

The co-evolution process of technological innovation—An empirical study of mobile phone vendors and telecommunication service operators in Japan

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Abstract

While the development of information and communication technology (ICT) is usually measured by quantitative indices such as penetration rate, the character and quality of development can vary from country to country even if the development seems to be similar as judged by quantitative standards. Mobile phone markets particularly lend themselves to analysis in both quantitative and qualitative perspectives.

In this research, the empirical analysis has focused on the mobile phone market in Japan, which has achieved a high Internet access rate and a significant range of applications. First, by classifying the existing handset models, the analysis shows that high-end handsets occupy the largest share in Japan's market, and the ratio is much higher than the average worldwide level. Further analysis reveals that most domestic handset vendors offer made-to-order models to maintain high quality and to meet the specific demands of each telecommunication service operator. As a result, global handset vendors find it difficult to enter the "co-evolution cycle" by simply offering global models to Japanese service operators. Moreover, although the close connection between service operators and handset vendors may be criticized as a conservative or closed relationship, strong consumer demand of high quality and innovative phone functions creates a complex, demand driven, marketplace. In this environment service operators' and handset vendors' commitment to quality enables the "virtuous cycle" of technological innovation to progress smoothly.

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Keywords: ICT; Mobile phone; Vendor; Operator; Co-evolution; Innovation

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1. Introduction

1.1. Background

Rapid growth of information and communication technology (ICT) has attracted much attention in both business and academic fields. Among all aspects of ICT, mobile phones and the Internet are two sectors with a high growth rate. As the International Telecommunication Union (ITU) points out, “virtually all of the growth in the global telecoms sector over the past decade has come from mobile communications and the Internet” [1]. The total number of mobile subscribers all over the world has risen to over 1300 million, with the penetration rate up to 24 users per 100 nations as demonstrated in Fig. 1.

However, after these technological innovations spread throughout the world, the maturity of a market can no longer be judged only by the penetration rate. The degree of market development should be evaluated not only by the quantity of use but also by the quality of use. Taking the overlapping technology of the mobile phone and the Internet as an example, mobile Internet broadens the possibility of mobile phone functions and allows more advanced applications. Among all the countries with a high-level penetration rate of mobile phones, Japan and the Republic of Korea were the first two nations to launch third generation mobile networks commercially. According to the 2005 White Paper of Information and Communications in Japan [2], more than 90% of mobile phone service subscribers in Japan can access the Internet through handsets; this is the world’s highest rate, much higher than the 33.5% level in the US as illustrated in Fig. 2. This can be partially attributed to the fact that subscribers enjoy much more functions through mobile Internet access [2]. Furthermore, since ITU also predicted in its Asia-Pacific Telecommunication Indicators 2002 that the global telecommunications epicenter was shifting from North America and Western Europe to Asia-Pacific [3], Japan, a developed market of mobile phone in Asia, has become an important model suggesting how other Asian markets might evolve. In 2000, American journalists also suggested in *Business Week* that

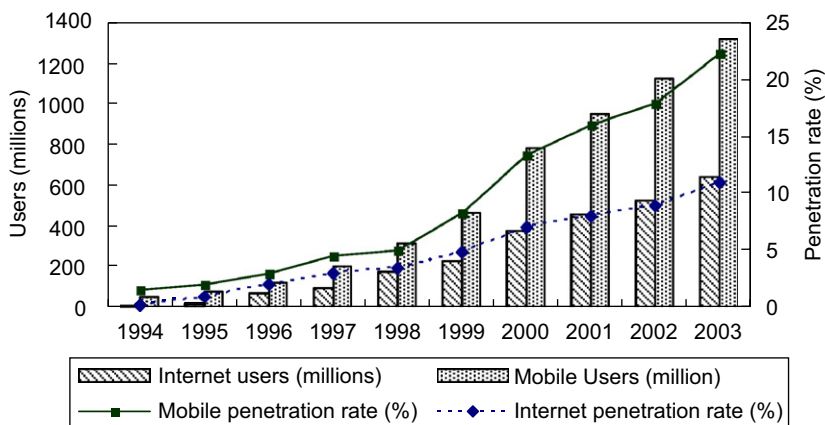


Fig. 1. The number/penetration rate of mobile subscribers and Internet users in the world (1994–2003). Source: Internet Reports 2004: The Portable Internet [1].

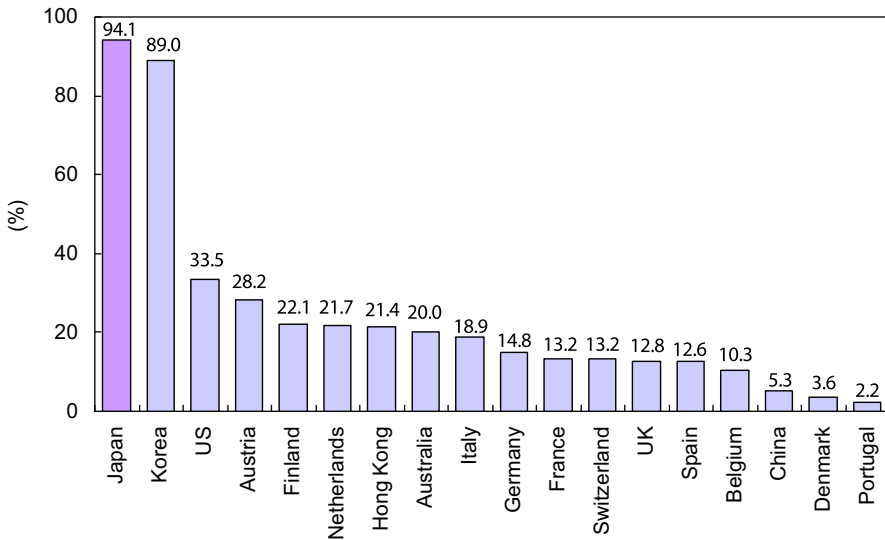


Fig. 2. Ratio of mobile Internet subscribers among mobile phone subscribers in leading countries (September 2004). *Source:* 2005 White Paper of Information and Communications in Japan [2].

the wireless Internet service that has become so popular among the Japanese could certainly spread around the world [4].

The handsets in Japan are equipped with various functions such as an Internet browser, music player, mobile phone camera, game applications and so on. All the functions require the contribution of both service providers and handset vendors. Consequently, the distinctive features of the Japanese market are that the service operators and all handset vendors work closely together. One good example of this synergy is the mobile Internet functionality. In addition to the advanced service offered by the service operators that utilize the mobile Internet, handset vendors also provide the subscribers in Japan with well-developed handsets equipped with an Internet browsing application. Taking the digital camera on the handset as another example, figures in 2005 show that over three-fourths of mobile subscribers in Japan can take pictures with their mobile handsets instead of using the handsets only for talking [2]. Fig. 3 shows the number of mobile subscribers and the ratio of handsets with camera features over the period 2001–2005 which demonstrate a conspicuous increase in the ratio particularly from 2003.

Such a rapid diffusion of camera-attached mobile handsets demonstrates the rapid growth of mobile phone driven innovation. Japan's demanding consumers induce new functionality and they can also learn promptly to use new features leading to the high-end handset dominated market. Furthermore, new functionality also promotes the learning effect of the market in Japan in a long-term perspective. Consequently, the close relationship between service operators and handset vendors enables a continuous supply of mobile phones with high-quality/new functionality to satisfy consumers' demand. At the same time, consumers also learn more promptly to adapt themselves to the new functionality and then become more demanding. Such a virtuous cycle involving the close cooperation of consumers, handset vendors and service operators drives the co-evolution of demand side and supply side in Japan.

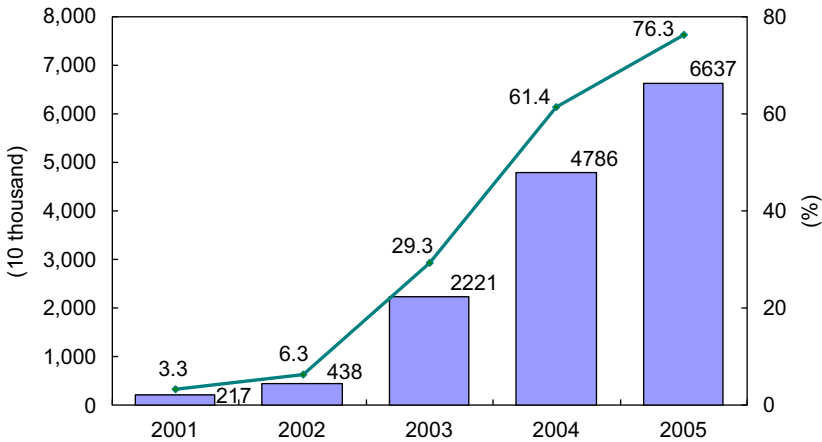


Fig. 3. Number of mobile phone subscribers and the ratio of mobile handset with camera feature in Japan (2001–2005).

1.2. Hypotheses

The foregoing observations prompt us to consider the following hypothetical views with respect to the systems dimension of the sources that enabled Japan's conspicuous advancement of mobile phone services:

- (a) Customers' demand for new functionality and high learning capability to use new features create a market dominated by high-end handsets.
- (b) In order to provide the market with high-quality handsets with new functionality all the time, service operators and handset vendors need to construct a closer relationship which might consequently mold Japan on a closed but independent market from others.
- (c) The customers' high demand for mobile phones with high-quality/new functionality and close relationship between service operators and handset vendors construct a virtuous cycle that drives the co-evolution between demand side and supply side in Japan.

1.3. Existing works

Many studies have considered the diffusion of technological innovation from the quantitative perspective. Woodlock and Fourt [5], Mansfield [6], Bass [7], Easingwood et al. [8], etc. analyzed the well-known first-purchase diffusion of new products in marketing by emphasizing the consumers' imitation and adoption behavior of product and constructed models dependent on the variable "time". Jun and Park [9] and Jun et al. [10] proposed a diffusion model for multiple generations and included other factors such as the price of products which reveals how price may affect the diffusion curve by affecting customers' choice. Although Yamada and Furukawa [11] demonstrated that almost all Japan's home electronic appliances were diffused at a slower rate than other markets, the advancement of the mobile phone market seems to be an exception. Iimi [12] suggested

that the mobile phone market in Japan is highly product-differentiated as well as service-differentiated so that conventional concerns such as the size of the network are no longer decisive factors in choosing a mobile phone carrier. Iimi's empirical analysis focuses on the billing plan instead of the technical specification of the handsets. Based on Jun and Park's empirical analysis [9] on Korean telecommunications market, Chen and Watanabe [13] further developed a model to take "function" as a variable that affects the diffusion curve by focusing on Japan's mobile phone market. In this empirical analysis by Chen and Watanabe, mobile phones without Internet service are the first generation and those without Internet service are the second. However, due to the limitation of the numerical model, even if it is identified that "price" and "new features" of mobile phones are important factors in the rapid growth of more advanced mobile phone penetration rate in Japan, it is not specified which functions determined the advancement of the mobile phone market. In addition, since almost all mobile phones are equipped with mobile Internet services, a further classification approach based on a precise definition of technical specifications (functions) is required to understand the segmentation of this market.

Regarding the supply side factors that affect the progress of the mobile phone market, Kondo and Watanabe [14] suggest that the non-elastic institutions existing in Japan might cause Japan to lose its international competitiveness but the case of mobile phone market is an exception. Nagamachi [15] points out that Japan's manufacturers (including mobile handset vendors Sharp, Sanyo, and Matsushita) keep making efforts to design products based on Kansei engineering which emphasizes consumer-oriented technology and takes consumers' satisfaction as the most important goal. This unique insistence of Japanese manufacturers reveals their high concerns about consumers' satisfaction and the demand driven nature of this sector. Kodama [16] analyzed the community-based firm structure of NTT DoCoMo and explained the way NTT DoCoMo opted to alter employee consciousness, vitalize organizational morale, entrench the new NTT "Phoenix" brand (video conferencing system) in the Japanese market, and create an emergent new video conferencing market. Funk [17] also emphasizes the importance of firms that provide services, content and technologies in the mobile phone market. Jonsson and Miyazaki [18] compared the 3G mobile phone strategies of top two service operators NTT DoCoMo and au KDDI and mentioned NTT DoCoMo's high-cost and high-quality strategies earned support in Japan but led to failure in the European market. Iimi [19] identifies that there was almost no effect of price competition across regions and that the incumbent carriers kept essentially related technology monopolized even after privatization and liberalization. All the studies above suggest there are unique institutions in Japan, but most of them focus on the analysis of strategies of a singular service operator or manufacturer. No attention is paid to the relationship between the service operators and handset vendors, i.e. the characteristics of the supply side in the market and its intimate relationship with the demand side.

1.4. Prime objectives of the research

While Japan's rapid advancement of mobile phone service is expected to be an important model for similar advancement in other countries, applying solely the experience of Japan to other markets does not promise the same level of success due to various distinct market attributes. First, even if it is noticed that Japan has achieved a relatively

high performance in the diffusion and innovation of mobile phones, the attributes of the market that made this possible are unclear. An identification of the quality and level of this market requires careful examination. Next, what are the factors that determine such an advanced market? Both the consumer side and supply side should be taken into consideration. Is R&D of the service operators and handset vendors or the consumers' demanding attitude toward new features fueling the high growth rate of new mobile services, such as mobile Internet, and innovative handset features, such as the mobile camera? Last, the mechanism that continues to drive the success of the mobile phone market in Japan should be the key factor for elucidating similar mobile phone markets. Demonstration of the three hypothetical views mentioned above would provide significant insight into these questions.

Therefore, this research attempts to demonstrate these hypotheses in the following ways. First, this study uses exact indicators to define "advanced" mobile features and show how advanced the mobile phone market in Japan is compared with the average level around the world. Further analysis by utilizing a learning curve model is conducted to analyze the trend in the learning curve coefficient in order to identify how the progress of new functions affected the mobile phone market in Japan. Second, in addition to identifying the uniqueness and quality of Japan's mobile phone market, the extremely close and mutually dependent relationship between the service operators and handset vendors in Japan is identified. Based on these analyses, the reason why the worldwide handset vendors are unable to perform in Japan as they do in other countries is explained. Finally, a co-evolution mechanism between the consumers and the supply side, including handset vendors and service operators, is elucidated in order to point out the barriers for worldwide handset vendors in penetrating such a well-defined market. This research also aims at explaining how the Japanese "inflexible" institutional system can drive the growth of penetration rate and enable the high-quality/advanced features of the mobile phone market while impeding the Japanese service operators and handset vendors from succeeding in foreign markets.

1.5. Structure of the paper

Section 2 demonstrates how the marketplace is dominated by high-end handsets and how it affects the learning curve of the market. Section 3 demonstrates how the service operators and handset vendors construct a close relationship to satisfy the consumers' demand and how this relationship molds this market. Section 4 demonstrates a virtuous cycle that drives a co-evolution between demand side and supply side in Japan due to its unique institutional system. Section 5 briefly summarizes new findings, policy implications and points toward future work in this area.

2. A market dominated by high-end handsets due to high learning effect

2.1. Methodology

2.1.1. Analysis of the degree of high-end handsets

In order to demonstrate that the mobile phone market in Japan is much more advanced than the average level in other countries, it is necessary to quantify the features of handsets by classifying the handsets currently available in Japan's mobile phone market into three

segments: high-end, midrange and entry-level. Since the handset vendors and operators keep releasing new models each season, the first step of this analysis is to clarify the range of handset models to be analyzed. The target handset models are those listed in the catalogs and websites of the operators in September 2005, and the specification information is collected from the catalogs and websites [19–21].

Next, the criteria to classify the models into three segments are fixed. In order to keep the consistency of classification standard with other existing analysis, the classification methodology is based on the aspects suggested by Slawsby and Leibovitch [22]. However, since “form factors,” such as small monoblock (not-foldable style) and clamshell (the foldable style), depends on the preference of usage and does not necessarily mean which one is more advanced than another, it is not included in the indicators used in this research. Since one “operating system” does not show clear superiority than another, this item is also neglected. All features taken into account are listed in Table 1. For each feature classified as high-end, the handset is credited with 3 points, 2 points for each feature classified as midrange, and 1 point for each feature classified as entry-level. Wireless generation is the exception since 2.5G handsets may be high-end or midrange. However, stricter criteria are preferred for high-end handset, so only 3G handsets obtain 3 points in “wireless generation” feature in this research. After crediting the points for the 7 features of all handset models, the average point of each model is computed. One handset model is classified as high-end if the average point is 2.5 or more, midrange if 1.5 or more, and entry-level if less than 1.5.

Based on the classification analysis results, the total number of high-end, midrange and entry-level models of each handset vendor and each operator is computed. By comparing the total score of the credits, it can be observed which segment each handset vendor and operator is focusing on.

2.1.2. Analysis of the learning effects in the mobile phone market in Japan

In order to assess not only the innovation mechanism of the supply side of the mobile phone industry in Japan but also the learning capability of customers toward new functions and technology, the learning effect is analyzed based on a learning curve where

Table 1
Criteria to classify high-end, midrange and entry-level handset

Feature	High-end	Midrange	Entry-level
Application processor	Integrated	Discrete	None
Memory	<32 MB	<16 MB	<4 MB
Display	Color display, 240 × 320 pixels or less	Color display, 100 × 100 pixels or less	Monochrome display
Wireless generation	2.5G or 3G+	Mostly 2.5G	Mostly 2G
Expansion	Yes	None	None
Camera	Standard, 1.5 MP or more	Standard, <1.5 MP	None
Applications	Full multimedia stream and content	Simple web-browsing and downloading games	Phonebook and text-messages

Source: Slawsby and Leibovitch, *Worldwide Mobile Phone 2005–2008 Forecast by Feature Tier: A Feature-Rich Future* [22].

the average price index of mobile phone (P) is influenced by the number of mobile phone subscribers (N) with a dynamic elasticity (learning curve coefficient) as a function of the determinants time (t). The number of mobile phone users is based on the monthly reports released by the Telecommunication Carriers Association in 2005 [23], and the price index of mobile phones is collected from the monthly reports of the price index published by the Bank of Japan (1996–2004) [24]. The determinant time (t) represents the maturity of technological innovation of the supply side while the number of mobile phone subscribers (N) corresponds to the population involved in the learning process.

2.2. Results and discussion

2.2.1. High-end oriented vendor structure in Japan's mobile phone market

By listing all target models and completing the classification, the results are shown in Tables 2 and 3 by handset vendor and service operator, respectively.¹

The result of the classification analysis demonstrates that all Japan's handset models are classified in either high-end or midrange, and high-end handset models share an extremely high ratio. According to the news release of IDC Japan in 2005, the top four vendors in 2004 are NEC, Sharp, Panasonic and SonyEricsson [25]. As listed in Table 2, these top four handset vendors provide the service operators with more high-end handset models. On the other hand, judging from the segment analysis of each service operator, it is shown that the top service operator NTT DoCoMo, which shares about 55% of the market, provides consumers much more high-end models than other service operators. Half of NTT DoCoMo's models belong to high-end while high-end models share only 20% of models provided by Vodafone, whose market share is the lowest among the three major service operators. These analyses demonstrate that, compared with the ratio of the worldwide market, Japan's mobile handset market is obviously dominated by the high-end handsets. As shown in Fig. 4, while the worldwide high-end ratio remained 7.8% in 2004, Japan displays a strikingly high level at 41.7% in 2005.

Fig. 5 demonstrates a positive correlation between market share and high-end ratio in Japan's mobile handset vendors. All demonstrate Japan's high-end oriented vendor structure.

2.2.2. Analysis of the "learning effect" of the mobile phone market in Japan

According to the regression analysis, at the early stage of the mobile phone market, the market was still monopolized and the price did not actually reveal the interaction of the supply side and the consumer side. Therefore, in order to maintain the statistical significance, the time-series data before 1997 is omitted from this analysis. The parameters of the learning effect model are estimated by applying the empirical data from January 1997 to February 2002; with the estimated model, the learning coefficient from January 1997 to June 2006 is computed.

The result of the empirical analysis of the learning effect model with dynamic learning curve coefficient identifies, with statistical significance, the correlation between the cumulated number of mobile phone subscribers and the price of mobile phones in Japan

¹Since Tuka and NTT DoCoMo (PHS) as a whole occupy less than 5% of the market, they are neglected in the table of handset vendors.

Table 2
Classification of handset models by handset vendor

Number of models	Segment		
	High-end	Midrange	Total
Handset vendor			
Casio		1	1
Fujitsu	5	4	9
Kyocera		1	1
Mitsubishi	2	4	6
NEC	6	3	9
Nokia		1	1
Panasonic	4	5	9
Sanyo		4	4
Sharp	5	8	13
SonyEricsson	8	6	14
Toshiba		5	5
Total	30	42	72

Table 3
Classification of handset models by service operator

Number of models	Segment		
	High-end	Midrange	Total
Service operator			
NTT DoCoMo Total	19	19	38
au KDDI Total	8	12	20
Vodafone Total	3	11	14
Total	30	42	72

(January 1997–February 2002) as follows:

$$\ln P = \frac{10.03}{(42.66)} - \frac{(5.76 \times 10^{-1})}{(24.74)} - \frac{1.78 \times 10^{-5} t^2}{(7.97)} + \frac{1.80 \times 10^{-7} t^3}{6.07} \ln N \quad \text{adj } R^2 = 986,$$

where P is the price index of handsets, t the time and N the cumulative number of mobile subscribers.

This result suggests that the learning curve coefficient of Japan's mobile phone market λ can be depicted as follows as a function of time t :

$$\lambda = 5.76 \times 10^{-1} - 1.78 \times 10^{-5} t^2 + 1.80 \times 10^{-7} t^3.$$

As illustrated in the learning coefficient curve (January 1997–June 2006) in Fig. 6, it is observed that after the mobile phone appeared on the market, the learning coefficient kept decreasing slowly as has been generally observed in the initial stage of the diffusion of new innovations. Existing empirical analysis also suggests that the learning coefficient of the market tends to drop due to technology obsolescence. However, the inflection point of the

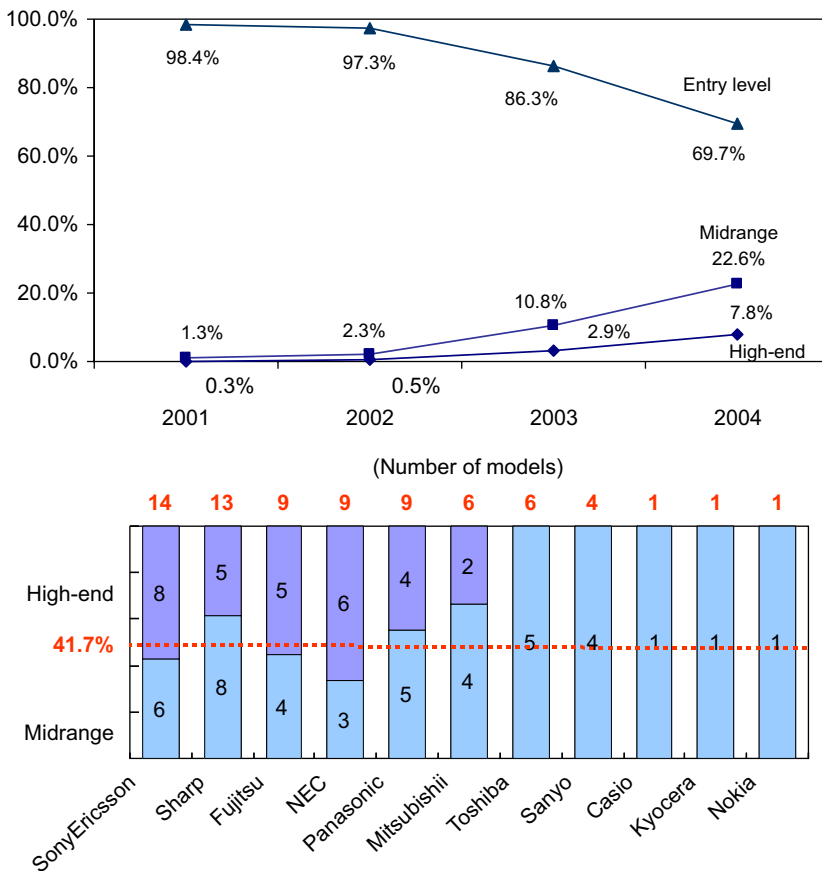


Fig. 4. Comparison of the ratio of high-end, midrange and entry-level handset ratios in the worldwide market (2001–2004) and in Japan (September 2005). Source: IDC [25] and empirical analysis of this research.

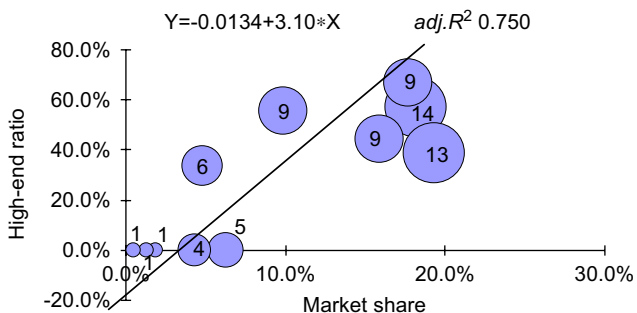


Fig. 5. Correlation between market share and high-end ratio in Japan’s handset vendors (2004).

learning curve coefficient in the mobile phone market in Japan lies on the point representing June 2002. Judging from the list of service/functions in Table 4, the curve turned upward after NTT DoCoMo and au KDDI started to offer handsets with the

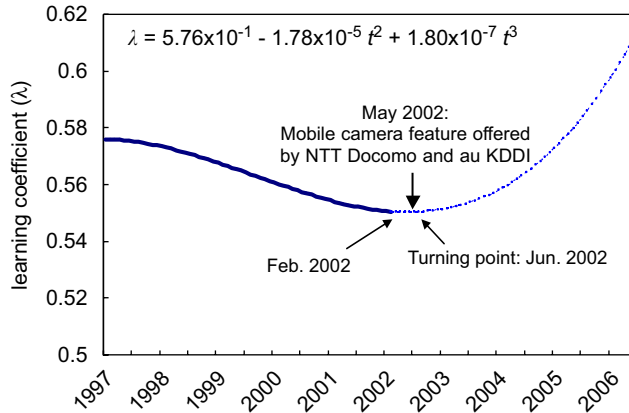


Fig. 6. Estimates (January 1997–February 2002) and extended estimates (March 2002–June 2006) of the learning curve coefficient in Japan's mobile phone market (January 1997–June 2006). Original statistics are based on monthly reports by Telecommunication Carriers Association (TCA), Japan (2005) and price index reports of Japan Bank (2004).

Table 4

New services and functions introduced by service operators (1999–2004)

Time	New service/function	Service operator
February 1999	i-mode (e-mail)	NTT DoCoMo
April 1999	Ezweb (e-mail)	au KDDI
December 1999	J-sky (e-mail)	J-phone ^a
January 2000	DoCoNavi (navigation)	NTT DoCoMo
May 2000	J-navi (navigation)	J-phone ^a
November 2000	J-pic-mail (camera)	J-phone ^a
January 2001	i-appli (Java)	NTT DoCoMo
June 2001	J-Appli (Java)	J-phone ^a
July 2001	Ezplus (Java)	au KDDI
November 2001	i-motion (video clip)	NTT DoCoMo
December 2001	Ezmovie (video clip)	au KDDI
December 2001	Eznavi (navigation)	au KDDI
May 2002	i-shot (camera)	NTT DoCoMo
May 2002	au-shot (camera)	au KDDI
December 2002	J-movie (video clip)	J-phone ^a
December 2003	Movie TV	Vodafone
December 2004	Music downloading capable handset	NTT DoCoMo
December 2004	Music downloading service	au KDDI
December 2004	3G mobile content downloading	Vodafone

Sources: IT White Book 2003 [26] and service operators' website [19–21].

^aJ-phone was merged into Vodafone Group and renamed as Vodafone KK in September 2003.

mobile camera feature in May 2002. Mobile handsets with camera features pulled up the learning coefficient and other functionalities accelerated the enhancement of learning curve coefficient.

In fact, J-phone (now Vodafone) has supplied handsets with the mobile camera feature since December 2000. Unfortunately, its market share was not high enough, so the effect was relatively minor. On the other hand, the effect of new features was significant when the top two service operators, NTT DoCoMo and au KDDI released handsets with the same feature. This observation demonstrates strong learning effects as a consequence of the intensive interaction between high-end oriented supply and demanding consumers leading further qualified functions in Japan's mobile phone market. These learning effects again support the perspective of the enormous power of service operators, instead of handset manufacturers, in the unique mobile market of Japan.

3. A market dominated by order-made models due to close cooperation between vendors and operators

3.1. Methodology

In order to elucidate the relationship between domestic handset vendors and service operators in Japan, it is necessary to clarify the pattern of how handset vendors provide handset models to the service operators. This analysis aims at classifying the handset models into three types: global, localized and customized model. Here “*customized model*” means that the handset vendor provides that handset model only to one service operator in the same country. “*Regional model*” means that the handset vendor provides very similar handset models to different service operators in the same country. “*Global model*” means that the handset vendor provides that handset model to different service operators in different countries.

The target handset models are those listed in the catalogs and websites of the handset vendors in October 2005; the spec information and photos of those handsets are collected from the catalogs and websites of NEC, Sharp, Panasonic, Fujitsu, Mitsubishi, Sanyo, Toshiba, SonyEricsson in September 2005 [27–34]. After the information of each model is collected, all the models are listed by handset vendor and then by service operator. By comparing the specifications and style of the same handset vendor, it can be observed whether the same or similar model is provided to different service operators. If the model is provided to only one service operator, it is categorized as a “*customized*” model. If it is provided to multiple service operators in Japan by only minor changes, it is considered a “*regional*” model. If it is also provided to other service operators in other countries, then it is classified as a “*global*” model.

3.2. Results and discussion

3.2.1. Japan's “customized” model oriented market

The models analyzed are listed in Fig. 7 by handset vendor and then by service operator. Some handset vendors, such as Panasonic and Fujitsu, only provide handsets to a specific service operator, so the models are clearly classified in “*customized*” models. Mitsubishi once provided handsets to two service operators, but tend to concentrate on one service operator after 3G models become the mainstream in the market. Other handset vendors, including Sanyo, Toshiba, and SonyEricsson, provide handsets to multiple service operators. However, by comparing the specification and style of the models, it is observed that these handset vendors provide different models to

	NEC		SHARP		Panasonic	Fujitsu
	DoCoMo	Vodafone	DoCoMo	Vodafone	DoCoMo	DoCoMo
3G/2.5 G	N901iS N901iC N701i N700i		SH700iS SH901iS SH700i SH901iC SH900i	703SH 903SH 902SH 801SH	P901iS P700i P901iS P900iV P900i	F901iS F700iS F901iC F700i RakuPhonell
	<i>N900iG</i>	<i>802N</i>		<i>802SH</i>		
	N900i N900iS	V-N70 1				
2G	N506iS N506i N253i	J-N51 V601N	<i>SH506iC</i>	V302SH V501SH V603SH	P506iC P252iS P253i Lechiffon Prosolid	F506i F505i(GPS) F672i

	SANYO			Toshiba	
3G/2.5 G	DoCoMo	AU KDDI	Vodafone	AU/Tuka	Vodafone
		SA700iS	W32SA W31SA W22SA	V801SA J-SA701	W31T W21T
2G	D253i D506i	Sweets A5505SA A5507SA	V401SA J-SA06 J-SA51 J-SA05	A5509T A5511T A5504T	V603T V501T V601T V303T V602T

	SonyEricsson			Mitsubishi	
3G/2.5 G	DoCoMo	Vodafone	AU KDDI	DoCoMo	Vodafone
			802SE	W32S W31S	D701i D901iS D901i
2G	Premi Rediden SO506i		A1404S/ S A1402S	D253i D506i	V301D

Fig. 7. Categorization of handset models by vendor and operator (September 2005). *Source:* Website and catalogs of NEC, Sharp, Panasonic, Fujitsu, Mitsubishi, Sanyo, Toshiba, SonyEricsson [27–34]. (*Italic*) indicates “regional” models while others are “customized” models.

different service operators. Only N900iG and 802N made by NEC as well as 802SH and SH506iC made by Sharp provide similar models to different service operators and are classified as “regional” models. Other models made by Sharp and NEC except these two pairs of models are, similar to Sanyo, Toshiba, SonyEricsson and Mitsubishi, classified as “customized” models.

Operator	Vender				Total		
		Customized	Global	Regional		High-end	Midrange
NTT DoCoMo	Fujitsu	9			9	5	4
	Mitsubishi	5			5	2	3
	NEC	7		1	8	5	3
	Panasonic	9			9	4	5
	Sharp	3		1	4	3	1
	Sony Ericsson	3			3		3
	Total	36		2	38	19	19
AU	Casio	1			1		1
	Kyocera	1			1		1
	Sanyo	3			3		3
	Sharp	3			3		3
	Sony Ericsson	10			10	8	2
	Toshiba	2			2		2
	Total	20			20	8	12
Vodafone	Mitsubishi	1			1		1
	NEC			1	1	1	
	Nokia		1		1		1
	Sanyo	1			1		1
	Sharp	5		1	6	2	4
	Sony Ericsson	1			1		1
	Toshiba	3			3		3
Total	11	1	2	14	3	11	
Total	67	1	4	72	30	42	

Fig. 8. Service operators and handset vendors in Japan's mobile phone market by types and classes (September 2005).

Based on these classifications, Fig. 8 lists the number of handset models by handset vendor and service operator by classifying “*customized*,” “*global*” and “*regional*” models. This demonstrates that 93% of the models in September 2005 can be classified as “*customized*” models. This analysis demonstrates that the relationship between handset vendors and service operators in Japan exists in the order-made pattern of cooperation resulting in depending on a “*customized*” model. There is not an open environment for a handset vendor to develop one model and simply provide it to different service operators. It is also observed that NTT DoCoMo, with its longest history of mobile phone business in Japan, demonstrates the highest ratio of customized and high-end handsets. On the other hand, Vodafone, the late comer among the top three service operators, demonstrates the lowest ratio of customized and high-end handsets. This is considered as one of the differences between traditional Japanese service operators and global-business oriented service operators.

3.2.2. Institutional sources molding Japan's market on “*customized*” model

In Japan, mobile handsets are sold with both the name of the handset vendor and the service operator on them.² Therefore, from the service operators' perspective, which model they should adopt is also a decision that will affect their share in mobile service market.

²This system is expected to be changed from the autumn 2006 by the launching of “number portability service”.

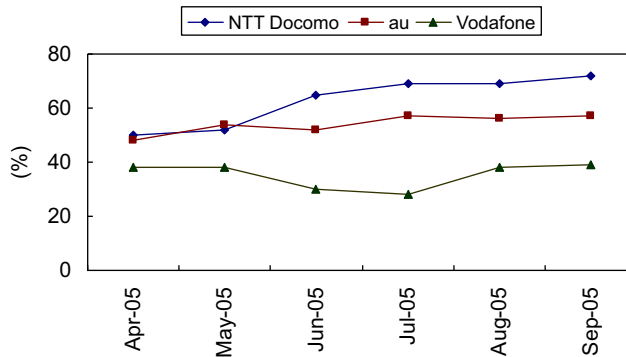


Fig. 9. Trend in the ratio of 3G mobile phone service subscribers of each service operator in Japan (April 2005–December 2005). *Source:* Database of subscribers by service operator [36].

For service operators, it is considered as an important strategy to obtain new subscribers and maintain existing users by launching more attractive handset models [35]. Moreover, the models that the service operators adopt from the handset vendor for launch in the market also determine the structure of customers' subscription by digital segment.

Since the relationship between service operators and handset vendors is an important key factor in determining the provision of handset models in Japan's market, the ratio of high-end handset models adopted by service operators also affect their own 3G subscription rate. As illustrated in Fig. 8, the ratios of high-end handset models by service operator are 50%, 40% and 21% for NTT DoCoMo, au KDDI and Vodafone, respectively. Consequently, by the end of September 2005, more than 70% of NTT DoCoMo subscribers communicated through 3G wireless technology and had accessibility to various advanced application services while only 55% of au KDDI and 40% of Vodafone did so as illustrated in Fig. 9 [36].

Since all models are sold with both the names of the service operator and the handset vendor, both the service operator and handset vendor bear responsibility for the handsets in Japan. In other countries where the consumers choose the handset models with only the handset vendor's name, the handset vendors can focus simply on satisfying the demand of the immediate customers. Contrary to such a structure, the first step of the handset vendor to keep a place in the market in Japan is to satisfy the service operators and persuade them to adopt the handset models. Consequently, each model must meet the technical need of the service provided by the service operator as well as the brand image of both the handset vendor itself and the service operator. One manager of Fujitsu confessed, "While we would like to cooperate with multiple service operators, too; it is really difficult to afford the huge amount of R&D invested separately for each service operator." The one-to-one close relationship between the handset vendors and service operators can be considered as a consequence of supply side co-evolution in order to maintain a high-quality and rapidly innovative process.

In order to satisfy the demands of picky consumers, service operators use a high standard in choosing handset vendors and are the "real" customers of handset vendors in Japan. Handset vendors must develop and produce handsets to meet the technical specification and infrastructure of the service operators, and they also have to design fashionable products that can attract the end-users. Consumers, handset vendors and service operators form a strongly intertwined relationship where handset vendors and

service operators supervise each other and the consumers dominate both handset vendors and service operators as illustrated in Fig. 10. Customized production and model development link the handset vendors and service operators, leading to their branding targets to converge in order to satisfy Japan’s demanding customers’ functionality requirements. This supply structure, together with customers’ high level of demand, constitutes a sophisticated institutional system resulting in Japan’s rapid increase in high functional mobile phones in a self-propagating way.

However, this structure, on the other hand, resulted in the development of a barrier against global handset vendors. By comparing the market share of 3Q 2005 in the worldwide and Japan’s market, it is clear that top global handset vendors do not perform well in Japan’s market as illustrated in Fig. 11. Since most global handset vendors provide

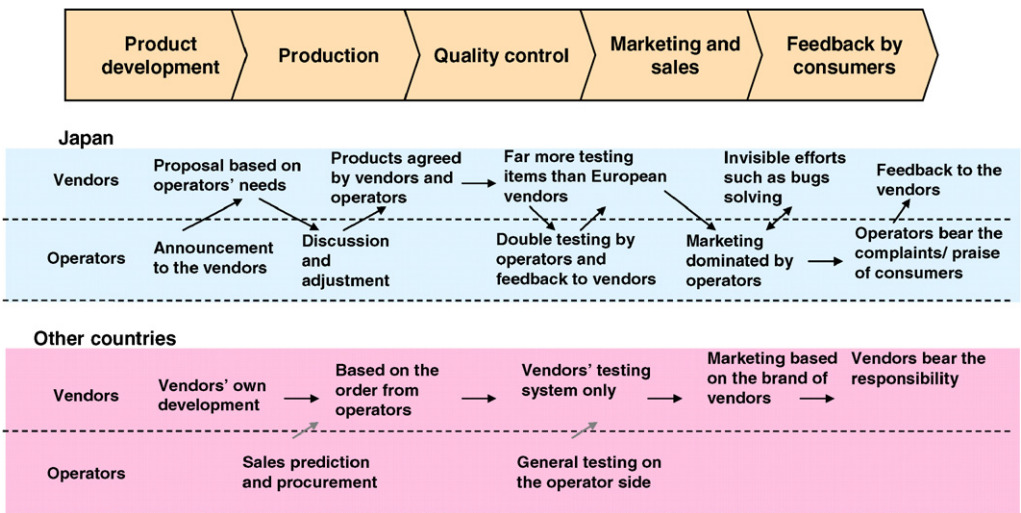


Fig. 10. The comparison of the mechanism under the mobile phone markets in Japan and other countries.

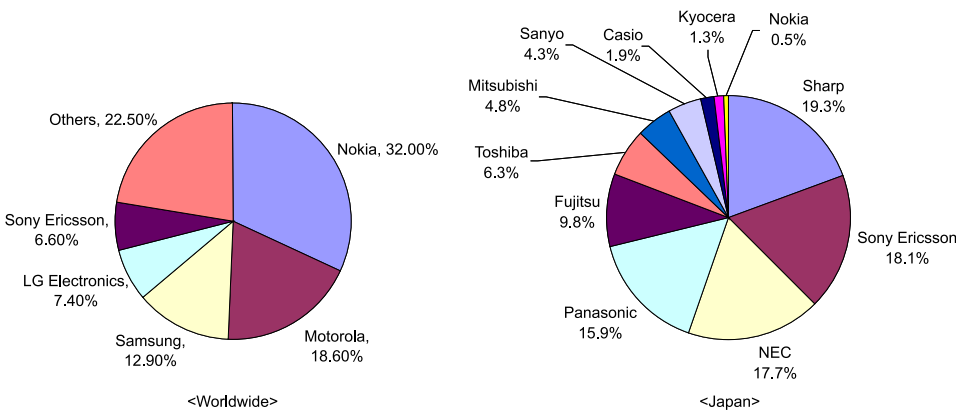


Fig. 11. Market share of handset in the worldwide market and Japan (3Q 2005). Source: Press release of International Digital Corporation (IDC) and IDC Japan [37].

global models in different countries, it is very difficult for them to become so intimately related to the service operators in Japan and enter the one-to-one made-to-order tight relations of Japan's mobile phone handset supply side.

4. A virtuous cycle between demand and supply sides driving Japan's co-evolutionary mobile-driven innovations and institutions

Analyses in the preceding sections suggest that not only does the supply side provide the market with advanced hardware (features of handsets) and software (service such as mobile Internet) but also the consumers play a significant role in inducing innovative product and services through their learning effects. Compared with other markets with high usage of ICT, Japan's customers appear to be more willing to regularly use a wider variety of features on their mobile phones. This aggressive customer behavior compels the handset vendors and service operators to provide handsets with high-quality, as well as innovative features which, in turn, stimulate customer demand leading to a virtuous cycle between them. The extremely high penetration rate of the mobile phone camera illustrated in Fig. 3 and the high penetration rate of mobile e-mail shown in Fig. 12 can be considered the result of the virtuous cycle where consumers are willing to adopt new technology and handset vendors/service operators respond positively to demanding consumers.

Fig. 12 demonstrates that while Japan's e-mail utilization ratio by means of mobile phones and PCs is similar at 87.7% and 94.2%, respectively, in the US it is much lower for mobile phones at 12.4% while extremely higher for PCs at 96.1%. This contrast demonstrates the demanding nature of Japan's customers for well-functioned mobile phones. This virtuous cycle constructed by both the demanding customer side and the closely intertwined supply side is illustrated in Fig. 13. The customers' demanding request urges service operators to set up stricter requirements for handset vendors. Next, in order to satisfy service operators, handset vendors have no choice but to conduct cooperation in R&D with service operators. Such a close relationship enables the supply side to provide customers with high quality services and products. However, customers with high learning capability get used to such high quality and become more demanding. Consequently, further R&D cooperation of the supply side and R&D investment tie the handset vendors

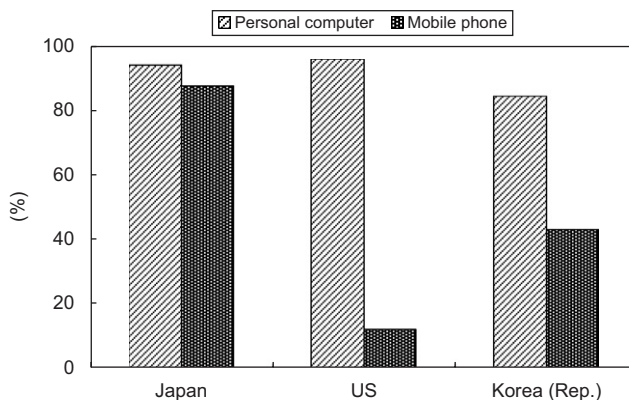


Fig. 12. Penetration rate of e-mail user by personal computer and mobile phone in Japan, US and Korea (Rep.) (2001–2005). Source: 2005 White Paper of Information and Communications in Japan [2].

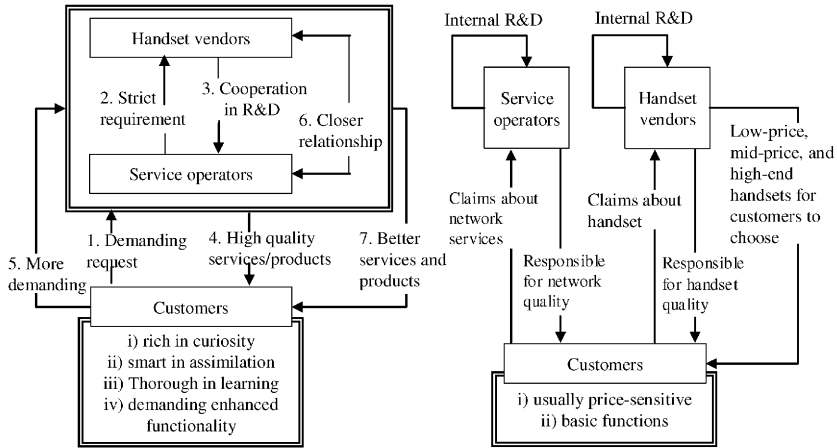


Fig. 13. Comparison of institutional systems in Japan's mobile phone market and in other markets.

and service operators more tightly and enables the supply of even better services and products. These processes construct the virtuous cycle in Japan's mobile phone market. On the other hand, the structure of other markets is different from that of Japan. Service operators are responsible only for telecommunication services, and handset vendors offer the handsets according to their own R&D development and marketing strategy. Without the close relationship with service operators, various handset vendors could offer various kinds of handsets, including low-price, mid-price and high-price handsets, directly to the customers to choose by their own concerns such as price factors.

On the basis of this virtuous cycle, Japan's noticeable advancement in mobile-driven innovation emerged and changed its institutional systems in a way to induce further innovation. Thus, the co-evolutionary dynamism between them can emerge. A virtuous cycle between demand side and supply side plays a significant role in reactivating Japan's indigenous co-evolutionary dynamism between mobile-driven innovation and institutional change. In this marketplace, consumers play a distinctive role bringing to this cycle unique characteristics such as being (i) rich in curiosity, (ii) clever in assimilation, (iii) thorough in learning, and (iv) demanding enhanced functionality play a leveraging role.

5. Conclusions

5.1. General summary

This research elucidates the specific structure of the mobile phone market in Japan as follows. The first part of the analysis classified the existing handset models showing that high-end handsets occupy the largest share in Japan's market, and that the ratio is much higher than the worldwide average level. The second part of this analysis demonstrated that most domestic handset vendors offer customized models to satisfy the specific demands of each service operator. Consequently, global handset vendors have difficulty entering the marketplace by simply offering global models to the service operators. Similarly, because of the unique institutional structure in Japan, particularly the mutual dependence of the handset vendors and service operators on each other for their success,

the Japanese vendors/service operators also struggle in other markets. Due to Japan's social institutions, consumers' strong consciousness toward high quality and innovative functions drive both service operators' and handset vendors' commitment to quality. A closed but high-standard relationship between handset vendors and service operators has been developed, which reacts closely to consumer demand. This mutually dependent relationship pushes the virtuous cycle of technological innovation so that it works smoothly and efficiently.

5.2. *New findings*

The following are new findings of particular note based on this analysis:

- (i) Japan has become a market dominated by high-end handsets since customers in Japan prefer high quality and new functionality. According to the learning curve the introduction of the mobile phone camera was the most important time point that triggered the learning coefficient to turn upward.
- (ii) Japan has also become a market dominated by made-to-order handset development between service operators and handset vendors whose close relationship supports this demanding market. Both the service operators and handset vendors are responsible for the quality of handsets, and the service operators, not the mobile phone end-users, are actually the immediate customers of the handset vendors.
- (iii) The interaction of the demand side and supply side in the mobile phone market of Japan formed a co-evolution mechanism. It enables extraordinarily high achievements in terms of quality and the level of technology in this unique marketplace. However, the marketplace is relatively closed and also prevents other global handset vendors from succeeding in Japan making it difficult for Japanese vendors and operators to succeed in other markets as well.

5.3. *Policy implications*

Based on these unique findings, there are important implications for policy makers inside and outside Japan who are interested in creating an environment that stimulates an innovative marketplace of similar attributes. The following are some of the major policy implications:

- (i) The first lesson learned from Section 2 is that one or two groundbreaking but user-friendly function expansions are necessary to stimulate the demand of a saturated market. The mobile camera feature combines handset and digital camera, and it showed the market a new possibility for using the mobile phone device. However, too many minor functions might only cause the consumers to spend more time to adapt and should be avoided.
- (ii) Handset vendors in Japan rely on the service vendors very much. This close relationship of R&D, manufacturing and sales cooperation drives the progress of the mobile phone market in Japan, but may not be applicable in other markets where the service operators and handset vendors have to face the market separately. Japanese vendors and service operators should learn to be more independent from each other and more flexible in order to adapt themselves to the local supply side structure in other markets.

- (iii) Although Japanese handset vendors and service operators are good at satisfying the demanding consumers of Japan with high-quality products and services, this high-cost business would be impossible without sufficient support from consumers. The positive co-evolution mechanism in Japan builds on the foundation of a unique social institution. To succeed in other markets, Japanese businesses have to adapt their strategies to the attributes of each market and learn to balance the cost and quality requirement. Another possible way is to wait or educate the consumers until they also request services and products at the same level as Japanese consumers.

5.4. *Future works*

Through this research, sources of Japan's co-evolutionary dynamism between mobile phone driven innovation and its unique institutional systems have been identified. While this dynamism induces the dramatic advancement of mobile phones by enhancing functionality in a self-propagating manner, it incorporates structural constraints to embarking into a global market where more flexible options of both supply and demand structure are required.

Given that Japan's sustainable development depends on its own economic co-evolution with global sustainability, Japan's driven and innovative mobile phone industry should be globally expansive. Thus, Japan's mobile phone industry should shift from a homogeneously integrated structure that works well, but only in Japan, to a heterogeneous structure which is able to adapt and thrive amidst other demand side factors. While Japan's current system appears to be homogenous, even in the relatively high-standard market in Japan, there are still differences among major players with respect to their strategic positioning, technology standards decisions and global strategies. While NTT DoCoMo's focus is on maintaining domestic supremacy in the consumer market with 3G capabilities by targeting "discerning customers" who want high quality service, au KDDI seems to be positioning itself for broader application. How such differences in strategy and positioning may affect their achievement in penetrating into other markets is still a critical question worthy of further exploration. After certain markets reach a saturation point, how to accelerate co-evolution process not only in the domestic market but also in other markets will determine the long-term success of the firms involved. Future work should focus on this critical dimension.

References

- [1] International Telecommunication Union (ITU). Internet reports 2004: the portable internet. Geneva: ITU; 2004.
- [2] Ministry of Internal Affairs and Communications (MIAC) Japan. 2005 white paper of information and communications in Japan. Tokyo: MIAC; 2005.
- [3] International Telecommunication Union (ITU). Asia-Pacific telecommunication indicators 2002. Geneva: ITU; 2002.
- [4] Business Week. Feature article of i-mode. New York: The McGraw-Hill Companies Inc.; 2000.
- [5] Woodlock JW, Fourt LA. Early prediction of market success for grocery products. *J Marketing* 1960;25:31–8.
- [6] Mansfield E. Technical change and the rate of imitation. *Econometrica* 1961;29:741–66.
- [7] Bass FM. A new product growth model for consumer durables. *Manage Sci* 1969;15(5):215–27.
- [8] Easingwood C, Mahajan V, Muller E. A nonuniform influence innovation diffusion model of new product acceptance. *Marketing Sci* 1983;2(3):273–95.

- [9] Jun DB, Park YS. A choice-based diffusion model for multiple generations of products. *Technol Forecasting Social Change* 1999;6:45–58.
- [10] Jun DB, Kim SK, Park YS, Park MH, Wilson AR. Forecasting telecommunication service subscribers in substitutive and competitive environments. *Int J Forecasting* 2002;18:561–81.
- [11] Yamada M, Furukaw R, Ishihara M. Classification pattern of new product diffusion. *Marketing Sci Jpn Inst Marketing Sci* 1995;4:16–36 [in Japanese].
- [12] Iimi A. Estimating demand for cellular phone services in Japan. *Telecommun Policy* 2005;29:3–23.
- [13] Chen C, Watanabe C. Diffusion, Substitution and competition dynamism inside the ICT market: a case of Japan. *Technol Forecasting Social Change* 2006;73(6):731–59.
- [14] Kondo R, Watanabe C. The virtuous cycle between institutional elasticity, IT advancement and sustainable growth: can Japan survive in an information society? *Technol Society* 2003;25:319–35.
- [15] Nagamachi M. Kansei engineering as a powerful consumer-oriented technology for product development. *Appl Ergon* 2002;33:289–94.
- [16] Kodama M. Strategic community-based theory of firms: case study of NTT DoCoMo. *J High Technol Manage Res* 2003;14:307–30.
- [17] Jonsson M. 3G mobile diffusion in Japan: technology strategies of au KDDI and NTT DoCoMo and technology adoptive users. *J Jpn Society Manage Inform* 2004;13:57–77.
- [18] Funk J. The future of the mobile phone Internet: an analysis of technological trajectories and lead users in the Japanese market. *Technol Soc* 2005;27:69–83.
- [19] Website of NTT DoCoMo. Product information; September 2005 <<http://www.nttdocomo.co.jp/>>.
- [20] Website of AU. Product information; September 2005 <<http://www.au.kddi.com/>>.
- [21] Website of Vodafone. Product information; September 2005 <<http://www.vodafone.jp/top.htm>>.
- [22] Slawsby A, Leibovitch AM. Worldwide mobile phone 2005–2008 forecast by feature tier: a feature-rich future. Framingham: International Data Corporation (IDC); 2005.
- [23] Website Telecommunications Carriers Association (TCA) Japan. <<http://www.tca.or.jp/japan/database/daisu/index.html>>.
- [24] Website of Bank of Japan. Monthly report of price index; 1996–2005 <http://www.boj.or.jp/stat/stat_f.htm>.
- [25] Website of International Data Corporation (IDC). 2005 <<http://www.idc.com>>.
- [26] Japan Information Processing Development Corporation (JIPDC). IT white book. Tokyo: JIPDC; 2003.
- [27] Website of NEC. Product information; September 2005 <<http://www.n-keitai.com/>>.
- [28] Website of Sharp. Product information; September 2005 <<http://www.sharp.co.jp/products/index.html>>.
- [29] Website of Panasonic. Product information; September 2005 <<http://panasonic.jp/mobile/>>
- [30] Website of Fujitsu. Product information; September 2005 <<http://www.fmworld.net/>>.
- [31] Website of Mitsubishi. Product information; September 2005 <<http://www.mitsubishielectric.co.jp/products/index.html>>.
- [32] Website of Sanyo. Product information; September 2005 <<http://www.e-life-sanyo.com/>>.
- [33] Website of Toshiba. Product information; September 2005 <<http://www.toshiba.co.jp/digital>>.
- [34] Website of SonyEricsson. Product information; September 2005 <<http://www.sonyericsson.co.jp/>>
- [35] NTT Mobile Communications Network, Inc. NTT DoCoMo's vision towards 2010. Tokyo: NTT Mobile Communications Network, Inc.; 1999.
- [36] GfK Marketing Services Japan Ltd. (GfKMSJ). Panel survey: profidence of mobile market in Japan. Tokyo: GfKMSJ; 2005.
- [37] Website of International Data Corporation (IDC) Japan; September 2005 <<http://www.idcjapan.co.jp/Press/index.html>>.

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