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Co-evolution between internal motivation and external expectation as a source of firm self-propagating function creation

Chihiro Watanabe [a,*], Masayo Hobo [b]

[a] *Department of Industrial Engineering & Management, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8552, Japan*
[b] *ViryaNet Japan Ltd., 4-12-2 Shiba, Minato-ku, Tokyo 108-0014, Japan*

Abstract

A rapid surge in information technology (IT) around the world is forcing firms to transform their traditional practices to a co-evolutional structure with external expectations. IT differs from other technologies in that it is characterized by dynamically increasing multiplier effects through network externalities, and its unique nature is formed during the course of interaction with institutional systems. Under the new paradigm of an information society, while the advanced innovation-oriented projects of firms are undergoing a structural change, Japan's institutions do not function as efficiently as they did in the 1980s. As a result, Japan is experiencing a vicious cycle between non-elastic institutions and insufficient utilization of the potential benefits of IT that impedes the structural change efforts of firms. A novel concept for overcoming this impediment was triggered by the introduction of Enterprise Resource Planning (ERP) software that induces active interaction with institutional systems, thereby maximizing the benefit of network externalities leading to the creation of a firm's self-propagating function. The advanced innovation-oriented projects of firms can be expected to develop in the process of embodying this function. Prompted by the dramatic advancement of ERP software, this paper, on the basis of an empirical analysis of the interaction between the introduction of ERP software and the creation of new functional business practices thereon attempts to demonstrate the foregoing hypothetical view with respect to advanced innovation-oriented projects of firms in the light of a new paradigm.

Keywords: Advanced innovation-oriented project; Interaction with institutions; Self-propagating function; ERP

1. Introduction

A rapid surge in information technology (IT) around the world is hastening Japan's paradigm shift from an industrial society to an information society leading to transformation of traditional firms business practice (Watanabe et al., 2001). Since IT waves are characterized by dynamically increasing multiplier effects through network externalities[1] (e.g. Ruttan, 2001, US DOC, 2000a) that construct a self-propagating "virtuous cycle" between the expanding number of users and the rising value of networks (Watanabe et al., 2002), IT not only enhances task efficiency but also permeates an organization to have an impact on structure and behavior. Thus, full utilization of the potential benefits of IT depends on the flexibility of individuals, organizations and societies. This "institutional elasticity" is a prerequisite for nimbleness and adoption in business practice (Watanabe and Kondo, 2002). If IT is merely introduced to replace part of the workforce so as to improve productivity, as was the case with automation, the full benefits of IT are not fully utilized.

Although IT waves are also gaining strength in Japan, Japan does not seem to utilize fully the potential benefits of IT. Comparative analyses of IT and productivity have revealed that Japan's IT contribution to productivity is far behind the average level of developed countries (e.g. Dewan and Kraemer, 2000; OECD, 2001). Dewan and Kraemer, for example, demonstrate that Japan's productivity level (average GDP per worker over 1985–1993) was much lower than that explained by the level of IT capital stock per worker. A similar trend can be found also in the OECD's analysis (OECD, 2001).

During the period of industrialization of society

* Corresponding author. Tel.: +81-3-5734-2248; fax: +81-3-5734-2252.
E-mail address: chihiro@me.titech.ac.jp (C. Watanabe).

[1] The value to a consumer of product increases as the number of compatible users increases (Oster, 1994).

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initiated by the manufacturing industry, Japan's domestic institutions[2] functioned efficiently towards catching-up (Watanabe, 1995). In the 1990s, Japan's economy dipped in contrast to the strong growth in preceding decades. Facing a new paradigm characterized by a shift to an information society, Japan's traditional institutions do not function efficiently as they did in preceding decades (Watanabe, 1999). Consequently, a "virtuous cycle" between institutional elasticity and economic development changed to a "vicious cycle" between non-elastic institutions and economic stagnation. This vicious cycle resulted in the loss of Japan's international competitiveness leading to further economic stagnation and even more loss of institutional flexibility (Watanabe et al., 2002).

The OECD (1997) analyzed the potential of IT to "automate" and "informate." It observed that more relative emphasis has been given to the "automate" option and that IT has often been introduced into organizations that were shaped independently of it. Thus, if an organization can re-engineer itself to shift the balance away from the "automate" option towards the "communicate" option, it can become a learning institution with successively increasing new sets of skills.

Accordingly, IT differs from other technologies since individuals, organizations, and societies, or departments, firms and enterprises use it to interact, and its unique nature is formed dynamically through this interaction. Institutions behave differently depending on institutional elasticity. In other words, the unique nature of IT is formed during the course of interaction with institutional systems (e.g. Cairncross, 1997; US DOC, 2000b).

Following their induced innovation concept (Binswanger and Ruttan, 1978) Ruttan (2001), in his postulate of "institutional innovation," suggests that "institutions are the social rules that facilitate coordination among people by helping them form expectations for dealing with each other" and also that "they reflect the conventions that have evolved in different societies regarding the behavior of individuals and groups." Consequently, the unique nature of IT can be identified in the diffusion process with respect to institutional systems.

Research on the diffusion process of innovation has been undertaken in broad fields and Rogers (1962) attempted to systematize these works in his pioneer study "Diffusion of Innovations." He defined "diffusion" as the process by which an innovation is communicated through certain channels over time among the members of a social system. He also identified four main elements in the diffusion of innovations: innovation features, communication channels, time, and social system. All of Rogers's postulates support the foregoing view that the unique nature of IT can be identified in its diffusion process, particularly interaction with institutional systems.

In the past, IT deployments in firms were chiefly aimed at in-house development, furthermore, the project objective was aligned with the end-user's objective, such as shortening the delivery time/development cycle, quality improvement, and cost reduction. This is also the case in application software development. In terms of application software, the issue was how actively to involve the end-users for defining their requirements, application design and function test processes. These are the most critical success factor.

However, since this type of application development style causes a longer development cycle and logical database fragmentations increasing risk, it has become crucial for firms to actively interact with the institutions in a way that responds to external requirements, and positively stimulates external change in order to maximize the benefit of network externalities.

This trend compelled firms to pay serious attention to the co-evolution of customer satisfaction and sustaining their strength by focusing on their core competence and differentiation in non-core competence processes through out-sourcing. However, Japan's institutions are not flexible enough to achieve this.

A novel concept enabling firms to overcome this impediment is the deployment of Enterprise Resources Planning (ERP) software. ERP software offers an integrated data model and simplified business processes (Sakakibara, 1999). It has thus become popular as the cooperate-wide IT solution in the information driver to corporate world of the 1990s.

While Japan is experiencing a vicious cycle between inflexible institutions and insufficient utilization of the potential benefits of IT, the success of the i-mode service (NTT DoCoMo's mobile Internet access service) at the end of the 1990s opens the door to greater flexibility. This is due to a growing familiarity with mobile information technology and its integration into standard communication processes. The dramatic advancement of ERP in a co-evolutional way prompts us to examine a business practice. One of particular interest is the implication for advanced innovation-oriented projects.

To date, a number of studies have reviewed the development of ERP software (e.g., Sakakibara (1999), but none has analyzed the "self-propagating" phenomenon based on the technology and human interaction.

This paper, on the basis of an empirical analysis of the interaction between the introduction of ERP software

[2] While a scope of institutions is broad with multi-layer structure and their system concept is not necessary uniformed, Watanabe and Kondo (2002) identified the role of institutions as a stimulator of technological innovation and diffusion as follows: Institutions can be manifested as the soft instrument which stimulates interaction between internal technology (quality and quantity of resources of R&D) and external technology by coordinating external technology consisting of "economic environment," "physical and natural environment," "social and cultural environment" and policy system.

and the creation of new functional business practice attempts to demonstrate the foregoing hypothetical view with respect to firms advanced innovation-oriented projects under a new paradigm.

Section 2 provides an analytical framework by identifying specific features of IT. Section 3 attempts to demonstrate the hypothetical view by conducting an empirical analysis. Section 4 outlines interpretations of the results of this analysis and Section 5 briefly summarizes the key findings and presents conclusions.

2. Mechanism in IT's new functionality development—an analytical framework

As emphasized in numerous studies, IT is a driving force transforming the existing socioeconomic structure by permeating people's daily lives, organizational activities, and society as a whole (e.g. Cairncross, 1997; US DOC, 2000a; MPT, 2000; Telecommunications Council (2000).

Table 1 compares the features of the core technologies in the 1980s and in the 1990s. During the 1980s, developing streamlined manufacturing technology was critical for firms' success in an industrial society. Manufacturing technology was developed by the supply side to provide end-users with products and was introduced to factories to replace part of the workforce for improving productivity. Like other technologies, features of manufacturing technology are established or programmed at the beginning, and once it leaves the supply side, it does not change its basic use substantially during its dissemination. In this case, individual firms were responsible for developing this technology to meet specific production needs.

With information technology (IT) development, and increased electronic connectivity in the 1990s, socioeconomic activities rely more on IT infrastructure. This has made business transactions and information exchange easier and cheaper, leading to the expansion of e-commerce (US DOC, 2000a) and moving the end-user or customer into the business process The end-user as a participant in this process engages in the development of the medium (IT) as well as the product or service, as summarized in Table 2.

These observations demonstrate that since IT products are often utilized as a communication tool, and exist in a complex technological 'web,' unlike manufacturing technology, suppliers of IT are more concerned about compatibility. On the other hand, any home appliances such as refrigerators or TV sets, can be purchased without being constrained by compatibility issues related to the technologies people possess, with the exception of electricity. In this context, IT products are subject to network externalities. With computers and telephones, for example, the more people use compatible systems or the more people are on a network, the more valuable the system or the network becomes, thus attracting more potential users (Ruttan, 2001).

In short, IT strongly possesses a self-propagating feature that closely interacts with individuals, organizations, and society during the course of its diffusion and behaves differently depending on the institutions involved. These observations suggest that functionality is formed dynamically during the course of interaction with institutions. Furthermore, whether the potential benefits of IT can be exploited largely depends on the nature of these institutions (Watanabe et al., 2002). However, as reviewed in Section 1, Japan does not fully utilize the potential benefits of IT because of its non-elastic institutions. In this situation, full utilization of the potential benefits of IT in a firm's business activities can be expected only in the process of shifting a "vicious cycle" to a "virtuous cycle" by embodying IT's self-propagating function in their business activities. Therefore, this process provides a constructive opportunity for firms strategically to accelerate advanced innovation-oriented projects.

With this objective in mind, Fig. 1 shows the dynamic framework in the IT functionality development process. In the process of IT diffusion, the number of customers increases as time passes, which induces interactions with institutions, leading to increasing potential customers by increased value and function as the network externalities

Table 1
Comparison of features between manufacturing technology and IT[a]

	1980s	1990s
Paradigm	Industrial society	Information society
Core technology	Manufacturing technology	IT
Fundamental nature	As given	Self-propagating
Key features formation process	**Provided by suppliers**	**To be formed during the course of interaction with institutions**
Actors responsible for formation of features	Individual firms/organizations	Institutions as a whole

[a] Source: Authors' elaboration based on Watanabe et al. (2002).

Table 2
Shift in firms IT focus from the 1980s to the 1990s

	1980s	1990s
Project scope	Individual process	Series of business processes
Objective	Quality, cost, delivery time	ROI, customer satisfaction
Outcome for	End-user	Management, customer
Initiator	End-user	Strategy planning
IT development	Make (In-house)	Buy (standard package)
TAT	Year	Month

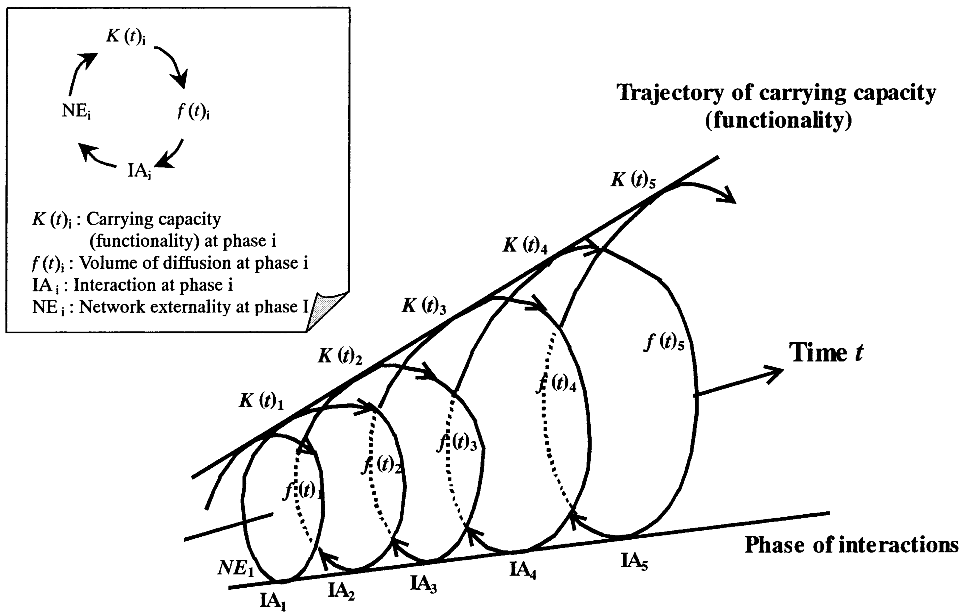

Fig. 1. Dynamism in creating IT's new functionality: self-propagating structure. Source: Authors' elaboration based on Watanabe et al., 2002.

gain momentum. Thus, IT creates new demand in this development process and new functionality is formed which, in turn, enhances customer interaction. Thus, the interactive self-propagating behavior continues (Watanabe et al., 2002). This suggests that when firms are inflexible, one mechanism for reconstructing the "vicious cycle" is to integrate IT into their business processes, particularly those involving the end-user.

Prompted by this hypothesis, the rest of this paper will extract suggestions for achieving this turn-around. Noteworthy observations in this regard can be obtained in the development and diffusion process of software. Contrary to the traditional business management concept, ERP depends on a concept of co-evolution as highlighted in Table 3. This unique co-evolutional concept of ERP enables firms at least to help the gain potential to change their trajectory. An empirical analysis is conducted taking a case of ERP's achievement in constructing this self-propagating structure. From this, we draw suggestions with broad applications for similar business transformations leveraging IT.

3. The interaction between ERP software introduction and the creation of new functional business practice—an empirical analysis

In IT deployment in the firms, the application areas and methods were dramatically expanded in the later part of the 1980s while application system development was

Table 3
Identity of ERP concept

	Traditional business management concept	ERP concept
Optimization point	Integration of individual optimization	Total optimization
Information sharing	Solid ownership	Co-sharing
Process evolution	Individual evolution	Co-evolution

limited in functional areas such as payroll, accounting, CAD/CAM and production control in the 1970s and the early 1980s. While this expanded application was a key improvement for firms, it still remained within the area of isolated segments in a series of business processes. However, stimulated by the strong requirement to shorten the lead-time that emerged in the end of the 1980s, firms realized the constraints of the limited application areas, and attempted a continuous improvement in each segment leading to a review of the data-processing from the business process point of view. The focus of firms' efforts has shifted from the optimization of each segment to the optimization through the entire processes, including interaction with customers. This shift revealed the impediments of separately developed software. Integration of these separate processes and databases is really tough for firms as it requires significant interaction between different entities of the institutional systems. Generally these entities have been isolated, and the managing system developed independently into information silos. Overcoming this hurdle led to ERP software which appeared in the market in the early 1990s (Sakakibara, 1999). ERP enables the co-evolution of systems and induces active interaction between developers and customers by offering an integrated data model and a rationally simplified process model as compared in Table 4.

ERP aims to control the resources, particularly capacity and capital, in the enterprises to track the real-time status of the enterprise to react promptly to the changes. It originally started from the accounting application, enabling the real-time integration of accounting information and transactions throughout the firm. ERP software was originally designed based on an integrated data model that covered all the data in the enterprise and the process model needed to manage the enterprise's resource planning and controlling application. From the late 1980s to the beginning of the 1990s with business process re-engineering, ERP aimed at shortening and simplifying the business processes. Subsequently, ERP software was recognized as a useful business process re-engineering tool. At the same time, in order to save the cost of in-house application software development, as well as to shorten the development time, standardized software became popular from the management perspective. The growth of the standard software business and the number of installations boomed. In Japan, the first ERP software, SAP R/3, released in the market in the end of 1993, then rapidly diffused in large Japanese firms such as Mitsubishi Corp., Sony, Hitachi, Nissan and Ricoh. SAP maintained the top share of the ERP market since then, and continuously expanded its business globally as demonstrated in Fig. 2. Currently, more than 800 companies are SAP customers in Japan and more than 13,000 customers worldwide in 110 countries. Fig. 2 suggests that firms' ERP introduction has dramatically increased in the later part of the 1990s, particularly since 1997.

In the development of ERP software, how to maintain continuous incorporation of customers' requirements into the software is essential, since how well to support the various qualified business scenarios, i.e., so-called 'Best Business Practices' is a critical requirement for ERP software. For standard pre-packaged software, not only the quantity of the business scenarios, but also their quality, are carefully evaluated by the market, particularly the requirements to change the data model and/or process model should be carefully examined, since the magnitude and workload delivered from the change is enormous. Even a simple increase in the number of scenarios sometimes increases the complexity of the logic with negative repercussions. In order to avoid this negative effect, the ERP vendor has to assess carefully what requirements are worth being incorporated in their products. Therefore, in the development of ERP software, the vendor must establish processes which incorporate market feedback as the first hand requirements for development, and also in order to co-evaluate both internal (functionality development) and external (market needs and usability). The most practical and, at the same time, most successful way to achieve this target is to examine certain customer firms who need this new business scenario, and encourage them to participate in the development team organized by the ERP vendor.

These customer firms are valuable platforms to evaluate the original development requirements in firms. The most important strategy is to sustain the continuous co-interaction between developers and customers with respect to the analysis of their requirements, conceptualization, and function test. For the ERP vendor,

Table 4
Comparison of conventional software and ERP software

	Conventional software	ERP software
Database	Separated by application	Integrated by data model Logical single database
Data	Duplicated	One data at one place
Processes	Fragmented	Seamless integration
Transaction	Real-time/batch	Real-time

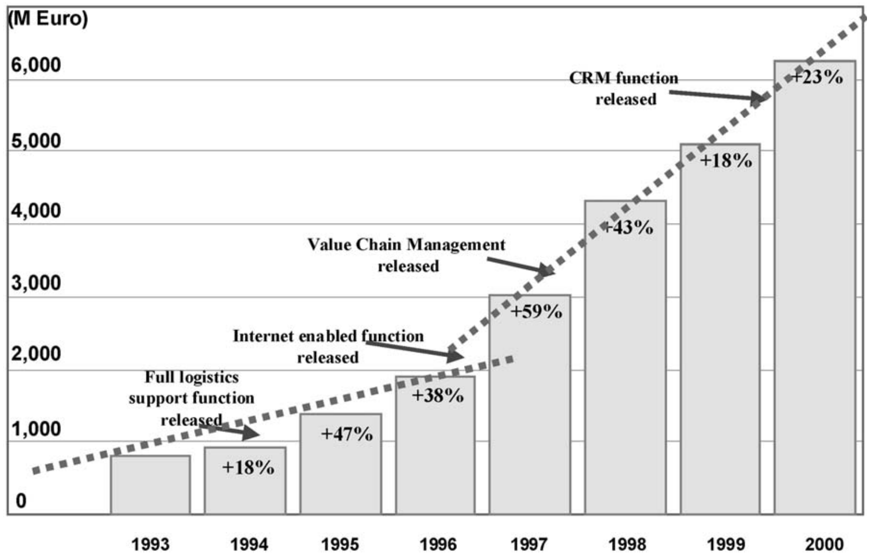

Fig. 2. Trend in SAP worldwide annual revenue (1993–2000). Source: SAP Annual Report (SAP, 1993–2000, 2001).

through this interactive processes and pilot project exercises, the emergence of customized software leads to a market situation where new functionality has been already proven by customers in the real marketplace. This provides extremely strong evidence that the software under development is useful and effective in the real market. Through this process, successful ERP software is developed and diffused smoothly into the market.

This success in ERP software development and diffusion can be attributed to the following interactive processes between the software vendor and customers:

1. **Develop business practice requirements (target business scenarios)**. When the customer starts an ERP project, the first important action is to conduct fit and gap analyses. Supported by consultants who know both the customer's business and function. The customer examines how to implement their business scenarios onto the software. When some gaps are found, consultants suggest how to resolve them with minimum effort and changes to the software. Gaps that could not be solved by 'work-around' solutions are reported to the ERP vendor as a Development Request (DRQ). Describing the business background and philosophy of each DRQ is critical, since it explains only functional requests. Developers often reject this, as it makes the process complicated, and no improvement can be shown as the outcome.
2. **Providing new functionality**. Developers collect the inputs as the DRQs for the new release. They prioritize all the requirements by strategic importance for the market and customers, urgency, and the magnitude of the impact to the existing logic. They also need to consider synchronizing to the periodical release of the upgraded version of software. Once developers recognize DRQs as high-level requirements to fulfill the strategic business scenario which is missing in the current software, developers obtain additional input from both customer support and the marketing point of view. Then, developers initiate meetings with the customers who submitted the DRQ to finalize the designs and specifications, both for the local customer and developers. At the customer site they have an opportunity to see how customers run their business. These experiences help developers understand business requirements promptly and appropriately. In the case where DRQ relates to in-depth accounting and logistic application, it is very tough to finalize how to develop the scenario in the current existing function. In this case, they propose to the customers to build the light prototype system to assure the functional requirement by themselves. In addition, several demonstration systems are built and examined. Usually, functionality is released as the temporary solution to the original customer within a year, to review how it would fit in to their real business processes. On the customers' side, they build the project team to implement the new software function in their live business processes.
3. **Business process innovation**. The DRQ submission triggers business process innovation. Once developers draw interest in the requirements, the discussion cycle starts, as explained in (2). In parallel, through the deep debate on the business scenario, customers find a better way to conduct their business. This represents co-evolution between customers and the software vendor, not only in terms of the software solution to support the business process but also in offering the opportunity to improve the targeted business process itself. Customers' internal improvement process itself quite often leads to a better way of executing their

business, since the target of the development is the processes and they are changing and improving this day by day in a rapid manner. Furthermore, in the real business situation, all the innovations that emerged in the business world are forwarded as significant inputs to the software.

4. **Further business requirements**. While using the temporary solution in their real business processes, customers are able to find out some additional requirements for improving their businesses. As explained in (3), not only from the software point of view, but also a new way of business is discovered from time to time, leading to new requirements. These requirements are summarized, together with the business needs and expected outcome, and are submitted to the developers.
5. **Provide standardized functionality**. After a few temporary releases are provided to the original requested customer, the ERP vendor finally provides the function as a standard, leading to the delivery of this function to all existing customers globally. Then, any companies that use this software have the opportunity to achieve the innovation which the original DRQ claimed.
6. **Broader customer involvement**. Attributed to the standard version, many existing customers all over the world gain an opportunity to testify to the new additional functionality which stimulates the function's applicability throughout the industry. Through this process, the software itself is proven as a global standard, which results in gaining an even greater number of customers, as well as enhanced business processes throughout a given industry.
7. **Broader business requirement**. In addition, more requirements are expected to be raised from the customers. The important point is that developers always benchmark their requirements, to see how strategic and how important they are. Therefore, if the functionality is flawed, it does not always become the standard function. This sophistication in the system is also the key to developing an excellent standard software, therefore, they pay close attention to offering better ways to do their business.
8. **Providing more standardized and improved functionality**. With the inputs from worldwide new customers, developers gain the opportunity constantly to provide more improved software. For example, the Internet enabled customers much easier and less expensive access, even higher than the interaction between customers and partners. Not only are these functional improvements but also technological improvements which can be spurred by customers' requirements.

These co-evolving processes between the ERP vendor and external institutions can be summarized as follows:

1. The customer **develops business practice requirements** (target business scenarios),
2. In response to the requirements, the software vendor (SV), **provides new functionality**,
3. Spurred by this new functionality provided by the SV, **business process innovation** emerges on the customer side,
4. **Further business requirements** emerge as business process innovation progresses,
5. Induced by broad business requirements, the SV **provides standardized functionality**,
6. As the standardization proceeds, **broader customer involvement** is accelerated,
7. Broader customer involvement generates **broader business requirements**, and
8. Broader business requirements stimulate the SV to **provide more standardized and improved functionality**.

These co-evolutional processes between the internal motivation of the software vendor and its external expectation in the market leads to a self-propagating structure as illustrated in Fig. 3 resonating with the framework described in Fig. 1.

Looking at Fig. 3 we note that the number of customers increases as time passes, which induces new functionality development in the software vendors leading to increasing potential customers by increased functionality stimulated by network externalities.

As a result of the above self-propagating processes, there is an increase in new functionality development as interactions proceed which dramatically increases the number of customers with higher quality dependency on ERP software as demonstrated in Fig. 4. This, in turn provides more demanding requirements to the software vendor.

Fig. 4 demonstrates this dynamic cycle by summarizing top ERP software customers in 14 industries in Japan and comparing customers introduced ERP software in 1995 and 2000.

Looking at Fig. 4, we note the following findings:

1. The number of customers dramatically increased over the period 1995–2000 which corresponds to trends in SAP worldwide annual revenue illustrated in Fig. 2.
2. Until 1995, bigger firms share majority of customers in 2000.
3. Typical high-technology industries such as electric machinery and pharmaceuticals introduced in earlier years are demonstrating their business practices were streamlined in the software in the early years in 1990s.
4. Unlike these high technology industries, the general trading industry started ERP implementation only recently since trading practices of this industry were too unique to be standardized by the software. This

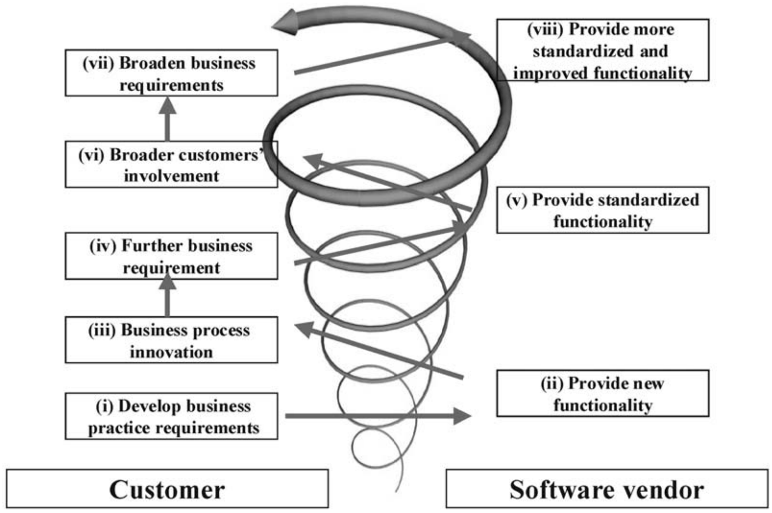

Fig. 3. Self-propagating structure based on co-evolutional processes between internal motivation of software vendor and its external expectation.

	1	2	3	4	5	6	7	8	9	10
ELECTRIC	HITACHI 13	MATSUSHITA 17	TOSHIBA 36	SONY 43	NEC 48	FUJITSU 61	MITSUBISHI ELE. 62	SANYO 183	SHARP 185	NIPPONDENSO 236
PHARMA.	TAKEDA	SANKYO	OHTSUKA	YAMANOUCHI	SHIONOGI	SUMITOMOSEIYAKU	FUJISAWA	EIZAI	TANABE	TAISHO
CHEMICAL	MITSUBISHI KASEI 246	ASAHI KASEI 306	FUJI PHOTO FILM 372	SUMITOMO KAGAKU 172	DAINIPPON INK 453	KAO 490		SHOWADENKO	UBE KOUSAN	SHISEIDO
FOOD	JAPAN TABACCO 175	KIRIN BEER 435	SUNTORY 494	ASAHI BEER	AJIMONOTO	SAPPORO BEER	NIPPON HAM	YUKIJIRUSHI	YAMAZAKI BREAD	ITO HAM
AUTO	TOYOTA 11	NISSAN 23	HONDA 45	MITSUBISHI MOTOR 55	MAZDA 112	ISUZU 204	SUZUKI 270	FUJI JYUKO 336	DAIHATSU 483	HINO
TRADE	MITSUBISHI 1	MITSUI 2	ITOCHU 3	SUMITOMO 4	MARUBENI 6	NISHO-IWAI 9	TOMEN 18	NICHIMEN 24	KANEMATSU 25	TOYOTA TSUSHO 179
OIL	JAPAN ENERGY 203	IDEMITSU 223	COSUMO 284	SHOWA SHELL 304	MITSUBISHI OIL 454	JAPAN ENERGY	NIPPON OIL SEISE	GENERAL	TOHNEN	KYUSYU OIL
PRECISION	CANON 148	RICOH 373	CITIZEN 406	NIKON	MINOLTA 469	OLYMPUS	SHIMAZU SEISAKU	DAINIPPON SCREEN	HOYA	SANKYO SEIKI
COMM.	NTT 16	NTT DATA	KDD	DDI	TBS	NIPPON TELECOM	NIPPON TV	ALL JAPAN ASAHI	TV TOKYO	ASAHI HOSO
SERVICE	DENNTSU	NIPPON LEASE	NINTENDO	HAKUHODO	KOUGIN LEASE	SEGA	CENTURY LEASE	NTT IDO	NIPPON DENSHI	HITACHI LEASE
RETAIL	DAIEI 65	ITO-YOKADO 80	JUSCO 141	NICHII 217	SEIYU 257	TAKASHIMAYA 299	MITSUKOSHI 379	DAIMARU	UNY	MARUI
BANK	JAPAN INDUSTRIAL67	FUJI 73	MITSUBISHI 74	SUMITOMO 76	SANWA 78	DKB 91	SAKURA 93	NIPPON LONG TERM 100	NOURIN CHUKIN 124	TOKYO 173
ELECTRIC POWER	TOKYO 32	KANSAI 96	CHUBU 131	TOHOKU 224	KYUSHU 240	CHUGOKU 360	HOKKAIDO	SHIKOKU	HOKURIKU	DENGEN KAIHATSU
GAS	TOKYO GAS 418	OSAKA GAS	TOHO GAS	SEIBU GAS	KEIYO GAS	HOKKAIDO GAS	HIROSHIMA GAS	HOKURIKU GAS	SHIZUOKA GAS	CHUBU GAS

Fig. 4. Top 10 ERP software customers in 14 industries in Japan.

finally emerged as one of the industry specific solutions in 1997.

In order to demonstrate the hypothesis that new functionality development coincides with the introduction of ERP software, a numerical analysis is attempted focusing on the diffusion process of ERP software using an epidemic (logistic) function within a dynamic carrying capacity.

Following Mayer and Ausubel (1999), logistic growth within a dynamic carrying capacity approach demonstrates the distribution of innovation waves which, as Kodama (2000) and Watanabe et al. (2002) demonstrate, entail major features of functionality development.

The diffusion process of innovative goods is generally expressed by the following epidemic (logistic) function:

$$f(t) = \frac{K}{1 + a\exp(-bt)} \tag{1}$$

where $f(t)$: number of adopters; a and b: coefficients; K: carrying capacity (ceiling of the adoption of innovative goods); and t: time trend.

The epidemic function expressed by Eq. (1) assumes that the level of carrying capacity $K(t)$ is constant through the dissemination process of innovation. However, as reviewed in Section 2, in particular innovations typically observed in IT, this is a correlation between the innovation and institutions displays a systematic change in the process of growth and maturity leading to the creation of a new carrying capacity in the process of its diffusion. In these innovations, the level of carrying capacity will be enhanced as their diffusion proceeds, and carrying capacity K in Eq. (1) should be treated as the following function:

$$\frac{df(t)}{dt} = bf(t)\left(1-\frac{f(t)}{K(t)}\right) \quad (2)$$

where $K(t)$ is also an epidemic function enumerated by Eq. (3).

$$K(t) = \frac{K_K}{1 + a_K \exp(-b_K t)} \quad (3)$$

where a_K and b_K: coefficients; and K_K : carrying capacity (the ultimate upper limit).

The solution of a differential Eq. (2) under the condition (3) can be obtained as Eq. (4).

$$f(t) = \frac{K_K}{1 + a\exp(-bt) + \frac{b \cdot a_K}{b-b_K}\exp(-b_K t)} \quad (4)$$

When a_K=0, Eq. (4) is equivalent to Eq. (1). Thus, Eq. (4) is a general function of the epidemic behavior encompassing a simple logistic growth function.

Utilizing Eq. (4) and applying the stock of ERP software assets over the period 1993–2000,[3] trends in the diffusion process of ERP software is estimated as illustrated in Fig. 5 and summarized in Table 5.

Table 5 demonstrates that all indicators are statistically significant[4]. The adjusted R demonstrates that the logistic growth function within a dynamic carrying capacity approach represents the actual diffusion behavior of ERP software in the market place. Parameters a_K and b_K demonstrate statistically significant suggesting the following dynamic carrying capacity, not the behavior of simple logistic growth:

$$K(t) = \frac{6.35}{1 + 0.46\exp(-0.03t)} \quad (5)$$

Eq. (5) suggests that carrying capacity continues to increase with slight logistic behavior as demonstrated in Fig. 5. This behavior demonstrates that new functionality develops as ERP software diffuses. All the above findings demonstrate the foregoing hypothesis with respect to self-propagating structure of ERP software.

4. Interpretation of the result of the empirical analysis

Fig. 6 illustrates the direction of firms' strategic business over the last two decades and corresponding development trajectory of ERP.

As described in the beginning of Section 3, ERP came into the market to improve the total efficiency and optimization of the enterprises. Since this new concept first emerged in the application software, its functional scope has been continuously expanded as demonstrated in Fig. 6. SCM (Supply Chain Management) software focuses on the solution of the entire optimization and planning for entire supply chain, and CRM (Customer Relationship Management) software focuses on the interaction between firms and customers as significant entity. This ERP development trajectory corresponds to the direction of firms' strategic business over the last two decades. The original ERP aims at shifting IT as the tool to streamline the firm's business to enterprise-wide business process re-engineering. Achievement of the re-engineered business processes led to simplified and optimized ways of doing business. At this first stage, firms deployed the best business practices in a standard function. Then, at the second stage, they need to create better business practices. At this stage, a self-propagation function between the software vendor and customers enabled the enhancement of business process reengineering to business invention. Through these processes, firms succeeded in constructing strategic business scenarios inducing customers' involvement into new inovation.

As explained in Section 3, eight processes driven by network externalities between the software vendor and customer provide dramatic outcomes to both sides. For the software vendor side, these processes bring two advantages: First, they accelerate an improvement in the depth of the functionality. As long as customers use the functionality in their institutions and continuously submit DRQs to the software vendor to improve the function, the software itself continues to evolve. Second, they accelerate to enhance the coverage of the software vendor offers the upgraded functionality continuously over the industry, over the country, it become more and more standard and proven software. In the situation, then, this self-propagating function process once established, it automatically proceeds and continuous innovation is created. At the same time, as for the customer side, the above processes provide customers opportunity to periodically get the new releases of the software, which every-time is enriched by industry-wide and worldwide customers' requirements. When compared with conven-

[3] Stock of ERP software assets at time t T_t is measured as follows: $T_t = S_t + (1-\rho)T_{t-1}$ where S_t: SAP's worldwide annual revenue (half year base) at 1995 fixed prices; and ñ: rate of obsolescence of ERP software assets. SAP annual report for its annual revenue and EU GDP deflator for 1995 fixed prices are used. Considering an average life time of ERP software, ñ is estimated 10% p.a.

[4] Since stock of ERP software assets are used for this analysis and the stock of assets depend on the previous period, DW is structurally far low than 2.

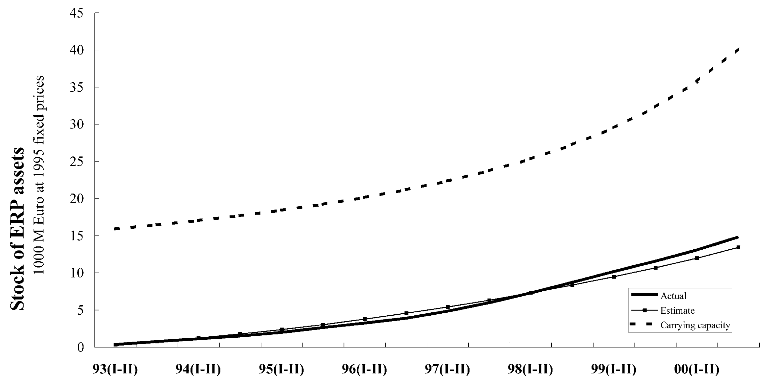

Fig. 5. Trends in the diffusion process of ERP software (1993–2000).

Table 5
Comparison of the fit of logistic growth function within a dynamic carrying capacity for the diffusion process of ERP software (1993–2000)[a,b]

K_K	a	b	a_K	b_K	adj. R^2	DW
6.35 (2.45)	12.96 (2.42)	0.31 (34.06)	0.46 (2.43)	0.03 (1.66)	1.000	0.79

[a] Parameters are indicated in the following function: $f = \dfrac{K_K}{1 + a\exp(-bt) + \dfrac{b\cdot a_K}{b-b_K}\exp(-b_K t)}$.

[b] Figures in parentheses indicate t-value.

tional software development in the 1980s by individual company, it dramatically saves IT cost and delivery time of the software. Moreover the offered business scenarios which customers themselves have not yet been aware of the potential contribution to the better business. For the software vendor, it has spent almost ten years, finally they achieved to establish the stable self-propagating system.

Fig. 3 demonstrates the spiral cycle of a self-propagating structure illustrated in Fig. 3, the influence and power of improved products through this self-propagating process develop further profound direction in depth and width. Table 6 summarizes a development path of ERP functionalities in the 1990s by tracing trends in functionalities of SAP.

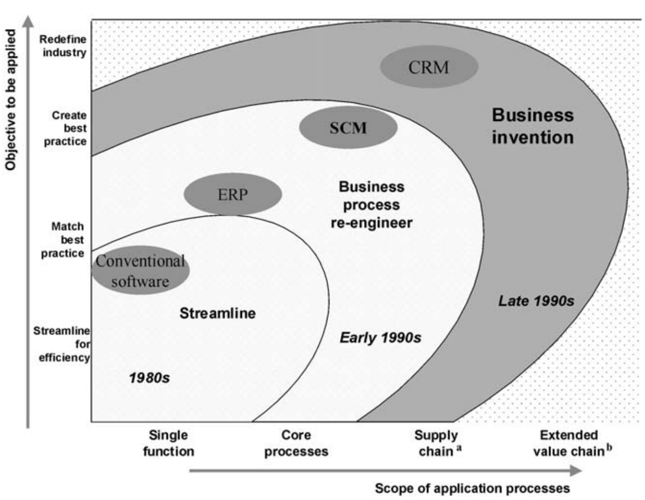

Fig. 6. Scheme of the direction of firm's strategic business and corresponding development trajectory of ERP.

During the course of the 1990s, many of strategic functionalities were released to customers almost every year as a standard version. In order to demonstrate an evidence how this self-propagating function has been appropriately established and worked well, take SAP as an example, in 1996, JSUG (Japan SAP User Group) was organized voluntarily by customers. This association aims at sharing the experience and information for the implementation of SAP R/3. They are also eager to lobby strategic requests to SAP. As is shown in Table 6, the number of involved customers has steadily increased. As the activities in the user group, they form active study groups by industry, by function, and by technology. The number of these study groups also has steadily increased and now it covers functions and industries. All these facts relevant to development trajectory of ERP development and diffusion provide profound background supportive to integration of the results of the empirical analysis demonstrated in Section 3.

Table 6
Development path of ERP functionalities in the 1990s by year[a]

Year	Version	Topics	No. of customers in Japan user group	No. study groups in Japan user group
1993		First Japanese version	N/A	N/A
1994	2.1	Windows NT version	N/A	N/A
	2.2	Logistics function		
1995	3.0		N/A	N/A
1996	3.1	Internet enabled function	69	6
1997	3.3	Value chain (supply chain management) function	114	11
1998	4.0	Industry specific solution released	147	14
1999	4.6b		186	17
2000	4.6c	mySAP.com released	213	20
		CRM (Customer relationship management) 2.0		
2001		CRM 3.0	257	N/A

[a] Source: JSUG Annual Report (1998–2000) JSUG 1998–2000, 2001.

5. Conclusion

The rapid surge in IT around the world is forcing firms to transform their traditional practices to a co-evolutional structure with external expectations. While the advanced innovation-oriented projects of firms are undergoing a structural change, Japan's vicious cycle between non-elastic institutions and insufficient utilization of the potential benefits of IT under the new paradigm of an information society impedes their structural change efforts. This paper focuses on a novel concept of ERP software corresponding to a co-evolutional concept, and attempts to demonstrate that the firms' advanced innovation-oriented projects can be expected to develop by overcoming the foregoing impediment in the process of embodying a self-propagating function through the interaction between the introduction of ERP software and the creation of new functional business practices thereon.

First, with the recognition that full utilization of the potential benefits of IT in firm's business activities is essential for the firms' advanced innovation-oriented projects and that full utilization can be expected only by shifting a vicious cycle between non-elastic institutions and insufficient utilization of the potential benefits of IT to a virtuous cycle, IT's feature formation mechanism was analyzed.

On the basis of this analysis, it was identified that IT possesses a self- propagating feature that closely interacts with institutions and that new functionality is formed dynamically during the course of interaction with institutions. This identification provided an analytical framework and also led to an empirical analysis of the development and diffusion process of ERP software.

An empirical analysis of the development and diffusion process of ERP software focusing on the interaction between its introduction and the creation of new functional business practices demonstrates the following:

1. ERP corresponded to the shift in firms' focal efforts to shift from the optimization of individual process to the optimization through the total processes including interaction with customers, and firms' ERP introduction has dramatically increased in the later part of the 1990s, particularly since 1997.
2. In the course of this development and diffusion, the following co-evolutional processes which resemble IT's unique nature formation process were observed.
3. The customer raises business practice requirements,
4. The software vendor (SV) provides new functionality responding to customer's requirements,
5. Business process innovation emerges in customer side spurred by this new functionality,
6. Further business requirements emerge as business process innovation progresses,
7. The SV provides standardized functionality induced by broad business requirements,
8. Broader customer involvement is accelerated as the standardization proceeds,
9. Broader business requirements generated by broader customers' involvement, and
10. Further standardized and improved functionality are stimulated by these broader requirements.
11. These co-evolutional processes leading to self-propagating structure were demonstrated by a trend in top ERP software customers in Japan's 14 industries and also a numerical analysis using an epidemic function within a dynamic carrying capacity.

These results obtained from the empirical analysis fit with the direction of firm's strategic business over the last two decades and corresponding development trajectory of ERP as well as a development path of ERP functionalities in the 1990s.

Under the new paradigm of an information society, the firms' advanced innovation-oriented projects depend not only on the internal motivation of the firm but also on external institutional systems. It is crucial for a firm to actively interact with institutional systems rather than just passively respond to external requirements. This serves to stimulate external change in a positive manner, thereby maximizing the benefits of network externalities leading to the creation of the firm's self-propagating function. The advanced innovation-oriented projects of firms can be expected to develop in the process of embodying this function.

For the manufacturing firms, continuously delivering innovative and superior products to the customer is the key to success. Corresponding to the customers' expectation and satisfying their requirements are important mission of the developers'. Therefore, the most critical process is catching customers' requirements and getting appropriate feedback regardless customer expectation. Customers' involvement through the development process is a reasonable answer for this question. Since business process itself has been evolving, the software to manage this evolving process should be evolved simultaneously.

Once establishing this self-propagating function, sustaining this process becomes the key issue. In the internal development processes in the software vendor, how to maintain the strong developers' motivation of is important. The driving factors of this motivation are the high quality of the product, broad acceptance from the market and customers, and growth of the firm. These motivations induce continuous external requirements submission by customers leading to a crucial strategic option for software vendor, how to promptly and appropriately respond to customers expectation. Key strategy responding to this question would be the appropriate assessment of their requirements, design and specification.

Further work should be focused on an in-depth coevolutional analysis between internal motivation management and external expectation management as the coevolution of these two management features are decisive in the success of advanced innovation-oriented projects.

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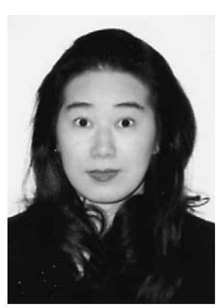
Chihiro Watanabe graduated from Tokyo University with a Bachelor's Degree in Engineering (urban planning) in 1968 and received his PhD (arts and sciences) in 1992, also from Tokyo University. He began his affiliation with the Ministry of International Trade and Industry (MITI) in 1968. He is a former Deputy Director-General of Technology Development in MITI. He is currently Professor of the Department of Industrial Engineering and Management, Tokyo Institute of Technology, and also Senior Advisor to a Director on Technology at the International Institute for Applied System Analysis (IIASA).



Masayo Hobo graduated from Kansai University with a Bachelor's Degree in Law in 1983. Afterwards, she received an MSIA Degree from the Carnegie Mellon University Graduate School of Industrial Administration in 1993. She worked for IBM Japan as management consultant, and SAP Japan and SAP AG as a Director of Advanced Solution Center. Currently she is a Representative Director of Viryanet Japan.