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Implications for national information infrastructure development

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Abstract

Purpose – The purpose of this paper is to investigate the effect of inter-platform competition on the adoption of different broadband technologies (i.e. among xDSL, fibre-optic technologies, and hybrid fibre coaxial (HFC)), examine the direction of the effect, and identify potential technology convergence and the speed of technology innovation.

Design/methodology/approach – It uses Lotka-Volterra equation to determine the dynamic competition pattern for xDSL, fibre-optic technologies, and HFC.

Findings – The influence of inter-platform competition on the adoption rate may vary depending on the market conditions, the phase of the adoption period, and the types of competing technology. Even though new technology has competitive advantage, it still requires time to acquire market share. Even though fibre-optic is leading in the market, alternative technologies have also garnered significant market share in the early stage. Specifically, HFC has gained its own market position, making it a valuable alternative in the short term. Nonetheless, the market will eventually converge to fibre-optics.

Originality/value – The findings show that inter-platform competition does not always exert positive influence on broadband adoption as indicated in previous literature. Instead, the influence may vary from negative to neural. This information is an important knowledge addition to the literature. Overall, the study has important implications to governmental effort in managing market competitions and in planning national broadband infrastructure policies. It also provides valuable implications on how ISPs should strategize their investment in new broadband technologies.

Keywords Broadband access network, Korean broadband policy, Lotka-Volterra equation, Platform competition, Technology substitution

Paper type Research paper

Introduction

Having advanced network infrastructure is critical to develop a better information and communications technology (ICT) ecosystem (Garfield and Watson, 1997; Picot and Wernick, 2007; Rasmussen, 2001; Chang *et al.*, 2014; Rampersad and Troshani, 2013; Chang *et al.*, 2015). Recognizing this, many developed and newly industrialized

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countries have implemented national information infrastructure policies for their broadband market as far back as two decades ago (Frieden, 2005; Štefan and Imre, 2012). Most of these policies focus on increasing the adoption rate and incentivizing investments in the next generation network (Røpke, 2012). One strategy that is often used to increase rapid growth in broadband adoption is to practice inter-platform competition (Lee and Brown, 2008). For inter-platform competition to function, it becomes essential to lower the price, improve the quality of service, and promote investment and innovation (DotEcon, 2003). Guided by the market trend, research in the broadband market also tend to focus on topics such as strategies to stimulate the adoption of broadband technology and methods to facilitate inter-platform competition as the driving force to encourage the entrance of alternative broadband platforms into the marketplace (Denni and Gruber, 2007).

As market and consumer demand increases, internet service providers (ISPs) face challenges to offer not only significantly better quality connections but also to create more business opportunities especially in a saturated ICT market. To provide differentiated services in terms of speed and quality, ISPs need to make prudent investment decision on broadband technologies (EC, 2013). Among the next generation broadband technologies, fibre platforms such as fibre-to-the-home (FTTH) and local area network (LAN) are outstanding options (Lee *et al.*, 2003) because these technologies can provide reliable speed up to 10 Gbps. However, despite having the support of the regulators to substitute old technologies, ISPs are careful and conservative in their investment decisions due to unpredictable future profit and commercial viability. According to the OECD (2013), digital subscriber line (DSL) is still the dominant technology with 52.69 per cent share in fixed broadband subscriptions and 30.91 per cent share in cable subscriptions. Even though DSL is being gradually replaced by fibre at a rate of 15.75 per cent, fibre deployment still presents a great challenge (Briglauer and Gugler, 2013).

Furthermore, despite the increasing attention given to the mobile market, fixed broadband network is still the basic infrastructure needed to ensure ubiquitous connection. Delayed substitution to faster and more reliable networks can mean a loss of competitiveness in the broadband market. In particular, substitution from old technologies to new fibre platform is important to prepare for future internet services such as ultra-high density quality contents, video streaming services, and the internet of things (IoT).

This paper is motivated by the following research questions. Many research in inter-platform competition found that it positively influences the level of market saturation and competitive relationship between technologies such as xDSL and hybrid fibre coaxial (HFC) as well as between xDSL and FTTH (Distaso *et al.*, 2006; Lee and Brown, 2008). We questioned:

RQ1. If the influence will always remain positive regardless of the market condition and market saturation level.

Another question that we raised is:

RQ2. The effect of inter-platform competition on the speed of technology innovation.

The high-speed internet market no long just concerns about the increment of adoption rate. Rather, now, it worries about the effect of new technology innovation on the market. Previous research only covers the rate of competition and adoption. To address the latest market trend, research needs to start investigating the effect of new technology innovation and its impact on the adoption rate of existing related technologies. Will the market converge to one broadband platform? Or will the market allow simultaneous existence and survival of multiple technological options?

Based on the research questions, the objectives of our paper can be grouped into three components. First, we investigated the effect of inter-platform competition on the adoption of different broadband technologies. Second, we examined if the effect is positive as indicated in the literature or is it possible to have negative or neutral effect. Third, we identified potential the convergence of technology, if any, and the speed of technology innovation. We used the Lotka-Volterra (LV) competitive equations to analyse the competitive relationship among the different broadband technologies. The goal was to provide a simplified view of the competitive substitution patterns among different broadband technologies.

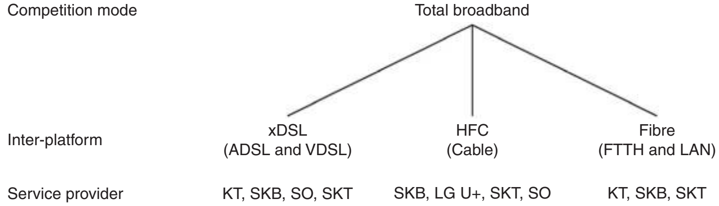
We adopted the South Korean broadband market as our backdrop to serve as a good case in analysing the dynamics of broadband development and technology competition in the market. Korea is one of the global leaders in broadband deployment since 1999 (Menon, 2011). In fact, the International Telecommunications Union ranked the country number one in ICT development index (Chang *et al.*, 2015). Many studies have analysed the Korean case to study ICT development, policies, and other ICT related social phenomena to identify success factors (Lee *et al.*, 2003; Lau *et al.*, 2005; Lee and Brown, 2008; Kim, 2006) and drew implications for international comparative analysis (Lee and Chan-Olmsted, 2004; Frieden, 2005; Lee and Brown, 2008; Lau *et al.*, 2005). Following the literature, we believe the data and findings from Korea's broadband market will serve as good guidelines as well to developed countries and many fast developing countries such as China that plan to follow similar road paths to push their broadband technologies forward.

The paper is organized as follows. Second section presents previous literature of the broadband market and its competition. It also explores the historical Korean broadband policy with government technical requirements. Third section introduces the LV competitive equations and details the data and analysis procedures. Fourth section presents the results of the data analysis. Fifth section discusses the results and provide some implications while sixth section concludes the paper.

Theoretical background

Inter-platform competition

Inter-platform competition refers to the competition among two or more technologies in the same market (Distaso *et al.*, 2006). In the Korean broadband market, there are three major types of technologies that are competing with each other: xDSL, HFC, fibre (see Figure 1). Previous research (Aron and Burnstein, 2003; Distaso *et al.*, 2006; Höffler, 2007; Waverman *et al.*, 2007; Bouckaert *et al.*, 2010) show that inter-platform competition creates positive effect on broadband adoption, which leads to either



Notes: *SKT: Resale; *SO: system operators

Figure 1. Inter-platform competition and the respective ISPs in South Korea

mutualism or commensalism. Aron and Burnstein (2003), for example, found a positive effect of inter-platform competition between cable modem and DSL on broadband penetration. Similarly, Bouckaert *et al.* (2010) showed that inter-platform competition is a main driver of broadband diffusion. The other competitive status (i.e. pure competition, predator-prey, amensalism, neutralism) are the results of either a negative effect or no effect on the adoption rate (see Table I). Even though many research have examined the importance and the effect of inter-platform competition, there is a lack of study that focuses on understanding the technological competition process in the broadband market.

Broadband technology competition

It is crucial to understand the competition process so that effective strategies to deploy resources can be made in a timely manner. When a new technology enters the market, it generally starts to compete with existing technologies. Depending on the level of competition, new technology may replace old ones gradually or very quickly. By assessing the competition process, regulators and ISPs can detect the signs of mature technologies and devise strategies to manage their behaviours accordingly (Pistorius and Utterback (1995).

To describe the interactive competitive markets, the LV equations were adopted because these equations can better explain the substitution process (Bhargava, 1989). The LV equations demonstrate the complicated relationships among technologies in a simple form with several logistic differential equations. Many previous research have used the LV equations to analyse technology competition (Morris and Pratt, 2003; Watanabe *et al.*, 2003; Kim *et al.*, 2006; Kreng and Wang, 2009a, b; Kreng *et al.*, 2012). Some of them provided insights into the performance of the LV equations and others tried to clarify the competitive relationships empirically and suggest political implications. We used the discrete time LV model to analyse the tripartite inter-platform competition process. Considering the importance of governmental role in the development of Korean broadband infrastructure (Picot and Wernick, 2007; Falch, 2007; Shin, 2007), we discussed the results with Korean broadband infrastructure policies in mind.

Korean broadband infrastructure policies

To catch up with other leading countries in equipping the country with advanced network infrastructure, the Korean government has articulated an action plan to promote a facility-based competition and subsidize infrastructure advancement (Choi, 2011). The plan provided guidelines to ISPs to build broadband infrastructure. ISPs in the country started their broadband connection with relatively low cost technologies such as asymmetric digital subscriber line and HFC using cable modems (Choi, 2011).

Today, however, South Korea has leapfrogged into a leading country both in broadband connection and in the ICT sector. As one of the leading countries in internet usage and traffic consumption (Weller and Woodcock, 2013), South Korea is ranked first in the diffusion of FTTH/LAN at 24.2/100 inhabitants. Its government also initiated the "Giga Korea" project which upgrades the current broadband infrastructure to 1-10 Gbps. A set of national policies was also established to provide sufficient and affordable broadband services to homes, businesses, and the public sector.

Table II shows the timeline for Korean broadband policies. Korean Information Infrastructure Policy (KII) focused on infrastructure building while National Informatization Master Plan (NIMP) provided generic policies for a knowledge-based society. At the early

Study	Independent variables	Significant variables	Sign of platform competition	Findings of platform competition
DotEcon (2003)	Facilities-based competition (inter-platform competition); access-based competition (inter-platform competition)	Facilities-based competition	+	The broadband penetration tends to be higher in some EU countries where DSL and non-DSL platforms have more similar market share
Garcia-Murillo (2005)	Unbundling (inter-platform competition); ownership; competition; population; income; prices; education; content; personal computers; internet access	Results vary based on the models	n/a	No evidence is found on the positive role of unbundling policies towards broadband adoption. Strong evidence is found on the role of competition
Distaso *et al.* (2006)	Inter-platform competition; inter-platform competition; rights of way; prices of inter-platforms; price of call	Inter-platform competition; LLU price	+	Inter-platform competition drives broadband adoption but inter-platform competition does not play a significant role
Cava-Ferreruela and Alabau-Munoz (2006)	Supply side variables (infrastructure availability, investment, market competition, prices); demand side variables (penetration, internet/economic/demographic/education/social indicators)	Broadband supply (economic indicators, market competition, demographic indicators, infrastructure availability) Broadband demand (internet, education, economic indicators)	+	Inter-platform competition has a significant and positive impact on broadband penetration whereas unbundling has no significant effect
Lee and Brown (2008)	Inter-platform competition; price; speed; income; ICT use; education; population; price of mobile content	Platform competition; speed; ICT content	+	The impacts of inter-platform competition are strong when the market share of dominant technology and non-dominant technology is similar
Denni and Gruber (2007)	Inter-platform competition; firm size index; market fragmentation index; inter-platform competition; central office density; potential for broadband competition	Results vary based on the models	+	Inter-platform competition has a significant and positive impact on diffusion speed whereas inter-platform competition has a positive impact only if the number of entrants is not too large

(*continued*)

Table I. Empirical studies examining broadband adoption factors and platform competition

Study	Independent variables	Significant variables	Sign of platform competition	Findings of platform competition
Bouckaert *et al.* (2010)	Herfindahl index inter-platform competition; Herfindahl index inter-platform (facility-based and service-based) competition; price; speed; population; income; PC-penetration; time trend	Herfindahl index inter-platform competition; Herfindahl index inter-platform (only service-based) competition; price; speed; population (density only); income; PC-penetration; time trend	+	Inter-platform competition has a positive impact on broadband penetration whereas inter-platform competition is an impediment to penetration
Fageda *et al.* (2014)	Inter-platform competition; inter-platform competition; speed; bundle service provision; bitstream access provision; limited data allowance; scale of broadband subscription	Inter-platform competition; speed; bitstream; limited data allowances	Insignificant over prices	Inter-platform competition has no significant effect over prices while inter-platform competition is a key driver of the prices charged in the broadband market. The impact of different types of competition on prices is critically affected by the levels of development of the broadband market

Table I.

Period	KII		NIMP
1996-2000	KII-I (1995-1997)	NIMP I	Information Promotion Plan
1999-2002	KII-II (1998-2000)	NIMP II	Cyber Korea 21
2002-2006	KII-III (2001-2002)	NIMP III-1	e-Korea Vision 2006
2003-2007	NIMP III-2		Broadband IT Korea Vision 2007
2008-2012	NIMP IV		NIMP Stage IV
2013-2017	NIMP V		NIMP Stage V

Note: *2006-2010: u-Korea Plan

Table II.
Korean broadband policies

stage of broadband diffusion, both components of the Korean broadband policies were carried out almost simultaneously. When all KII objectives were implemented in 2002, the Korean broadband policies shifted the focus onto the NIMP starting from 2003. Despite the importance of NIMP in the Korean broadband development, the majority of the studies focus only on KII. Only a few fragmented ones investigate NIMP.

As shown in Figure 2, most of the market growth took place after NIMP III-2. Up until NIMP III-1, the focus of the policies was not on providing better bandwidth. Rather, it was on promoting the diffusion of broadband connection. The goal of access network policy was to supply a secure 1 Mbps connection to universal subscribers and to supply 20 Mbps connection to 84 per cent of the general subscribers.

The direction of the broadband policy has changed from a quantitative expansion to a qualitative evolution during NIMP III-2 with a project named "Broadband IT Korea

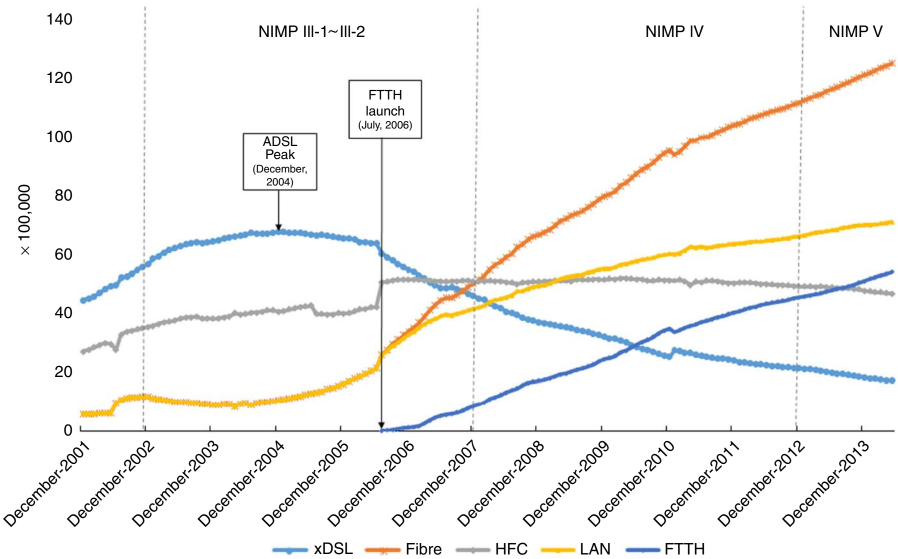


Figure 2. Total number of subscribers of broadband market by technologies

Vision 2007". During this period, xDSL usage gradually declined as it moved into the maturity stage. At the same time, the construction of LAN in apartment areas expanded. The service quality required for subscribers was a 50-100 Mbps end-to-end connection. fibre-to-the-curb in subscribers' line was improved with FTTH that was launched in December 2004 after deliberate consideration of the market demand and investment returns. While fibre connection has many advantages, xDSL and HFC had relatively large portion of the total market during the NIMP III-2 period.

From NIMP IV onwards, the Korean broadband market rapidly shifted to fibre connection. Interestingly, HFC was still surviving with its operators trying to increase the speed by adopting DOCSIS 3.0. From Figure 2, it is evident that there is no significant change in the market share for HFC, but the usage of xDSL declines rapidly. This means we may forecast the decline of xDSL from the real market status but we would not know whether HFC usage will decline or when the technology will be out of the market.

Each ISP adopts different technologies depending on their facilities. KT, the largest ISP in Korea, enhances more than 90 per cent of its facilities with fibre-optic technologies such as LAN and FTTH, and supplies services with 100 Mbps connections. SK Broadband and LG U+ use more diverse technologies including LAN, FTTH, and HFC while cable TV operators use only HFC. The availability and adoptability of alternative technologies are directly linked to the sustainable growth of the ISPs and cable operators. This is the reason why we attempted to trace the competitiveness of each technology. With the results, government can devise intervention programmes on how to promote market competitiveness and how to develop national network infrastructure.

Research model

LV model for tripartite technologies competition

In order to investigate technology competition, the competition itself needs to first be translated into economic activities. These activities can be indices of benefits to consumers such as the volume of reduced costs, new technological functions, the number of advertisements, and the sales volume. In this paper, we adopted a model that incorporated competition explicitly to investigate the competitive process among tripartite technologies. Following the literature (Kim *et al.*, 2006; Kreng and Wang, 2009a, b; Kreng *et al.*, 2012; Lee *et al.*, 2011), we used the number of subscribers as a representative index to adopt the technology for analysis.

We assumed that the derivation of a discrete time analogue of the tripartite technologies competition on the Korean broadband market corresponds to the LV equations. After launching the broadband technologies, it competes with each other to attract subscribers who want to connect to the broadband network. The competing technologies were classified into xDSL, fibre connections, and HFC. Following the OECD statistics report, fibre connection includes FTTH and LAN connections. With three technologies in the analysis, our study focused on the process of inter-platform competition. The competition among the three technologies can be expressed as in the following equation:

$$\frac{dX_i(t)}{dt} = X_i(t)\left(a_i(t) - b_i(t)X_i(t) - \sum_{j=1}^{3} c_{ij}(t)X_j(t) \right) \tag{1}$$

where X_i is the broadband technologies, $i=1, 2, 3$; X_j the competitive broadband technologies, $j=1, 2, 3$; t the time, $t>0$; a_i the capability of each technologies; b_i the limitation of the niche capacity; and c_{ij} the interaction with the other technologies.

In order to use discrete time data, Leslie (1958) transformed Equation (1) which originally used continuous time equation into a discrete time format:

$$X_i(t+1) = \frac{\alpha_i(t)X_i(t)}{1+\beta_i(t)X_i(t)+\sum_{j=1}^{3}\gamma_{ij}(t)X_j(t)} \tag{2}$$

The logistic parameters for the single technology α_i in Equation (2) refers to the growing capacity when it exists alone in the market. The parameter γ_{ij} shows the proportions of the impact a technology has on the rate of increase or decrease of the other technologies. Leslie (1958) also showed the derivation of the relationship between coefficients of differential equations as follows:

$$a_i = \ln \alpha_i \tag{3}$$

$$b_i = \frac{\beta_i a_i}{\alpha_i - 1} = \frac{\beta_i \ln \alpha_i}{\alpha_i - 1} \tag{4}$$

$$c_{ij} = \gamma_{ij}\frac{b_i}{\beta_i} = \frac{\gamma_{ij}}{\beta_i}\frac{\beta_i \ln \alpha_i}{\alpha_i - 1} = \frac{\gamma_{ij}\ln \alpha_i}{\alpha_i - 1} \tag{5}$$

As $\ln \alpha_i/(\alpha_i - 1)$ is always positive if $\alpha_i > 0$ and $\alpha_i \neq 1$, therefore the sign of γ_{ij} is the same as c_{ij} and we can determine the type of competitive roles based on the signs of γ_{ij}. Modis (1999) classified the type of competitive relationship in terms of c_{ij} and c_{ji}. After modifying the sign difference between Modis's model and our model, we followed the classification of competitive status in our model as shown in Table III.

Data and method

As previously noted, the Korean broadband market development is affected by the government's infrastructure policy. There are important modifications over the years as the policy changed. Thus, we divided the empirical data into three phases after considering the market situation. The first phase was from December 2001 to 2004 when the subscription of xDSL dramatically increased and finally reached the saturation point. The second phase was from January 2005 to December 2007 which was the end of NIMP III-2. At that time, the market required faster connection. As a result, the penetration of xDSL gradually declined. The government keenly promoted fibre connections then. However, since most of the fibre connections were built on LAN technology, the impact was relatively small at the early stage. The third phase was after July 2006 when FTTH was introduced. With the introduction of new technology, stiff competition took place.

To determine the dynamic competition pattern in each period, we first estimated the parameters of Equation (2) for each technology. The monthly number of broadband subscribers by technologies was designated as X_i where X_1 represents xDSL, X_2 represents fibre while X_3 represents HFC. The analysis was done using statistical package for social sciences and Microsoft Excel. Non-linear least-square method was used to estimate the coefficients of the model. For iterative procedure, we used the Levenberg-Marquardt algorithm. The convergence criterion value was set at 0.0001. If the maximum percentage variance of the parameter coefficients was less than 0.01 per cent, the iteration will stop. The initial value of a_i was set at 1 and the rest of parameters started from 0.001.

To estimate the competitive relationships among the three technologies, we investigated the sign and the significance of the estimated coefficients. Following Kim *et al.* (2006), we initially assumed the sign of the insignificant parameter γ_{ij} as 0 and we tried to find the implications. Even though the parameter is insignificant, if we need additional information, we can find implications from the original sign of the insignificant parameters following Kreng *et al.*'s (2012) suggestion.

Results of the analysis

Dynamic platform competition

The estimation results of the parameters, p-values and R^2 are given in Table IV. The estimation performance is good because all of the R^2 are greater than 0.85. Even though several parameters are statistically insignificant, many of the p-values are less than the

Sign of c_{ij}	c_{ji}	Type	Description
+	+	Pure competition	Both technologies have negative influence on the other technology
−	+	Predator-prey	New or old technology serves as direct food to the other technology
−	−	Mutualism	Both technologies have positive influence on the other technology, a win-win case
−	0	Commensalism	One benefits from other technology, where the former remains unaffected
+	0	Amensalism	One suffers from the other technology, where the former is impervious to what is happening
0	0	Neutralism	No interaction whatsoever

Table III. The type of competitive relationship according to the signs of c_{ij} and c_{ji}

Table IV.
Estimation results

	Coefficients (t-value)						
X_i	α_i	β_i	γ_{i1}	γ_{i2}	γ_{i3}	R^2	F-value
Phase 1							
X_1	1.080 (86.404***)	−1.59E-08 (−1.624)		−3.80E-08 (−4.119***)	5.49E-08 (3.018**)	0.997	231863
X_2	1.454 (6.029***)	1.68E-07 (1.235)	−5.65E-08 (−0.465)		1.66E-07 (0.735)	0.858	2043
X_3	1.141 (28.927***)	3.45E-07 (6.205***)	−1.67E-07 (−5.699***)	−1.36E-07 (−5.060***)		0.975	28329
Phase 2							
X_1	1.641 (5.376***)	7.98E-08 (2.057*)		5.77E-08 (2.119*)	8.98E-09 (0.714)	0.996	111603
X_2	0.439 (7.321***)	−6.31E-08 (−6.636***)	−8.54E-08 (−10.001***)		1.91E-08 (2.344*)	0.998	23394
X_3	0.526 (5.411***)	3.10E-08 (2.326*)	−7.73E-08 (−6.381***)	−6.47E-08 (−5.708***)		0.938	10918
Phase 3							
X_1	1.025 (6.873***)	6.37E-09 (0.691)		1.88E-09 (0.449)	4.72E-10 (0.023)	0.999	216509
X_2	0.905 (12.975***)	−4.88E-09 (−2.062*)	−2.01E-08 (−3.910***)		−6.50E-10 (−0.085)	1.000	817925
X_3	1.052 (13.668***)	5.79E-09 (0.625)	2.76E-09 (0.536)	1.77E-09 (0.754)		0.954	850209

Notes: *,**,***Significant at $p < 0.1$; $p < 0.05$; $p < 0.01$

0.1 level. From the results, we can see that while emerging technologies have technical advantages compared to existing technologies, they cannot immediately threaten older technologies. Nonetheless, established technologies are continuously being substituted by newer technologies in the market.

In the first phase, xDSL usage continuously increases in the market even though one of the fibre-optic technologies (i.e. LAN) has since been launched in the broadband market. However, the number of xDSL subscribers gradually declines and HFC successfully erodes the market share of xDSL.

Assuming that the insignificant values γ_{21} and γ_{23} are 0, the relationship between fibre-optic as represented by LAN and other technologies is essentially a commensalism. This means that LAN subscription is not affected by the fluctuating numbers of other technologies in the market. In fact, as LAN usage increases, other technology adoption also increases at the same time. This implies that not many of the existing xDSL and HFC subscribers switch to LAN. Even though LAN provides faster connection, it does not fulfil the needs of general users in phase 1. Regardless of the reasons (e.g. limitation of price strategy, coverage or lack of promotion), HFC is the most attractive technology in this phase.

The findings on the relationship between xDSL and LAN as well as between HFC and LAN in phase 1 echo the same positive effect on adoption rate found in the literature. However, when HFC competes with xDSL, it displays a prey-predator relationship. Depending on factors such as market segments, technology characteristics, and marketing elements, the effect on the adoption rate may not always be positive. In fact, it could bring either negative or neutral effect. According to Choi, 2011, cable network operators (i.e. HFC) in Korean spend a lot of money on marketing activities. It indicates that the effect of competitive relationship can vary depending on market conditions at the time when ISPs adopt new technological platforms.

In phase 2, the market environment gets more complex. The market of xDSL is eroded by LAN but at the same time the market of LAN is also eroded by HFC. Even though the FTTH is launched, its impact is relatively small. Thus, we ignored the effect of FTTH in the penetration of fibre connection in this phase. Up until phase 1, there is no significant evidence that fibre connection plays the role of a predator in the market. However, in phase 2, it starts to threaten the market of xDSL. Even though the relationship between xDSL and HFC is a commensalism considering the significance level, the sign of the parameter indicates that HFC is still a threat to the xDSL market. Therefore, as a predator, HFC still commands a significant portion of the broadband market in phase 2.

The findings clearly show that inter-platform competition leads to erosion among the technologies in phase 2. Therefore, at the time when competition becomes more severe, if ISPs use inter-platform competition to facilitate adoption without considering the specific market condition, then cannibalism among the technologies could take place. Even though previous literature found that inter-platform competition leads to positive effect on adoption, our study shows that the actual situation is more complex in nature. In fact, we found that negative effect might take place. This provides evidence explaining why ISPs always have contrasting perspectives, i.e., a positive expectation of technology serving as market facilitator and a negative concern of technology eroding their own market. Therefore, when ISPs consider adopting inter-platform competition, their focus should not be solely on expanding the market size. Instead, they should also strategize to address the possibility of market erosion and its consequences.

After the introduction of FTTH, HFC cannot maintain its good market position anymore. Assuming the insignificant γ_{ij} and γ_{ji} equal 0, HFC does not have effect on other technologies in the market in phase 3. In other words, there is no relationship between HFC and other technologies. This can be interpreted as the HFC technology having its own market position. However, the relationship between xDSL and fibre connection may be a commensalism. If we were to focus on the sign for the interpretation, then it is obvious that fibre has a positive effect on xDSL and HFC. Therefore, in phase 3 where the market enters into saturation, inter-platform competition shows mostly no interaction among technologies. Compare to phases 1 and 2, the effect of inter-platform competition has reduced significantly. This means that the role of inter-platform competition as the facilitator of technology adoption varies depending on the phases.

Table V shows the competitive relationships over the three phases.

		Phase 1		Phase 2		Phase 3	
X_i	X_j	γ_{ij}	γ_{ji}	γ_{ij}	γ_{ji}	γ_{ij}	γ_{ji}
xDSL	Fibre	–	0 (–)	+	–	0 (+)	–
		Commensalism (mutualism)		Prey-predator		Commensalism (prey-predator)	
xDSL	HFC	+	–	0 (+)	–	0 (+)	0 (+)
		Prey-predator		Commensalism (prey-predator)		Neutralism (pure competition)	
Fibre	HFC	0 (+)	–	+	–	0 (–)	0 (+)
		Commensalism (prey-predator)		Prey-predator		Neutralism (predator-prey)	

Table V. Competitive relationships

Equilibrium analysis

The results of the tripartite competitive relationship provide information related to market equilibrium. We investigated whether the market will eventually converge to only one technology. To achieve reliable prediction of the future market, we used the estimation results in phase 3 which reflect the latest data.

We first transformed the differential equations provided by Equation (1) on each technology to the following equation by denoting $X_i = X_i^* + u_i$ and $X_j = X_j^* + u_j$. From this transformation, the origin is moved to the stable equilibrium point:

$$\frac{du_i(t)}{dt} = u_i(t)\left(a_i(t) - b_i(t)\left(X_i^* + u_i(t)\right) - \sum_{j=1}^{3} c_{ij}(t)\left(X_j^* + u_j(t)\right)\right) \tag{6}$$

To derive equilibriums, we used Equation (6). We transformed the coefficient parameters in Tables IV-VI with Equations (3)-(5).

When none of the market capacity changes, we can first derived eight equilibrium points as shown in Table VII. To calculate E123 that three kinds of technologies can survive in the market, we denoted D as follows:

$$D^* = b_1b_2b_3 + c_{13}c_{21}c_{32} + c_{12}c_{23}c_{31} - b_1c_{23}c_{32} - b_2c_{13}c_{31} - b_3c_{12}c_{21}$$

$$D_1 = a_1b_2b_3 + a_2c_{13}c_{32} + a_3c_{12}c_{23} - a_1c_{23}c_{32} - a_2b_3c_{12} - a_3c_2c_{13}$$

$$D_2 = a_2b_1b_3 + a_1c_{23}c_{31} + a_3c_{13}c_{21} - a_1b_3c_{21} - a_2c_{13}c_{31} - a_3b_1c_{23}$$

$$D_3 = a_3b_1b_2 + a_1c_{21}c_{32} + a_2c_{12}c_{31} - a_1b_2c_{31} - a_2b_1c_{32} - a_3c_{12}c_{21}$$

However, not all of the solutions are stable. So, we had to analyse the stability of the equilibrium points in a dynamic environment. To analyse the stability level, we used a Lyapunov function. In this case, we followed Krasovskiĭ's generalized method

Table VI. Coefficients which transformed from Table III

X_i	a_i	b_i	Coefficients c_{i1}	c_{i2}	c_{i3}
X_1	0.025	6.29E-09		1.86E-09	4.66E-10
X_2	−0.099	−5.13E-09	−2.11E-08		−6.83E-10
X_3	0.051	5.64E-09	2.69E-09	1.73E-09	

Table VII. Estimated equilibriums and determinant values of Jacobian matrix

Equilibrium		Det (F)
E_0=(0, 0, 0)	(0,0,0)	–
$E_1 = (\frac{a_1}{b_1}, 0, 0)$	(3,924,352, 0, 0)	−1.29E-04
$E_2 = (0, \frac{a_2}{b_2}, 0)$	(0, 19,379,205, 0)	5.91E-03
$E_3 = (0, 0, \frac{a_3}{b_3})$	(0, 0, 8,957,285)	−8.75E-04
$E_{12} = \left(\frac{a_1b_2-a_2c_{12}}{b_1b_2-c_{12}c_{21}}, \frac{a_2b_1-a_1c_{21}}{b_1b_2-c_{12}c_{21}}, 0\right)$	(8,451,127, −15,321,588, 0)	–
$E_{13} = \left(\frac{a_1b_3-a_3c_{13}}{b_1b_3-c_{13}c_{31}}, 0, \frac{a_3b_1-a_1c_{31}}{b_1b_3-c_{13}c_{31}}\right)$	(3,377,545, 0, 7,374,915)	−3.89E+11
$E_{23} = \left(0, \frac{a_2b_3-a_3c_{23}}{b_2b_3-c_{23}c_{32}}, \frac{a_3b_2-a_2c_{32}}{b_2b_3-c_{23}c_{32}}\right)$	(0, 18,954,745, 3,189,473)	−5.84E-03
$E_{123} = \left(\frac{D_1}{D^*}, \frac{D_2}{D^*}, \frac{D_3}{D^*}\right)$	(10,343,987, −24,635,488, 11,584,698)	–

which suggests a simple form of a Lyapunov function for non-linear systems (Krasovskiĭ, 1963).

To derive the Lyapunov function, we denoted the Jacobian matrix of the system as given in the following equation:

$$J = \frac{df}{du} = \begin{bmatrix} \frac{df_1}{du_1} & \frac{df_1}{du_2} & \frac{df_1}{du_3} \\ \frac{df_2}{du_1} & \frac{df_2}{du_2} & \frac{df_2}{du_3} \\ \frac{df_3}{du_1} & \frac{df_3}{du_2} & \frac{df_3}{du_3} \end{bmatrix} \quad (7)$$

According to the Krasovskiĭ's method, Lyapunov function V(x) is defined as V(x) = $f(x)^T P f(x)$ when the condition $P = I$ is more general. Thus, when we defined the matrix $-\mathrm{F} = \mathrm{J} + \mathrm{J}^T$, the sufficient condition for asymptotic stability is $\mathrm{F} > 0$, all $x \in N$ (neighbourhood of 0). If the condition holds that all $x \in R^n$ and V(x) are radially unbounded, we have achieved global asymptotic stability.

Of the five equilibrium points, we found that E2 is the only equilibrium point that met the condition, Determinant F > 0. E2 indicates that fibre connection is the only technology to survive in the market. The value of the determinant F is also shown in Table VII.

Based on the constraint of the definition, a Lyapunov function for E2 can be obtained using the following equation:

$$V(x) = f(u_1)^2 + f(u_2)^2 + f(u_3)^2 \quad (8)$$

where:

$$f(u_1) = -(6.29\text{E-}09)u_1^2 - (1.13\text{E-}02)u_1 - (1.86\text{E-}09)u_1u_2 - (4.66\text{E-}10)u_3u_1$$

$$f(u_2) = (5.13\text{E-}09)u_2^2 - (9.94\text{E-}02)u_2 + (2.11E\text{-}08)u_1u_2 - (6.83\text{E-}10)u_3u_2 + (0.4081)u_1(0.0132)u_3 - (2.33E\text{-}10)$$

$$f(u_3) = (5.64E\text{-}09)u_3^2 - (1.73E\text{-}02)u_3 - (2.69E\text{-}09)u_1u_3 - (1.73E\text{-}09)u_2u_3$$

We took the difference between the actual yearly subscriptions and the asymptotic stable equilibrium E2 from July 2006 to 2013 and calculated the V(x), respectively (see Table VIII).

As shown in Figure 3, V(x) is decreasing gradually. This means the subscription will eventually converge to the equilibrium. The result implies that subscribers will eventually choose fibre connection and previous technologies will be phased out. As observed in Figure 4, we can validate its asymptotic stability.

Year	u_1	u_2	u_3	$f(u_1)$	$f(u_2)$	$f(u_3)$	$V_{(x)}$
July-2006	6,039,875	−16,763,439	5,061,675	−1.24E+05	1.17E+05	6.92E+03	2.91E+10
July-2007	4,853,032	−14,846,495	5,088,150	−8.08E+04	1.34E+05	5.63E+03	2.45E+10
July-2008	4,016,117	−13,352,835	5,051,271	−5.68E+04	1.18E+05	5.00E+03	1.71FE+10
July-2009	3,456,736	−11,985,948	5,158,747	−4.56E+04	1.10E+05	−2.42E+03	1.41E+10
July-2010	2,818,174	−10,514,420	5,158,202	−3.36E+04	7.93E+04	−6.63E+03	7.46E+09
July-2011	2,537,761	−9,393,340	5,115,912	−3.10E+04	8.75E+04	−1.14E+04	8.74E+09
July-2012	2,237,146	−8,514,621	4,986,156	−2.66E+04	7.44E+04	−1.10E+04	6.36E+09
July-2013	1,979,036	−7,692,707	4,881,958	−2.33E+04	6.49E+04	−1.14E+04	4.89E+09

Table VIII. The values for calculating V(x)

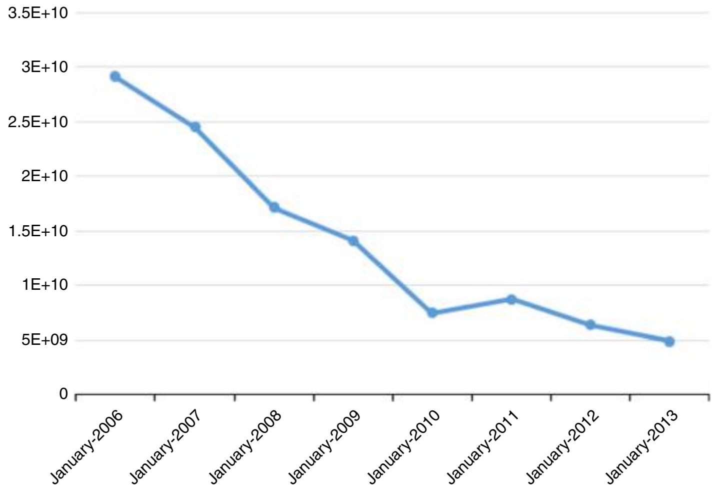


Figure 3.
V(x) values for E2 over time

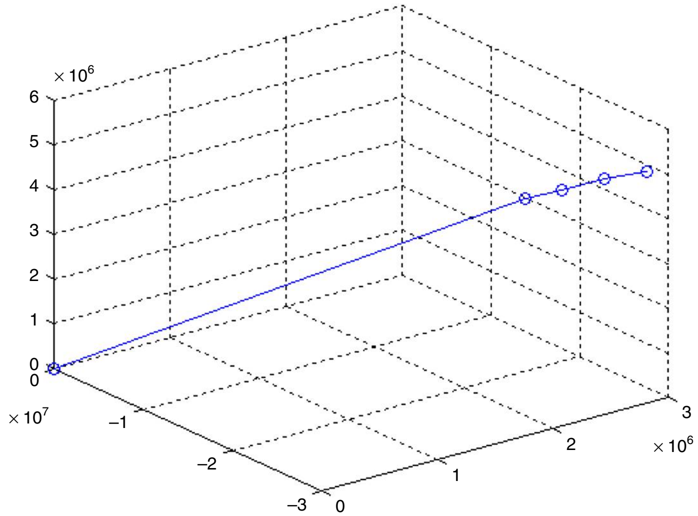


Figure 4.
Phase portrait of dynamic system based on equilibrium E2

Discussion and implications

Recent advances and rapid changes in the mobile market and the ICT sector have raised an important challenge in infrastructure advancement for ISPs, telcos, and regulators. ICT leading countries such as South Korea now face stagnation in infrastructure development and a saturated fixed broadband market. Meanwhile, the mobile broadband market is growing fast with a bandwidth higher than the bandwidth of legacy broadband technologies. Regardless of how fast the mobile market grows, it requires reliable and faster fixed broadband internet infrastructure to provide better services for future ultra-high density video contents and the IoT. In future ICT ecosystem, both fixed and mobile broadband companies must enhance and advance their network to achieve sustainability and constant market growth.

Therefore, it is timely to revisit the fixed broadband market and study its sustainability and potential future advancement by looking at the inter-competition among various technologies.

From the analysis of the competitive relationship among different technologies in the Korean fixed broadband market, we reached three important implications. First, previous research focus on positive influence of inter-platform competition on broadband adoption. Our study, however, shows that other factors such as market conditions, the phase of the adoption period, and the types of competing technology may exert neutral or even negative influence on broadband adoption. Specifically, in the introduction and early growth stage, our findings reinforce the results found in previous research, i.e., inter-platform competition has a positive influence on broadband adoption. However, in the late growth and maturity stage, the influence can change to either neutral or negative. This has important implications for policy makers. While they are always keen to encourage inter-platform competition with the goal of increasing the adoption rate, careful consideration should be exercised to address potential negative or neutral effect of such competition. For ISPs, extra care should be also practiced when using inter-platform competition during the saturation phase to avoid cannibalization.

Second, even if a technology has competitive advantage from a technological viewpoint, it cannot immediately win in the market. However, after entering the market competition for sometimes, a new technology will slowly take over the market share, and drive older technologies out of the market. This is exactly what happens in the Korean broadband market. Now, Korea leads the world in its video and cultural content market as well as the ICT devices market. Its government intends to maintain this leadership position. To achieve the objective, the government ought to initiate effective regulations and policies to drive the whole ICT ecosystem.

Third, unlike the general expectation where fibre connection has a leading position in the market, alternative technologies have also garnered significant market share in the early stage. HFC has its own market position after the competition among technologies while fibre connection has eroded the xDSL market. In the short term, HFC is still valuable as an alternative technology in the market. To maintain a healthy market competition, there should be checks and balances among dominant players. From our analysis, we found that the competition between HFC and other technologies provide evidence on the sustainability of ISPs in the market. Therefore, the Korean government should support the ISPs that use HFC and help them to upgrade their broadband technology and bandwidth.

Conclusion

The Korean Government recently decides to initiate a project to call "Giga Korea" – a Giga bps network and whole ICT ecosystem and infrastructure upgrade project. To achieve this goal, having effective and efficient infrastructure advancement is the fundamental requirement and mandatory process to provide a reliable and faster network to all stakeholders in the ecosystem. However, despite the government's effort to drive the advancement of legacy broadband technology to into the era of fibre technology, its growth is rather slow. Therefore, the Korean's next generation Giga internet policy should focus on strategies to substitute the current legacy system with fibre technology in order to establish a concrete foundation for the ICT ecosystem.

To promote resource investment beyond fibre technology, the challenges faced by the Korean ICT ecosystem are how to best formulate technological objectives for the ISPs, and how to attract application providers to develop suitable software applications and contents. Overcoming these challenges requires timely government policy and regulation (Johnson, 2013). Bouras *et al.* (2009) state the most important factor that affects broadband growth is the regulatory framework and policy support. Choi (2011) also emphasized that policy implementation greatly affects broadband penetration and a nation's broadband compatibility. Therefore, for timely and effective implementation of network advancement in the broadband internet market, the government should have a wholesome view of the national internet infrastructure development policy and should try to implement infrastructure upgrade plan as quickly as possible.

References

Aron, D.J. and Burnstein, D.E. (2003), "Broadband adoption in the United States: an empirical analysis", in Shampine, A.L. (Ed.), *Down to the Wire: Studies in the Diffusion and Regulation of Telecommunications Technologies*, available at: http://ssrn.com/abstract=386100; http://dx.doi.org/10.2139/ssrn.386100

Bhargava, S.C. (1989), "Generalized Lotka-Volterra equations and the mechanism of technological substitution", *Technological Forecasting and Social Change*, Vol. 35 No. 4, pp. 319-326.

Bouckaert, J., Van Dijk, T. and Verboven, F. (2010), "Access regulation, competition, and broadband penetration: an international study", *Telecommunications Policy*, Vol. 34 No. 11, pp. 661-671.

Bouras, C., Gkamas, A., Papagiannopoulos, J., Theophilopoulos, G. and Tsiatsos, T. (2009), "Broadband municipal optical networks in Greece: a suitable business model", *Telematics and Informatics*, Vol. 26 No. 4, pp. 391-409.

Briglauer, W. and Gugler, K. (2013), "The deployment and penetration of high-speed fiber networks and services: why are EU member states lagging behind?", *Telecommunications Policy*, Vol. 37, pp. 819-835.

Cava-Ferreruela, I. and Alabau-Munoz, A. (2006), "Broadband policy assessment: a cross-national empirical analysis", *Telecommunications Policy*, Vol. 30 Nos 8-9, pp. 445-463.

Chang, Y., Wong, S.F. and Park, M.-C. (2014), "A three-tier ICT access model for intention to participate online a comparison of developed and developing countries", *Information Development*, Vol. 32 No. 3, pp. 226-242.

Chang, Y., Kim, H., Wong, S.F. and Park, M.-C. (2015), "A comparison of the digital divide across three countries with different development indices", *Journal of Global Information Management (JGIM)*, Vol. 23 No. 4, pp. 55-76.

Choi, S. (2011), "Facilities to service based competition, not service to facilities based, for broadband penetration: a comparative study between the United States and South Korea", *Telecommunications Policy*, Vol. 35 Nos 9-10, pp. 804-817.

Denni, M. and Gruber, H. (2007), "The diffusion of broadband telecommunications in the US-the role of different forms of competition", *Communications & Strategies*, Vol. 4 No. 68, pp. 139-157.

Distaso, W., Lupi, P. and Manenti, F.M. (2006), "Platform competition and broadband uptake: theory and empirical evidence from the European Union", *Information Economics and Policy*, Vol. 18 No. 1, pp. 87-106.

DotEcon, C.E. (2003), "Competition in broadband provision and its implications for regulatory policy", a report for the Brussels Round Table, 7 July 2006, DotEcon and Criterion Economics, available at: http://ssrn.com/abstract=463041; http://dx.doi.org/10.2139/ssrn.463041

EC (2013), "Information from European Union institutions, bodies, offices and agencies", *Official Journal of the European Union*, Vol. 56 No. C25, pp. 1-26.

Fageda, X., Rubio-Campillo, R. and Termes-Rifé, M. (2014), "Determinants of broadband access: is platform competition always the key variable to success?", *Information Economics and Policy*, Vol. 26, pp. 58-67.

Falch, M. (2007), "Penetration of broadband services – the role of policies", *Telematics and Informatics*, Vol. 24 No. 4, pp. 246-258.

Frieden, R. (2005), "Lessons from broadband development in Canada, Japan, Korea and the United States", *Telecommunications Policy*, Vol. 29 No. 8, pp. 595-613.

Garcia-Murillo, M. (2005), "International broadband deployment: the impact of unbundling", *Communications & Strategies*, TPRC 2003, No. 57, p. 83, available at: http://ssrn.com/abstract=977405

Garfield, M.J. and Watson, R.T. (1997), "Differences in national information infrastructures: the reflection of national cultures", *The Journal of Strategic Information Systems*, Vol. 6 No. 4, pp. 313-337.

Höffler, F. (2007), "Cost and benefits from infrastructure competition. Estimating welfare effects from broadband access competition", *Telecommunications Policy*, Vol. 31 Nos 6-7, pp. 401-418.

Johnson, I.M. (2013), "Development goals after 2015 – the role of information, books and libraries", *Information Development*, Vol. 29 No. 4, pp. 294-296.

Kim, J., Lee, D.-J. and Ahn, J. (2006), "A dynamic competition analysis on the Korean mobile phone market using competitive diffusion model", *Computers & Industrial Engineering*, Vol. 51 No. 1, pp. 174-182.

Kim, P. (2006), "Is Korea a strong internet nation?", *The Information Society*, Vol. 22, pp. 41-44.

Krasovskiĭ, N.N. (1963), *Stability of Motion: Applications of Lyapunov's Second Method to Differential Systems and Equations with Delay*, Stanford University Press, Stanford, CA.

Kreng, V.B. and Wang, H.T. (2009a), "The interaction of the market competition between LCD TV and PDP TV", *Computers & Industrial Engineering*, Vol. 57 No. 4, pp. 1210-1217.

Kreng, V.B. and Wang, H.T. (2009b), "A technology replacement model with variable market potential – an empirical study of CRT and LCD TV", *Technological Forecasting and Social Change*, Vol. 76 No. 7, pp. 942-951.

Kreng, V.B., Wang, T.C. and Wang, H.T. (2012), "Tripartite dynamic competition and equilibrium analysis on global television market", *Computers & Industrial Engineering*, Vol. 63 No. 1, pp. 75-81.

Lau, T.Y., Kim, S.W. and Atkin, D. (2005), "An examination of factors contributing to South Korea's global leadership in broadband adoption", *Telematics and Informatics*, Vol. 22 No. 4, pp. 349-359.

Lee, C. and Chan-Olmsted, S.M. (2004), "Competitive advantage of broadband internet: a comparative study between South Korea and the United States", *Telecommunications Policy*, Vol. 28 Nos 9-10, pp. 649-677.

Lee, H., O'keefe, R.M. and Yun, K. (2003), "The growth of broadband and electronic commerce in South Korea: contributing factors", *The Information Society*, Vol. 19 Nos 9-10, pp. 81-93.

Lee, S. and Brown, J.S. (2008), "Examining broadband adoption factors: an empirical analysis between countries", *Journal of Policy, Regulation and Strategy for Telecommunications, Information & Media*, Vol. 10 No. 1, pp. 25-39.

Lee, S.G., Yu, M., Yang, C. and Kim, C. (2011), "A model for analyzing churn effect in saturated markets", *Industrial Management & Data Systems*, Vol. 111 No. 7, pp. 1024-1038.

Leslie, P. (1958), "A stochastic model for studying the properties of certain biological systems by numerical methods", *Biometrika*, Vol. 45 Nos 1-2, pp. 16-31.

Menon, S. (2011), "The evolution of the policy objectives of South Korea's broadband convergence network from 2004 to 2007", *Government Information Quarterly*, Vol. 28 No. 2, pp. 280-289.

Modis, T. (1999), "Technological forecasting at the stock market", *Technological Forecasting and Social Change*, Vol. 62 No. 3, pp. 173-202.

Morris, S.A. and Pratt, D. (2003), "Analysis of the Lotka-Volterra competition equations as a technological substitution model", *Technological Forecasting and Social Change*, Vol. 70 No. 2, pp. 103-133.

OECD (2013), "Broadband statistics: OECD fixed and wireless broadband subscriptions, by technology", available at: www.oecd.org/sti/ict/broadband

Picot, A. and Wernick, C. (2007), "The role of government in broadband access", *Telecommunications Policy*, Vol. 31 Nos 10-11, pp. 660-674.

Pistorius, C.W. and Utterback, J.M. (1995), "The death knells of mature technologies", *Technological Forecasting and Social Change*, Vol. 50 No. 3, pp. 215-233.

Rampersad, G. and Troshani, I. (2013), "High-speed broadband: assessing its social impact", *Industrial Management & Data Systems*, Vol. 113 No. 4, pp. 541-557.

Rasmussen, A.M. (2001), "Information and development: the information effect", *Information Development*, Vol. 17 No. 4, pp. 12-18.

Røpke, I. (2012), "The unsustainable directionality of innovation – the example of the broadband transition", *Research Policy*, Vol. 41 No. 9, pp. 1631-1642.

Shin, D.-H. (2007), "A critique of Korean national information strategy: case of national information infrastructures", *Government Information Quarterly*, Vol. 24 No. 3, pp. 624-645.

Štefan, B. and Imre, F. (2012), "Broadband availability and economic growthnull", *Industrial Management & Data Systems*, Vol. 112 No. 9, pp. 1292-1306.

Watanabe, C., Kondo, R. and Nagamatsu, A. (2003), "Policy options for the diffusion orbit of competitive innovations – an application of Lotka-Volterra equations to Japan's transition from analog to digital TV broadcasting", *Technovation*, Vol. 23 No. 5, pp. 437-445.

Waverman, L., Meschi, M., Reillier, B. and Dasgupta, K. (2007), "Access regulation and infrastructure investment in the telecommunications sector: an empirical investigation", LECG Analysis with Support of ETNO, WC2E 7HA, London.

Weller, D. and Woodcock, B. (2013), *Internet Traffic Exchange: Market Developments and Policy Challenges*, OECD Publishing, available at: http://dx.doi.org/10.1787/5k918gpt130q-en

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