Competitiveness Ranking Report", recently published in April 2001 by the International Management Development Institute (IMD), revealed that Japan's ranking has dropped further to twenty-sixth (from twenty-fourth in 2000). The report also revealed that this is due primarily to the deterioration of such institutional elasticity as venture spirit, accountability of shareholders, and transparency of government policy. These factors are closely linked to factors that hinder the effective utilization of the benefits of the advancement of IT and support our hypothesis as well as the above analysis.

2.2. IT characteristics with respect to institutional elasticity

A number of studies have identified characteristics of technology and also of particular features of IT (e.g. US DOC, 2000a; Telecommunications Council, 2000; MPT, 2000; Cairncross, 1997; MacRae, 1995; EPA, 2000), Among the specific features of technology with respect to interaction with the economy, the following five characteristics should be highlighted as IT characteristics with respect to institutional elasticity (Table 3). In other words, whether a nation can fully enjoy the benefits of IT greatly depends on the relation of a nation's institutional elasticity to the following features of IT:

Global. IT, especially network technology, realizes global information exchange independent of time, distance, and even borders. Accordingly, unknown but maybe effective services and cultures flow in incessantly. To make the best use of this information exchange, high adaptability to changing environments and the ability to absorb heterogeneous cultures are required. As mentioned previously, the melting pot of the US well matches this heterogeneous environment and enjoys globalization brought about by IT.

Invisible. IT should be referred to as cross-industrial technology and would play its role as the invisible infrastructure. "Digital Economy 2000" (US DOC, 2000a) claims that IT innovations can be applied across the economy and throughout the economic process: IT provides new ways of managing and using a resource that are common to every sector and aspect of economic life. The IT infrastructure is invisible and various application services are expected to develop on it. Because of the unlimited potential of IT, creativity and entrepreneurship play a key role in developing various application services to be successful on this infrastructure.

Interactive. With the development of advanced networks, more and more people can communicate globally, and new communities formed by people with the same objectives or interests would emerge independent of existing organizations or communities. In this environment, the less people participate in the community, the less information they can obtain. In this sense, a traditional hierarchical organization hinders communication within the organization even though IT provides an interactive environment.

Disseminative. As the famous Moore law shows,[7] technological development of IT is very rapid. This rapid development of the technology and so-called "network externality"[8] enables IT-related products and services to disseminate rapidly. The Economic Planning Agency (EPA, 2000) points out that appropriately judging the surrounding environment and quickly commercializing new products and services are crucial for survival in the information society. To make the best use of this disseminative nature of IT, organizations are required to make decisions quickly and react flexibly to changing environments.

Coevolutional. As mentioned in Section 2.1, IT itself transforms economic, social, and cultural system of nations while it disseminates as the social infrastructure. With the indigenous nature of IT as the social infrastructure, the most effective way to maximize the benefits of IT should be the spontaneous evolution of the society itself as the technological development proceeds.

These unique features of IT with respect to interaction with institutions inevitably lead to the increasing significance of institutional elasticity. In the light of the increasing significance of these unique features of IT

Table 3
IT characteristics with respect to institutional elasticity

Specific features of technology		IT characteristics
1	Intangible	(a) Global
2	Uncertainty	
3	Huge risk	(b) Invisible
4	Costly	
5	Long lead time	(c) Interactive
6	Opportunity for enormous benefit	
7	Broad dissemination	(d) Disseminative
8	Cumulative development	
9	Path dependent	(e) Coevolutional
10	Learning effects	

[7] Chip capacity doubles every 18 months.

[8] The more the technology is deployed, the greater its value.

which increase as the IT wave emerges, the question of how to complement institutional elasticity for active inducement and diffusion of IT will become crucial for international competitiveness.

3. The IT testbed as a complement of institutional elasticity

3.1. The role of the IT testbed

Facing the surging IT waves, where speedy R&D and the timely introduction of products and services into the market play a key role in successfully establishing a competitive position in the world, it is crucial to minimize the span required to bring the R&D achievement into practical use. On the other hand, as Watanabe (1996) argues, a virtuous interaction between vigorous R&D investment and advancement of testing and analysis significantly contributed to Japan's sustainable development with respect to industrial competitiveness against such a grave situation as the energy crises, testing and analysis of technology is essential in the development process.

Accordingly, a testbed which provides a field for testing or verifying preceding services and advanced technologies plays a significant role in inducing and diffusing new technology. Given the unique features of IT as mentioned above, an IT testbed is particularly important to accelerate inducing and diffusing processes of the technology, and is expected to incorporate the following systems functions:

Predictability. An IT testbed provides preceding services with a field to demonstrate their hidden benefits and complements the gap between theory and practice, thus improving the predictability of emerging new services.

Observability. An IT testbed instills confidence by providing a testing environment which embodies service images or the effect of advanced technologies. An IT testbed provides visualization, thus complementing the invisible nature of IT.

Triability. With the indigenous nature of an IT testbed as a testing field, it stimulates learning exercises leading to the construction of a virtuous cycle between IT inducement and diffusion.

Since IT waves are now shifting from personal computers to high-speed networks, it should be appropriate to focus on a "network testbed" when examining an "IT testbed."

Recognizing the importance of an IT testbed as a catalyst to accelerate the diffusion of IT, large-scale network testbeds have been developed in IT advanced nations with collaboration among universities, industries, and governments. Some of these network testbeds are summarized in Table 4.

In the US, MCI Worldcom and the National Science Foundation (NSF) jointly established vBNS (very High performance Backbone Network Service) in 1995, a nationwide network that supports high-performance, high-bandwidth applications. Abilene, a US network testbed established in 1999, also supports the efforts of the Internet2 community, which is a university-led consortium.

CA*net3 is Canada's research and education optical Internet backbone established in 1998, connecting individual universities, federal and provincial government laboratories and research institutes through provincially based Regional Advanced Networks. CA*net3 is operated by CANARIE.Inc., which is an industry-led consortium.

NORDUnet, established in 1989, is the Nordic Internet highway to research and education networks in Denmark, Finland, Iceland, Norway and Sweden. It is a collaboration between the Nordic national research and educational network organizations UNI-C/DENet, FUNET, SURIS, UNINETT and SUNET to provide international network services to these organizations. The UK's first Joint Academic NETwork (JANET) was created in 1984. Since then, it has been upgraded continually. The backbone of JANET is called SuperJANET, which is expected to shift to SuperJANET4 to shape the future of networking for education.

In Japan, the Telecommunications Advancement Organization and the Ministry of Posts and Telecommunications (MPT) established the Japan Gigabit Network (JGN), the first gigabit-class nationwide open-network testbed, in 1999. Since then, JGN has been widely utilized by universities and private companies for developing advanced IT services and networking technology.

3.2. The significance of the IT testbed for remediation of Japan's institutional elasticity

As analyzed so far, institutional elasticity plays a significant role in inducing and diffusing IT. If a nation's indigenous institution can react elastically to the advancement of IT, that nation should be able to fully enjoy the potential benefits of IT, resulting in enhancing its international competitiveness.

In fact, respective nations have comparative advantages and disadvantages (Watanabe, 1999), and how to complement disadvantageous aspects of institutional elasticity is crucial to survive in the IT waves. This complement is of particular importance for Japan as under the new paradigm in the 1990s including low or negative economic growth and a conspicuous aging trend, it has been suffering from the loss of its institutional elasticity.

Table 4
IT network testbeds in the world

Name of the testbed	vBNS, vBNS+	Abilene	CA*net3	NORDUnet	JANET, SuperJANET	JGN
Nation	US	US	Canada	The Nordic countries	UK	Japan
Since	1995	1999	1998	1989	1984	1999
Operation entity	NSF	UCAID	CANARIE. Inc.	NORDUnet A/S	UKERNA	TAO
Fee	Charged	Charged	N/A	Free	Charged	Free
AUP (Acceptable Use Policy)	Any research institutes can connect. Commercial offering of vBNS+ began in 2000	For R&D purpose only	Any Canadian entity can connect. For R&D purpose only	Abide by each network's AUP. For R&D purpose only	Approved entities can connect. For R&D purpose only	Any entity can connect. For R&D purpose only
Number of organizations connected	101 (as of 1999)	191 (as of March 2001)	N/A	5700	280 (as of 1999)	270 (as of 2001)
Number of access points	16	50	12	8	17	64
Transmission speed	Mostly 622 Mbps; Max. 2.4 Gbps	2.4 Gbps	2.4 Gbps	622 Mbps	155 Mbps	2.4 Gbps

Sources: http://www.vbns.net/, http://www.ucaid.edu/abilene/, http://www.canet2.net/, http://www.nordu.net/, http://www.ja.net/, http://www.shiba.tao.go.jp/, MPT (2000).

With its systems functions analyzed as in Section 3.1, an IT testbed is expected to play a significant role in complementing Japan's shortage of institutional elasticity by bypassing the direct connection between the advancement of IT and institutional elasticity (Fig. 8).

Specifically, for each of the unique features of IT with regard to institutional elasticity—global, invisible, interactive, disseminative, and coevolutional—an IT testbed complements Japan's shortage of institutional elasticity as analyzed below:

Global. As described in Section 2.1, the Japanese are homogeneous by nature and tend to have a prejudice against unfamiliar things. Systems functions of an IT testbed such as predictability and observability mitigate such prejudice by gradually removing the unfamiliarity and uncertainty of the IT waves, leading the nation to a more open heterogeneous environment.

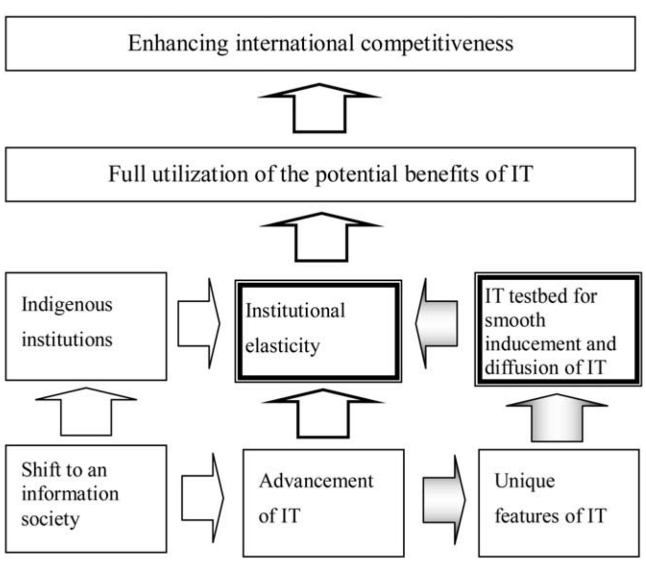


Fig. 8. Bypass function of an IT testbed.

Invisible. The Japanese are generally risk averse. For example, Japanese venture capitalists tend to invest in later-stage (almost established or just before going public) companies while the US venture capitalists invest in start-ups (MPT, 2000), expecting a high return in exchange for taking a high risk. MacRae (1995) points out that while the Japanese education system emphasizes a learning-by-rote approach and has produced excellent line-workers, it has not produced the original thinkers that the best US universities have. By providing predictability, observability, and triability, an IT testbed complements invisible risks and induces an entrepreneurial spirit.

Interactive. Although IT provides an enhanced communication environment, the hierarchical structure of Japanese organizations hinders effective utilization of a network as a communication tool. With regard to R&D, as Callon (1995) analyzes, researchers prefer private-sector-led research cooperation to government-led forced joint research. An IT network testbed provides basically an unregulated and open communication environment, thus inducing spontaneous formation of research groups and promoting network-type, not hierarchical, communication.

Disseminative. Most of the Japanese people feel comfortable when they recognize that they are the same as their neighbors (neighbor effect). Consequently, the Japanese tend to wait and see what others do, and then take action. On the other hand, the "i-mode" service that allows users access to the Internet from their cell phones has been rapidly diffusing in Japan. Since February 1999 when NTT DoCoMo[9] launched its i-mode service, subscriptions to this kind of mobile Internet access service have been dramatically increasing (Fig. 9). This exceptional diffusion can be explained by such factors as (i) cell phones were already diffused, (ii) users had already experienced the "short message service" that enables message exchange, (iii) users already recognized how useful the Internet is, together with the neighbor effect. An implication of the i-mode case is that if some previous experience is available, Japan's institutions can react elastically to the disseminative feature of IT. In this context, an IT testbed effectively provides previous experience with its systems functions such as triability and observability.

Coevolutional. Japanese organizations tend to stick to the ways taken by past achievements because they are safe: "precedent" must be the most persuasive word used by Japanese senior managers. In other words, breaking with precedent is very difficult. Up to the 1980s when Japan enjoyed comparative advantages in manufacturing, excellent line-workers were appreciated and following "precedent" was the most reliable way. However, in the information society where things change rapidly, the nation cannot survive if it sticks to precedent. By providing a field for testing, an IT testbed helps to construct precedent in the newly emerged paradigm, resulting in mitigation of the solidity of institution.

Fig. 10 summarizes the complementary role of an IT testbed for full utilization of the potential benefits of IT. Systems functions of an IT testbed turn out to correspond to requirements for complementing the constraints of Japan's institutions. Thus, an IT testbed can unexpectedly play a significant role in the remediation of Japan's lost institutional elasticity.

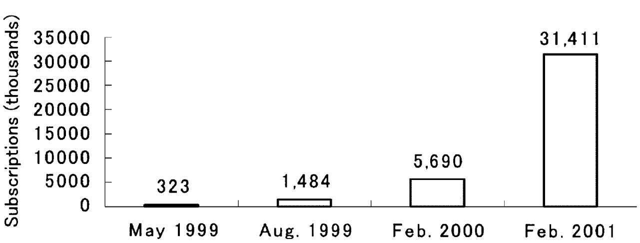


Fig. 9. Total number of mobile internet service subscriptions. *Sources*: MPT, 2000; http://www.tca.or.jp/.

[9] The largest mobile phone provider in Japan.

In order to verify the complementary role of an IT testbed, partial evaluation of the actual IT testbed, the Japan Gigabit Network (JGN), was conducted.

JGN was established by the Telecommunications Advancement Organization of Japan and the Ministry of Posts and Telecommunications (MPT) in 1999, comprising the gigabit network, linking 10 pieces of ATM switching facilities nationwide by gigabit-class fiber-optic circuits, and the Gigabit Labs, shared R&D facilities.[10] JGN is open to universities, research institutes, national and local government entities, and corporations for R&D of high-speed networking technology and high-performance applications from 1999 to 2003. As a nationwide high-speed network testbed, JGN contributes to achieving the goals of e-Japan Strategy, mentioned in Section 2.1, such as establishing the ultra high-speed network infrastructure and facilitation of electronic commerce.

Although only two years have passed since the operation of JGN started, in addition to its original role as a field for testing preceding services and technology, JGN has revealed its effect on Japan's solid institutions with respect to global, interactive, invisible, disseminative, and coevolutional features of IT:

Global, interactive. JGN provides 64 access points nationwide to provide physically interactive environment as illustrated in Fig. 11. Since JGN is open to any entity except for commercial use, it consequently induces spontaneous formation of project teams. As of January 2001, about 270 universities and companies have conducted experiments using JGN, mostly by joint project teams. Considering that the number of universities and research institutes connected to vBNS amounted to about 100 after 4 years operation as Table 4 indicates, 270 in 2 years indicates a considerable number. The number of projects using JGN increased from 40 to 99 for the past year, about 30 of them consisting of industry–academic cooperation. Furthermore, JGN is utilized by various research areas as indicated in Fig. 12. JGN is consequently providing an environment where global and interactive communication is effectively induced.

Invisible. By using JGN, researchers can observe how their ideas or technology work, which leads them to be confident. Since the Japanese are excellent at incremental advance (MacRae, 1995), gaining confidence contributes to removing hesitation in pioneering invisible benefits of IT. As mentioned above, about a hundred projects are ongoing on JGN to verify advanced services and networking technologies. Their achievements have resulted in at least 430 pap-

[10] http://www.shiba.tao.go.jp/. All the data for JGN used in this paper were obtained from this web page.

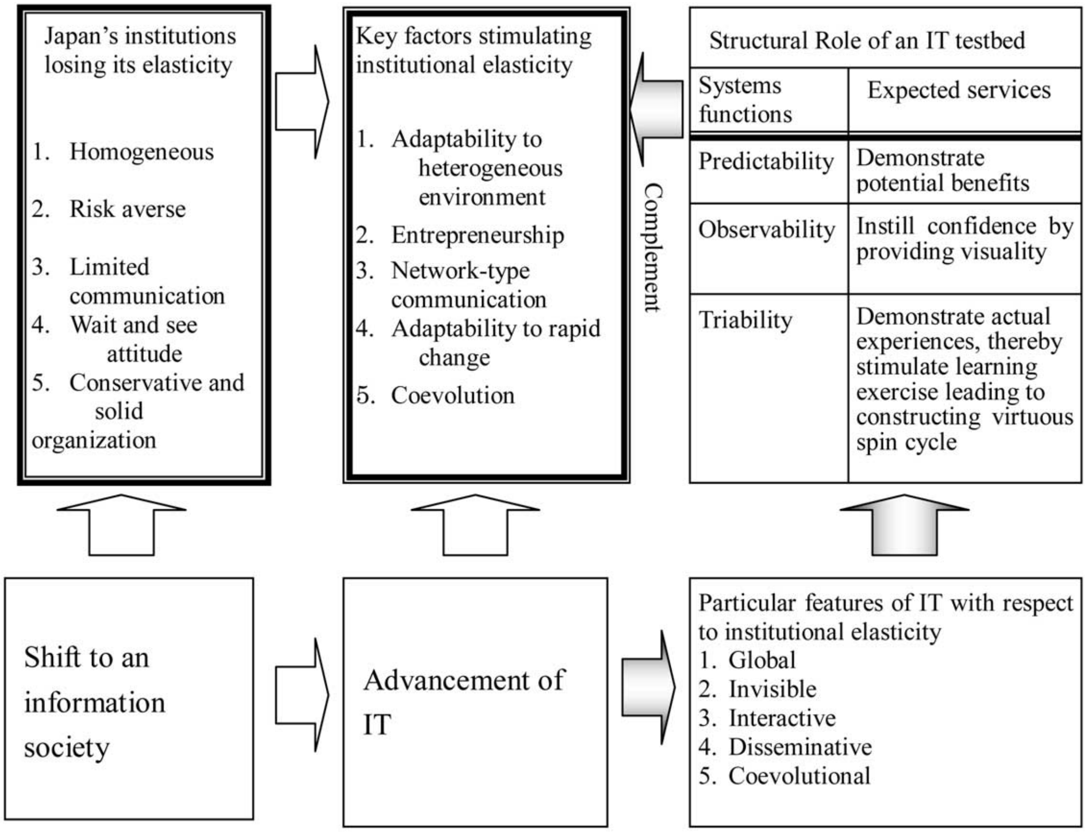


Fig. 10. Scheme of the complementary role of an IT testbed for full utilization of the potential benefits of IT.

ers in journals, and even a venture company was established. Furthermore, JGN users are not required to pay for the usage of JGN[11] while most of the other IT testbeds require usage fees as illustrated in Table 4, thus users do not have to worry about risky investment in the expensive access charge. In this way, JGN instills confidence in researchers, complements risks, and supports entrepreneurs.

Disseminative, coevolutional. As of January 2001, 42 projects have utilized JGN for demonstrating preceding service images at exhibitions. For example, at the INET2000/iGrid 2000 held in July 2000, attended by more than 6000 people from 80 countries, service images such as distributed collaborative virtual space and remote control of a microscope was demonstrated using JGN. Large-scale data transmission on JGN was also demonstrated at the Exhibition of Dream Technologies for the 21st Century held in August 2000, and more than 3000 people participated in the JGN demonstration sessions. These demonstrations contribute to enhancing predictability and observability of preceding service images, providing potential users of these services with previous experience, inducing the neighbor effect, and also establishing "precedent," thus relaxing such Japanese institutions as the wait-and-see attitude, and solidity of organizations.

As the above empirical analysis demonstrates, it turned out that JGN provides the bypass function as illustrated in Fig. 8 to avoid the direct interaction between the new technology and Japan's solid institutions such as homogeneous and risk-averse nature, and eventually complements Japanese institutional constraints for smooth inducement and diffusion of IT.

4. Conclusion

In the light of the understanding that effective utilization of potential benefits derived from the dramatic advancement of IT in recent years greatly depends on institutional elasticity, and that notwithstanding a high institutional elasticity towards "catching-up," Japan's institutional system lost its elasticity under a new paradigm that emerged in the 1990s, this paper analyzes the specific feature of interaction between IT and institutions, particularly the significant role of institutional elasticity, and, on the basis of a case evaluation of the Japan Gigabit Network, demonstrates a hypothesis with respect to an IT testbed's contribution to remediate Japan's institutional elasticity.

[11] Users have to prepare access lines to JGN access points.

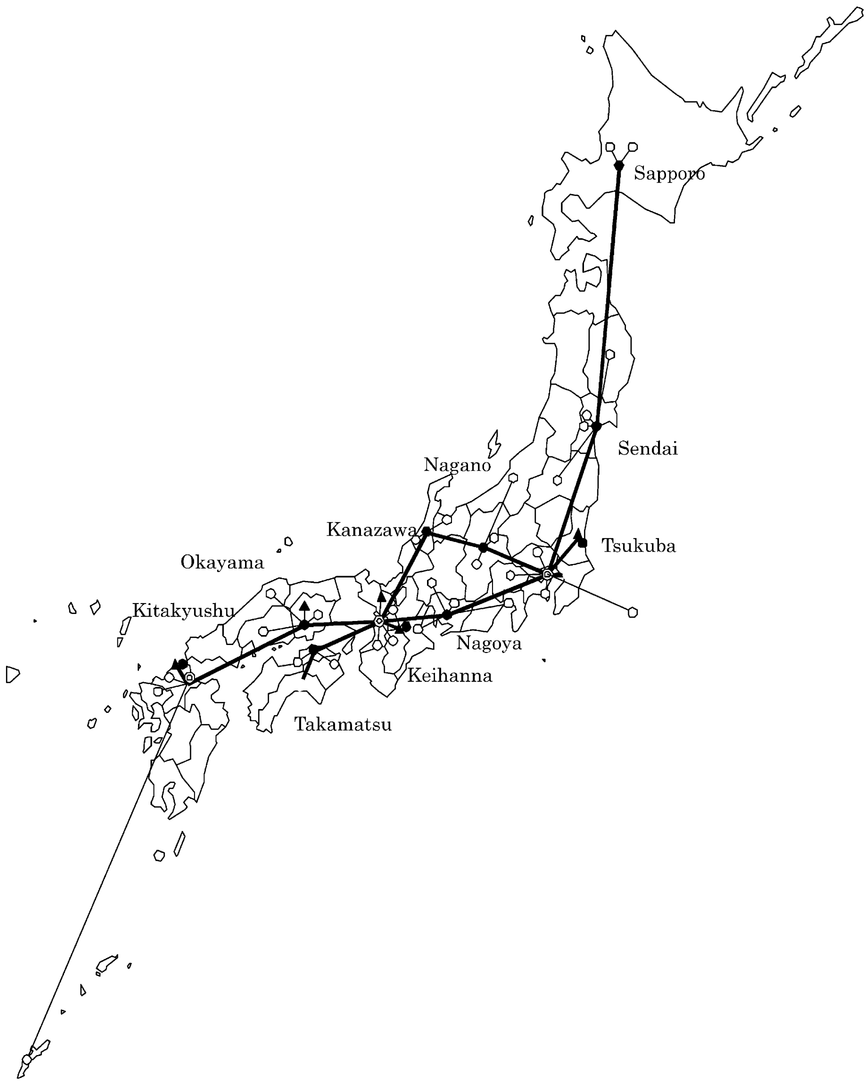


Fig. 11. Japan Gigabit Network backbone.

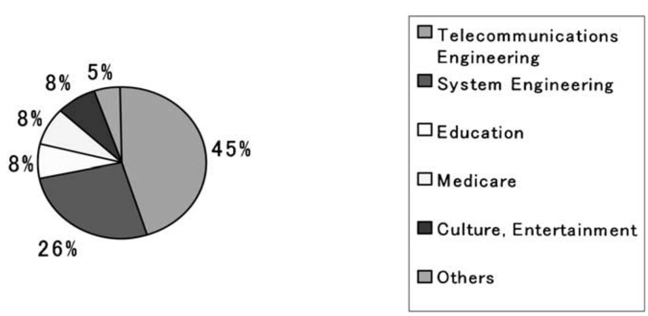


Fig. 12. Usage of JGN by research areas.

On the basis of intensive analysis it was clearly recognized that remediation of Japan's lost institutional elasticity has become crucial as advancement of IT and subsequent economic globalization has highlighted global, invisible, interactive, disseminative and coevolutional features, leading to an increased significance of institutional elasticity, thus constructing a virtuous cycle.

With the understanding of the significance of complement for remediation of the lost institutional elasticity, it was realized that systems functions of an IT testbed can play a significant role in inducing and diffusing new technology, and given the unique features of IT, an IT testbed is particularly important. With such systems functions as predictability, observability and triability, an IT testbed can provide services to demonstrate hidden benefits, instill confidence by providing visuality, and stimulate learning exercises leading to construction of a virtuous cycle between IT inducement and diffusion. These services correspond to requirements for complementing the constraints of Japan's institutions. Thus, an IT testbed can unexpectedly play a significant role in the remediation of Japan's lost institutional elasticity.

Based on a case evaluation of the Japan Gigabit Network, an IT testbed enabled bypass of the direct interaction between the new technology and Japan's solid institutions such as homogeneous and risk-averse nature, and the hypothesis that an IT testbed can contribute to the remediation of Japan's institutional elasticity was demonstrated.

In line with the progress of the demonstration research utilizing the Japan Gigabit Network, further empirical analyses are expected to provide additional insight with respect to the significant complementary role that an IT testbed contributes, leading to the further demonstration of the particular significance of an IT testbed for remediation of Japan's lost institutional elasticity.

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