# Forecast Models of Broadband Diffusion and Other Information Technologies

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***Abstract:*** Ultrabroadband (UBB) is becoming increasingly an important techno-economic and policy issue. New advances and greater convergence of wireline and wireless technologies allow for faster communications and more applications which require higher speeds of transmission. Many countries perform relatively well (Japan and Korea) but others lag. Economists, business analysts, policy makers and other stakeholders are interested in knowing the driving forces for UBB deployment and the new applications. Many models are used to forecast the rate of deployment and explain the factors for its widespread acceptance. A review of the recent literature reveals that demand and cost factors affect positively the deployment of broadband (BB) and other related emerging technologies such as UBB. The empirical studies which use the diffusion models to forecast broadband penetration demonstrate that the forecasting capacity of these models is relatively robust.

***Keywords:*** ultrabroadband, regulation, diffusion models, competition policies.

## ■ Introduction: the changing landscape of the telecommunications industry

In the past few years, mergers and acquisitions and buyouts of large telecommunications firms by private equity and investment funds have changed dramatically the landscape of the industry [1]. Traditional incumbents compete with new entrants to provide services, traditional and new ones,

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[1] For instance, in 2007 Bell Canada was in talks to become private. Three private investment funds were interested in concluding a $42 billion transaction.

such as double play, triple play, high speed fiber connections or advanced media services such as Internet Protocol TV (IPTV). Inter-platform competition is getting more and more intensive since new technologies, especially IP protocol, allow transmission of voice and data communications with an ever increasing security and full-fledged mobility across different network technologies. As a result, the industry is getting more concentrated, and the UBB fiber optic networks lead it into a monopolistic or duopolistic market structure [2]. Additionally, "competition has been giving way to consolidation" (NOAM, 2006:549), and a typical example is the AT&T's reacquisition of two Baby Bell spin-offs.

New technologies, such as wireless connectivity and increased mobility, lead to a greater deployment of future wireline and wireless UBB technologies. Further, UBB has been touted as the route for increasing firms' productivity (GILLETT, 2006) and a country's economic growth. Regulators and policy makers have adopted various approaches to promote the deployment of ultrabroadband and countries and international organizations compile statistics to measure broadband penetration and adopt policies to promote it. Emerging and future UBB providers are interested in the pace of evolution of the demand for ultrabroadband services and they adopt strategies that will allow them to get a significant chunk of the new growing market. Deployment of UBB is quite expensive and firms will hesitate to make important investments if they are not sure that there is sufficient demand to justify their investment. Policy makers are also interested to know the reasons behind the decisions of the firms to deploy UBB technologies. If these reasons are known appropriate policies can be adopted to promote UBB deployment that ranges a high speed information transfer deployment at the last mile beyond 1Gbps.

Various models have been developed and used to predict the diffusion and deployment of new information technologies, such as the UBB, but most of them are at their infancy stage. The precision and forecasting accuracy of these models are quite important for both firms and policy makers alike. Economic forecast models are quite rigorous, but there is an increasing debate whether these models are capable of predicting accurately the pace

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[2] France Télécom's recent attempt to purchase TeliaSonera would have created the world's fourth-largest mobile operator. Its strategy to offer fix, mobile and broadband and video services in a single package to all European customers and advertisers would have reinforced its monopoly position in the European industry. "Telecoms look to grow by acquisition", *International Herald Tribune*, June 2008.
http://www.iht.com/articles/2008/06/05/business/telecom.php?page=2?pass=true

of diffusion and the technologies substitution trends. It is thus advisable to review the literature and examine it critically as to its capacity to explain the growth of broadband diffusion and forecast what may happen with the ultrabroadband technology. UBB is developing quite fast, although not as fast as some would have liked. Existing economic models have done pretty well in identifying the potential drivers that could be used to explain the UBB deployment but as far as their empirical verification is concerned, their forecasting capacity depends on the availability of the data. This paper reviews the existing literature of broadband deployment, analyzes the drivers of change and attempts to reveal the successful path to the UBB deployment. Its main objective is to identify the variables that are most likely to have an impact on broadband deployment and to analyze their importance for the diffusion of the next generation BB, defined as the UBB.

The results of this study are useful for industry analysts, firm strategists and policy makers. In Canada, for instance, regulators promote local loop unbundling believing that competition at the infrastructure level could be the best way to promote UBB deployment in the future. Yet, empirically, it is not quite well understood whether service based competition or facilities based competition could promote the UBB deployment better. Modeling, for instance, demand for UBB services at the local exchange level, will permit to disentangle the impact of local loop unbundling on UBB penetration level.

The following Section reviews the mechanisms and policies for the UBB deployment including the role of the Research and Development (R&D). The section after reviews the empirical literature on competition and diffusion models used to forecast the diffusion of UBB. The last Section concludes and offers policy recommendations. The appendix makes a synthesis of the main arguments of the most recent literature dealing with issues of broadband deployment and economic growth.

## ■ Mechanisms and policies for UBB deployment

### Market forces and the impact of R&D

Firms and individuals use the BB technologies more frequently and more intensively [3], and this has an impact on productivity and on the economy as a whole [4]. Understanding the forces behind the deployment of UBB technologies is quite informative for both firms and policy makers. The former need this information for developing competitive strategies and the latter for developing policies that promote the UBB deployment and the country's economic growth. The theoretical models dealing with these issues fall chiefly into two main categories. On the one hand, there are the ones who believe in market forces to stimulate innovation and increase UBB deployment. On the other hand, there are the ones who argue that a monopoly structure is better for the deployment of UBB technologies. These arguments are not new, as Michael Porter Five Forces model is modified in HILL & JONES (2004) and applied in the Telecom industry as explained in ARAVANTINOS *et al*. (2006a); they emerge frequently, especially when new technologies disturb the market status quo by creating new opportunities that can be seized by incumbents and new entrants alike. Significant enabling and widespread applications such as interactive video and computer gaming opens the UBB market and this may lead to a greater diffusion of broadband technologies. Allowing more competition or restricting the number of players in the industry will have important repercussions on the speed of diffusion of these technologies. From a policy perspective, it is thus quite important to know the exact relationship between innovation and market structure.

Recent empirical papers on the subject (BLUNDELL *et al*., 1999; CARLIN *et al.*; 2004, AGHION & GRIFFTH, 2004) [5] confirm in a sense these findings. In a recent paper, ETRO (2004) reviews the arguments found in the literature and he states that industry leaders get involved in pre-emptive R&D investment and as a result of this strategy there is ultimately one firm in the industry. The latter displays a higher level of competitive behaviour than

[3] See recent statistics at http://www.itu.int/ITU-D/ict/newslog/

[4] See more details in the Appendix.

[5] These papers do not deal directly with ultrabroadband technologies but they examine the propensity to innovate of firms in various market structures.

the standard monopoly. Market structures predominantly monopolistic or with dominant firms exhibit a higher propensity to R&D investment and the dominant firm has a higher rate of survival over the long run than less innovative rival firms [6].

In another paper, KOVAC *et al.* (2006) develop a theoretical model in which the leader undertakes pre-emptive R&D investment making the entry difficult for new comers and exit easier for market followers. This situation is contrasted with another one where the leader accommodates the follower and a duopoly market structure emerges. In both market structures, it is assumed that the leader is the only one that invests in innovation while the followers imitate through R&D spillovers [7]. This assumption is quite novel and allows them to demonstrate that strategic pre-emption is an optimal strategy and the implications of R&D spillovers are to provide incentives to invest in R&D. In the traditional models, unilateral R&D spillovers create disincentives to invest in R&D.

Comparing the two situations, they demonstrate, quite persuasively, that the firms' optimization problem is different between the simple two-stage duopoly model and the dynamic model and this has significant implications on the outcomes of competition, i.e., on innovation. For the former, firms maximize their discounted profit for an infinite time horizon but in the latter, the leader minimizes the time that will lead it to expel the follower from the market. In such a context, the leader may bear losses for a certain period of time in order to be able to enjoy economic profits in the long run. The leader's strategic advantage lies on its pre-emptive investment in R&D which they assume to lead, eventually, to a reduction of its unit cost. The follower benefits from R&D spillovers, and the leader has to decide on the speed with which investments in R&D are translated into unit cost reductions. The initial advantage of the leader and its strategy of pre-emptive investment in R&D, turns the initial duopoly market structure into a monopoly.

The authors demonstrate as well that the strategy of pre-emptive investment in R&D becomes more attractive when the new technologies are

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[6] AT&T and Microsoft are cited as examples. It is true that AT&T has lost a significant chunk of its market power on long distance calls but it has kept investing aggressively in R&D, especially in global Internet Protocol technology. This strategy was quite important to assure the company the leadership in IP networking.

[7] This does not necessarily mean that imitators are laggards and not able to compete with the leader on new technologies. Imitation through spillover effects presupposes that imitators are able to imitate because they have the minimum required technical knowledge to do so. Firms with no particular knowledge in new technologies are not capable of imitating the leaders.

adopted quickly. Given that the costs of pre-emption are of a short duration, the leader exhibits a more aggressive attitude towards R&D compared to the duopoly situation. Social welfare is greater in the pre-emptive R&D situation compared to the duopoly one, given that innovation and output are larger and prices lower than the standard duopoly situation. Although the authors do not deal directly with UBB technologies, their model can be easily applied to these technologies given that the pace of UBB adoption could be quite rapid and the industry exhibits the characteristics of their model.

### Regulatory forces and UBB deployment

Government's intervention in a market can take various forms to stimulate interest in a new technology judged to be essential in terms of economic growth and prosperity. In the broadband area, governments intervene either directly by adopting public promotions policies in the diffusion of broadband networks or by leaving the regulatory agencies to determine the policies that are more likely to influence the decisions of decision makers in the diffusion of BB. Because it is increasingly questioned whether the government programs are efficient in promoting BB, it is advisable to review the existing literature and draw some conclusions. If government policies are, indeed, proven to be a determining factor in broadband diffusion, then, policies that promote economic development should also include the promotion of UBB penetration.

Government policies can be conceived to affect either the demand side or the supply side or both. On the demand side, government policies may make the UBB services more attractive by either aggregating demand or employing simply by promoting the use of these services. On the supply side, government programs may be viewed as facilitator in the process of migration from "older technologies" to new platforms at attractive prices. Or if regulation is used, the government may limit or expand the level of competition in the industry or decide to fix the terms and conditions for new entrants to access incumbents' infrastructure and the level of flexibility incumbents have to react to changing market and industry conditions.

Although cultural differences among countries may be one of the factors explaining the different adoption rates of UBB technologies around the world, industry strategies and government policies may be determining factors in the diffusion of these technologies (Korea and Japan for the NTT DoCoMo services vs. European markets). Government policies may thus guide consumers to develop specific patterns of behaviour, and then these patterns guide the governments to promote the diffusion of UBB technologies. It is thus appropriate to investigate the relationship between government diffusion policies for broadband technologies and service penetration (efficiency). This will provide guidance for future programs and policies concerning new technologies.

In a recent article, MIRALLES (2006) examines empirically the government promotion programs (more than 100) around the world. Applying cluster analysis, the author groups the countries in five categories according to the objectives of their programs. Each group contains countries with heterogeneous characteristics in terms of broadband penetration and economic development. If performance is judged by the BB penetration rate for each country, cluster one with programs aiming at the promotion of BB services seems to be the most successful. Clusters such as three (USA) and four (Canada) that aim at infrastructure development are relatively less successful in terms of BB penetration. Without being able to confirm it statistically, it can be argued this anecdotal evidence indicates that countries that promote BB and UBB services may be more successful in diffusing these technologies faster than others whose goal is the UBB infrastructure deployment. Table 1 summarizes the results.

**Table 1: Efficiency in government policies in promoting broadband deployment**

| | *Cluster 1*<br>*Information age services* | *Cluster 2*<br>*Demand stimulators* | *Cluster 3*<br>*Financial support for local and rural networks* | *Cluster 4*<br>*Infrastructure developers* | *Cluster 5*<br>*Subject oriented* |
|---|---|---|---|---|---|
| *Countries* | Denmark, Norway, Finland | Sweden, Italy | Austria, Republic of Korea, USA | Germany, Canada, France, The Netherlands, Ireland, Japan | Belgium, Spain, Estonia, UK |
| *Technological level* | High TAI<br>High penetration | No specific common characteristics | High TAI | High TAI<br>High GDP | No specific common characteristics |
| *Promotion programs characteristics* | Provide services for the information age | Stimulate demand and deployment of infrastructure | Programs for promoting rural and local initiatives | Setting specific goals for deployment of infrastructure | Provide support to citizens, institutions and companies |

*Source: MIRALLES, 2006*

Regulatory policies are industry specific government policies that aim to provide incentives to telecommunications firms to deploy the UBB technologies faster. Regulation determines, in a sense, the level of competition in the industry and the pace of deployment of innovations. There is considerable debate concerning the impact of regulation on competitive forces and the broadband deployment. A number of studies examines the role of regulation and the efficiency of various regulatory policies to affect the decision of firms to deploy broadband technologies (WALLSTEN, 2005, 2006; HAUSMAN & SIDAK, 2004; FRIEDEN, 2005).

Although in theory competitive markets are indeed conducive to innovation, it is not clear in broadband markets whether such competitive forces work the same way as in traditional commodities. Strategies and expectations about future prices and technological standards may retard investment in broadband or in some cases may accelerate them. Combining these markets with the uncertainties emanating from future regulatory policies concerning unbundling and access prices, the picture becomes more blurred. For instance, BLUM *et al*. (2006) developed a game-theoretic model in order to capture the effects of competition and regulation on broadband deployment. Given that Deutsche Telekom announced in 2005 that it will invest in a new broadband network under the condition not to be regulated with respect to pricing and third party access, BLUM *et al*. demonstrate that the incumbent, in the absence of regulation, will invest in broadband technology but the threat of potential regulation forces him to keep prices low. In that sense regulators, by using appropriate signals, are able to influence the incumbent's decision to invest and the incumbent's price without any explicit price regulation.

Indeed, the effects of regulation on broadband deployment are not entirely understood. In a recent article, WALLSTEN (2006, p. 4), argues that "the effects of policies, including unbundling regulations, continue to be debated internationally". To be sure, the effects of regulation can be direct and indirect. Although broadband rates are not regulated, regulation of basic telecommunication services and the different regulatory regimes that exist between telecommunications and cable may affect the broadband deployment differently. For instance, price caps regulation combined with low prices for Unbundled Network Elements (UNEs) may reduce broadband deployment by the telecommunication carriers but it may increase BB deployment by cable companies. The models used to measure the effects of regulation on broadband deployment should take into account both the direct and indirect effects. No wonder, the results of the empirical studies are quite controversial with respect to this matter.

## The empirical literature on UBB deployment

### Competition models explaining the UBB deployment

A lot of progress has been made and many theories and empirical analyses have been performed in order to better understand the diffusion of new technologies. The empirical studies have examined various factors such as demand, cost and regulatory factors to explain the prevalence of broadband technologies. The models examine either the characteristics of the broadband demand, from a consumer's perspective such as price, education, geography (FLAMM & CHAUDHURI, 2007) or they analyze the effect of the competitive environment (supply side) on broadband deployment (BLUM *et al*., 2006) from a firm's perspective. There is a third strand of studies that examines the role of regulation and the efficiency of various regulatory policies to affect the decision of firms to deploy broadband technologies (WALLSTEN, 2005, 2006; HAUSMAN & SIDAK, 2004; FRIEDEN, 2005). Although there is no major controversy over the effect of demand characteristics on broadband, there is considerable debate as far as the competitive forces determine the broadband deployment and the role of regulation. A critical review of these studies will offer a better understanding of the forces behind the deployment of UBB technologies and this knowledge could be used to make forecasts for its diffusion in the future.

Telecommunications carriers are increasingly facing important regulatory, technological and competition-related challenges. Not all firms react the same way to these challenges though. Some invest in broadband faster than others (first-mover advantage), while others wait till technology is well established and forcefully cheaper (second-mover advantage). Investments in new technologies made at a later date bring higher capacity per dollar spent than investments made earlier. Performance has thus been different across industries and countries. Apparently the next generation digital divide is becoming ever deeper among nations. Industrialized countries like the European Union and North America have long enjoyed the status of being ahead of developing nations in terms of bandwidth capacity, but recently, some developed and developing countries (Korea, Japan, China, etc.) are increasingly taking over the leadership in this area. What are the factors that may explain these differences in country performance? Does the industry structure play a determinant role in the telecommunications sector performance or is the regulatory regime more important in guiding the investment decisions of telecommunication firms in UBB technologies? Are investment decisions demand driven, technology (cost)-driven or regulation-related driven? What affects broadband penetration and demand for UBB?

Some answers to these questions are provided by the empirical studies which examine the effects of unbundling on broadband deployment. Unbundling may take many forms. One can be in the form of sharing facilities with competitors. Indeed, telecommunications carriers are required to make available parts of their network to competitors at regulated rates. At the local loop, unbundling requires that telecommunications allow competitors to get access to the "last mile" and connect to customers' homes and compete head to head with incumbents. This is called service-based competition as opposed to facility or infrastructure-based competition when entrants build their own facilities and compete with incumbents on a number of attributes (quality, reliability, etc). At the service-based competition, the entrant's service is identical to the incumbent's. The idea of having service-based competition is that it allows entrants to eventually build their own facilities once their position is entrenched and have a sufficient number of customers. The access to the network (service-based competition) serves as a "stepping stone" before entrants build their own network and move to facility-based competition (the so-called "stepping-stone theory").

The effect of unbundling on broadband deployment is the most convincing in explaining the difference in broadband performance among nations. Indeed, economists (HAUSMAN & SIDAK, 2004) argue that the stepping stone theory could be a valid explanation for the "relative US retardedness in broadband deployment". Sharing facilities with new entrants reduces the expected returns to investments, thereby discouraging incumbents to invest in infrastructure. This is not the approach taken by the regulatory agencies in Anglo-Saxon countries. There, the regulatory agencies believed that competition in retail markets and in wholesale access markets are prerequisites to stimulate growth and unbundling was one of the means to achieve that. Further, service-based competition will eventually lead to infrastructure based competition (stepping-stone theory). Empirical studies that examined the effects of unbundling on broadband deployment in Canada [8], the US, the UK, Australia, New Zealand and Germany showed that these expected results are more theoretical than real. Indeed, comparing the relative performance of telecommunications and cable

8 Not all unbundling requirements are alike among these countries. For instance, Canadian unbundling was much less demanding than the US. These differences may also explain the relative difference in performance among the countries of this group.

companies in terms of broadband deployment, HAZLETT (2005) shows that cable companies outperformed telecommunications in broadband deployment because the former were not regulated and invested faster in broadband networks than telecommunications which were obliged to share their networks with new entrants. Further, when in 2003 the mandatory line sharing agreements were lifted by the FCC, telecommunications, especially the new AT&T and Verizon, invested in DSL and in FTTH (Fiber To The Home) [9].

The situation in Korea and Japan has intrigued many economists who tried to investigate the reasons for this exceptional performance with respect to broadband deployment and speeds. Despite the growing number of studies that examine this phenomenon, little is known precisely that can explain the difference in performance. Many explanations have been advanced. Population density is higher in Korea and Japan compared to other countries making broadband deployment more attractive, the natural inclination of Koreans and Japanese for broadband and their demand for online applications (requiring more bandwidth) and the government policies, such subsidies to broadband providers, especially in Korea. The most convincing explanation of all is probably the difference in regulations, especially in unbundling that prevailed in Korea and Japan compared to other countries. Indeed, it seems that the regulation there played a predominant role in broadband deployment.

Korea unbundled its local loop in 2002 when its broadband network was already fully developed. New entrants who wanted to offer the service were obliged to build their own network since they were not allowed to connect to the incumbent's network. Facilities-based competition was developed *before* the service-based competition [10]. As far as Japan is concerned, unbundling of local loop has taken place as far back as in 1997. But Japan was one of the pioneers to unbundle fiber optic facilities and in 2001 the unbundling of FTTH was a reality. Competition thrived and many firms offered very high speed broadband connections to their users. By contrast, in the US, AT&T and other carriers have just started to build their networks to offer this type of services[11]. Other regulations in Japan, such as the possibility of broadband

[9] Since there is no any empirical study that examines the impact of lifting these regulations on broadband, this evidence may be purely coincidental (WALLSTEN, 2006).

[10] Some economists (WALLSTEN, 2006) doubt whether Korea's success in broadband will last (it has already been overtaken by Iceland).

[11] AT&T has announced (June 19, 2007) that it has contracted Alcatel-Lucent and Ericsson to provide equipment for an expansion of its U-verse fiber-to-the-home (FTTH) network. AT&T will

providers to offer cable television service over their high-speed networks, favoured technological convergence and eliminated the distinction between facilities and service providers (WALLSTEN, 2006) [12].

In a recent paper, WALLSTEN (2006) examines the relationship between unbundling and broadband deployment in detail for the OCDE countries. He tests the impact of different unbundling and price regulations that various countries have implemented and the effects of these regulations on the deployment of broadband technologies. It appears that regulation that allows easier interconnection with the incumbent is conducive to broadband deployment while unbundling and some types of price regulation act as disincentives to broadband deployment. In particular, Wallsten considers all three types of unbundling encountered in most European countries; LLU (local loop unbundling), bitstream and subloop unbundling [13]. Unbundling can be accomplished in several ways, one of them being collocation [14]. After constructing his data for 30 OECD countries for the period 1999-2003, he examines, using econometric techniques (regression analysis), the impact of unbundling, collocation and the type of wholesale price regulation on broadband penetration. He introduces a number of control variables acting as demand shifters including GDP per capita and the number of fixed lines per capita. Dummy variables for country-specific factors and time effects are used as control variables.

The results are quite interesting and very instructive. Broadband penetration is positively correlated with LLU but subloop unbundling reduces the growth in broadband penetration. Given that subloop unbundling is the most population density seems to be positively correlated with broadband penetration and this confirms the findings in other studies (FLAMM, 2005; DISTASO *et al*., 2004). As far as the effect of other variables is concerned, the results are inconclusive, especially when country and year fixed effects

deploy the Gigabit-capable passive optical network (GPON) equipment in new residential buildings as early as the beginning of next year. U-verse offers IP-based triple-play TV, telephony and internet services in 21 markets, including recent launches in San Diego, Detroit, Los Angeles, Kansas City and Dallas-Fort Worth.

12 This is almost impossible in the USA considering the high transaction costs that imply every individual negotiation with each municipality.

13 LLU, bistream and subloop unbundlings are three forms of unbundling that differ in terms of degree. The LLU gives to new entrants access to the copper wires of the incumbent. The latter is responsible for the maintenance of the wires but the entrant is obliged to invest in its own infrastructure. Bitstream is a more open unbundling giving to the entrants more access to the wires of the incumbent. Subloop unbundling is a full sharing of incumbent's wired network.

14 Collocation is the way an entrant connects to the incumbent's network. It can be caged, commingled, remote or virtual.

are controlled. In some cases they are significant but not in others. For instance, bitstream access is positive but occasionally statistically not significant. Co-mingled collocation is positively correlated with broadband penetration but it is not always statistically significant.

To explain the relationship between broadband speed and broadband deployment, WALLSTEN (2006) estimated an econometric model. This time, the analysis was more complicated given that data on speed are not widely available and the definition for high (ultra) speed varies from country to country. Finally, he calculated the median download speed offered by incumbents and price that allowed at least 1 Gb of monthly data transfer. Because of data limitations the results should be interpreted cautiously. Nonetheless, they are interesting. Download speeds are not affected by any type of unbundling. Yet, population density does have an impact on speed. Countries with high population density have faster broadband connections.

HU & PRIEGER (2007) in their empirical study found that actual competitive conditions among Local Excahnge Carriers (LECs) and cable companies (intermodal competition) reduce the incentive of the incumbent to invest in new technologies, especially broadband, but potential competition has the opposite effects. This is precisely what BURNSTEIN & ARON (2003) found in their study; multiplatform competition (competition between cable and telecommunications companies) is positively affecting the deployment of broadband technology. Further, WALLSTEN (2005), in a similar study, finds that the differences in broadband penetration rates among states may be explained by the differences in the level of competition among LECs. The higher the level of competition in the industry, the higher is the level of broadband deployment. POLYKALAS & VLACHOS (2006) in a study on broadband penetration in Europe found as well that countries with similar regulatory frameworks but different levels of competition have different performance in terms of broadband penetration.

This result brings them to conclude that it is the level of competition in the market that determines the speed of deployment of broadband technologies. PRIEGER & LEE (2006), in contrast, find that price cap regulation increases the probability of broadband deployment in the USA. Prices, especially UNE rates, do contribute to broadband availability, particularly when UNE rates and price cap regulation exist.

**The diffusion models as a possible explanation of future UBB deployment**

Another strand of studies uses alternative models to explain broadband penetration and make forecasts about its speed of deployment. The most prevalent model in forecasting demand and new technologies is the diffusion model. Since its inception by ROGERS (2003), it has became quite popular and nowadays is widely used in economics and business. Many industry analysts base their predictions on this model. It has been observed that demand for new products and new technologies exhibit a stylized pattern. It starts at low levels to attain a critical mass, then saturation and, in some cases a decline. The pattern of this S-shaped curve is quite well known and the diffusion models examine whether broadband follows the same path and where the inflexion points on the curve are.

Diffusion models are based on the idea that innovations (services, goods and technologies) pass through a regular process of recognition and adoption. According to the *two-step hypothesis*, opinion leaders are the first ones to be aware of their existence and then they succeed to transmit this information to the general public. This theory stems from TARDE's (1890) ideas about innovators and imitators according to which innovations are spread from social elite to society (KINNUNEN, 1996). These ideas form the basis of the model developed by Bass about the diffusion of consumer durables (BASS, 1969) and validated more extensively in MEADE *et al*. (1998)

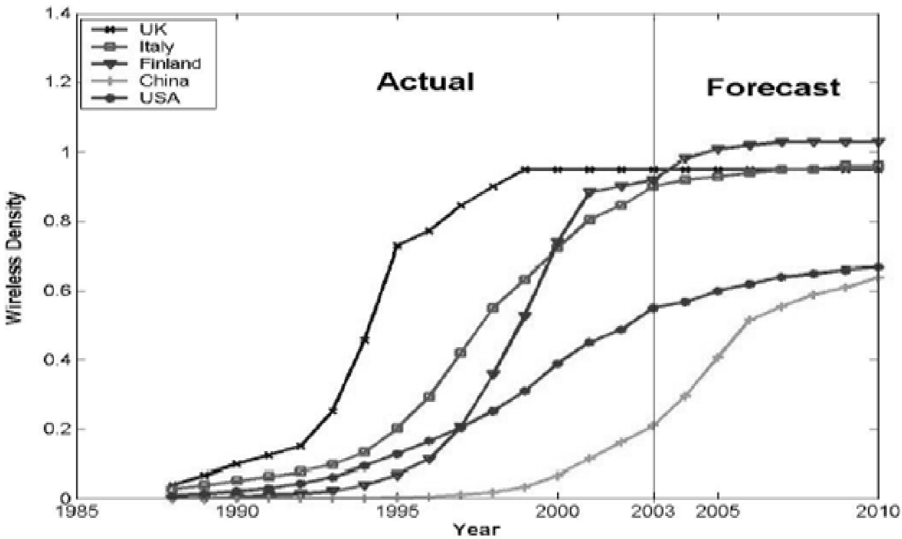
ROGERS' (2003) *diffusion model* is more sophisticated than the previous one because it examines the attributes of innovations, the propensity to innovation by the adopters and how the innovation is diffused in the system. According to ROGERS (*ibid*., p. 222), the rate of adoption is determined by a number of factors such as; (1) perceived attributes of innovations, (2) type of innovation-decision, (3) communication channels, (4) nature of the social system, and (5) extent of change agents' promotion efforts. The financial aspects of new technologies and services such as the return on and the size of the investment are equally important factors that affect diffusion.

Predicting diffusion patterns of innovations are quite useful to business, industry analysts and policy makers in general. In the area of marketing, predicting sales, timing and the levels of adoption are valuable information to the business decision makers and the development of the market depends on how these models are capable of predicting accurately the evolution of the market (ELIASHBERG & CHATTERJEE, 1986). Unfortunately, these models have added very little to the understanding of the actual decision process, chiefly because they don't allow interaction among agents, they ignore contextual characteristics and they don't allow for accumulation of information and for the experience gained in the past with the services or technologies.

Despite these limitations, diffusion models are, nonetheless, quite useful in circumstances where little information is available, particularly when the demand for a new product or for a new technology is unknown and there is considerable uncertainty as to their adoption by the general public. These models are used to estimate the parameters of the diffusion process without considering the underlying specific drivers of the diffusion process. The curves obtained exhibit the basic characteristics that decision makers need to know before they launch the new product or the new technology in the market. There are various mathematical formulations that are used in the literature to test the rate of diffusion of new products or technologies. The logistic and the Gompertz models are the most widely used. There are many variations of both of them. For instance, the Gompertz model may take the following mathematical form:

$$Y(t) = e^{-e^{-b(t-a)}}$$

**Figure 1 - Gompertz example for international technology adoption**



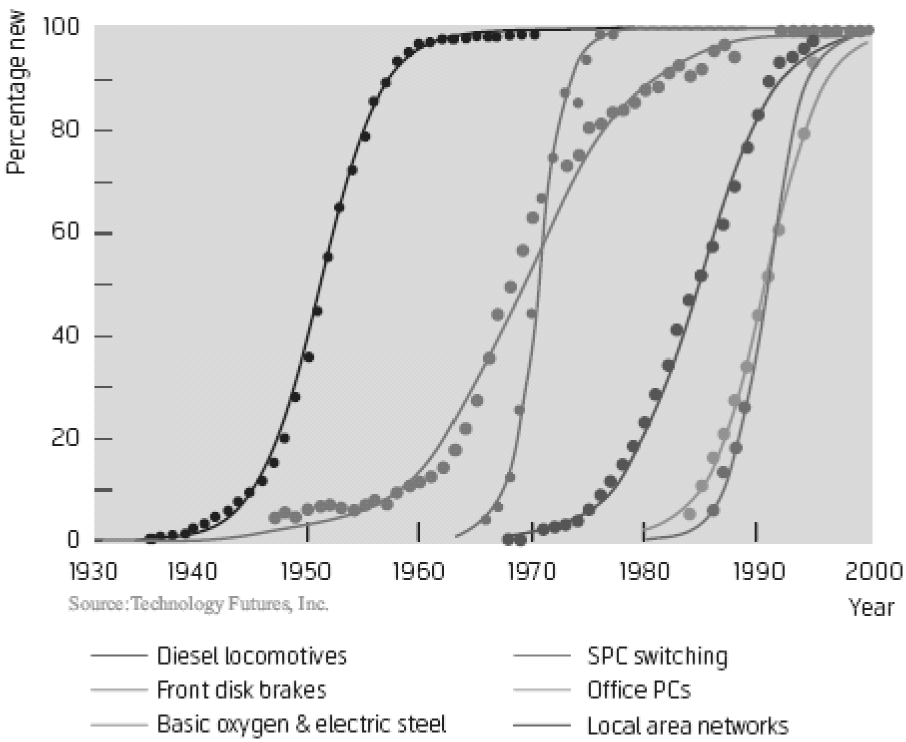

*Source: ARAVANTINOS et al.(2006b)*

The Gompertz model gives an S-shaped curve but it is asymmetric with adoption slowing down as it progresses. This model is particularly good for forecasting consumer attitudes towards adoption of new products or technologies. The parameters that determine the level of diffusion $Y(t)$ at time *t* are: *a,* which gives the inflection point at the curve. This occurs at the year when the diffusion rate reaches 37% of its upper level; and *b* (the diffusion speed or the rate at which the new products or technologies diffuse in the system). The rate of adoption depends on the nature of the technology.

Logistic curves, also represented by Fisher-Pry models, are quite suitable to forecast how fast new technologies will displace the old ones and what will be the adoption of these new technologies. Their general formula is:

$$Y(t) = 1/(1 + e^{-b(t-a)})$$

**Figure 2 - Fisher-Pry examples for technology**

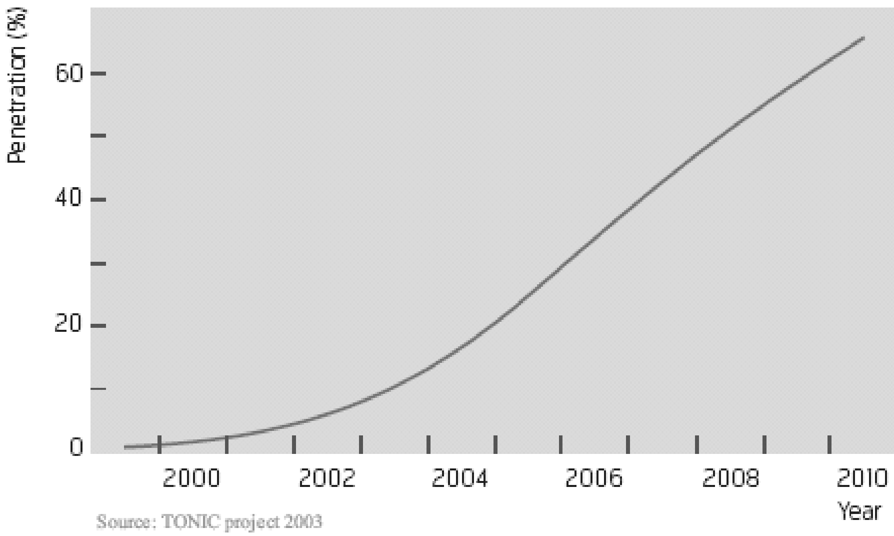



*Source: VANSTON & HODGES, 2004*

The logistic curve is symmetric about the 50% penetration rate and this is given by the parameter *a*. The parameter *b* indicates the diffusion speed or the rate at which the new products or technologies diffuse in the system), where b>0. The rate of adoption depends on the nature of the technology. The b parameter remains constant but it varies among adoptions (see figure 4).

The attractiveness of Logistic and Gompertz models is that they can be applied at the country or worldwide levels and for a variety of technologies or products and services. The figure below indicates the broadband penetration in Europe.

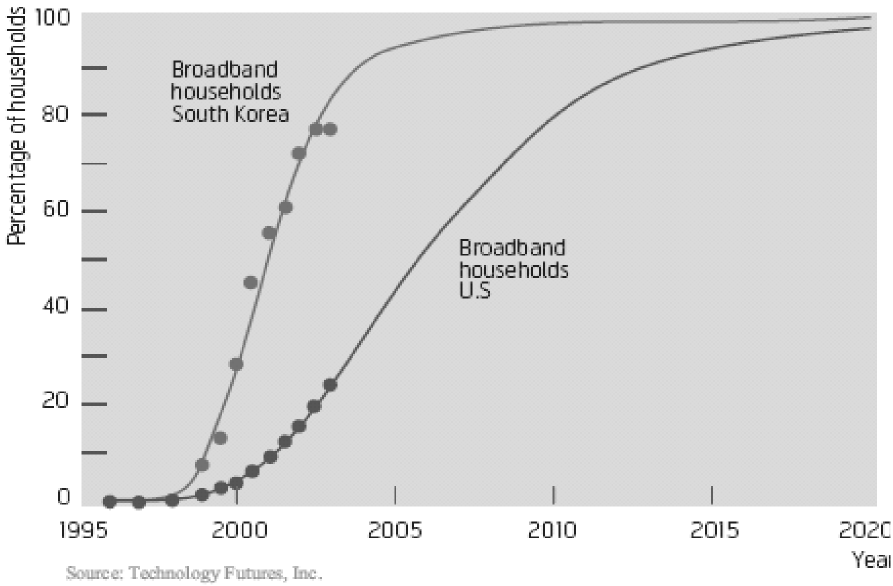
**Figure 3 - Broadband adoption in Europe**




*Source: VANSTON & HODGES, 2004*

Forecasting with these models is done by using regression methods. The appropriate model is fit to the historical data in order to be able to get the best-fit estimates for the parameters ***a*** and ***b***. Assuming that users will eventually adopt the new technology or product by a certain percentage, the model gives the shape of the curve and the rate of diffusion. The figure below illustrates the Gompertz model which was used to forecast broadband demand in the US and Korea.

**Figure 4 - Broadband adoption in Korea and the US**

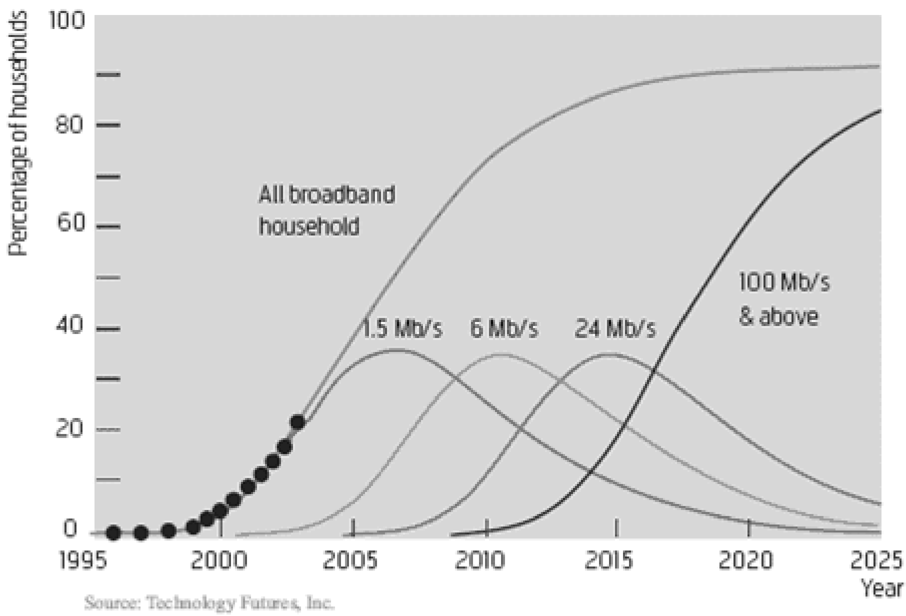



*Source: Vanston & Hodges, 2004*

On many occasions historical data are not available as it is the case with high speed broadband or UBB. By taking into account the experiences of other similar technologies, it is possible to make certain assumptions and use one of the models to make the forecast. For instance, the TFI forecasts the demand for high speed broadband as indicated at the figure 5.

The advantages and disadvantages of these models are well known and reviewed many times (VANSTON & HODGES, 2004). In some cases synthesized methodologies might give satisfactory results, especially when it's difficult to estimate the upper bound diffusion level of each country due either to poor data or dynamic markets that could lead to inaccuracies. To improve upon these estimates, ARAVANTINOS & FALLAH (2006) used a synthesised method, including historical analogy and interpolation, applied to patterns of growth in relevant neighbour countries with similar mobile markets characteristics. In the case of a developing BB country like Greece, prediction based on the Italian mobile market came very close to the actual market growth.

**Figure 5 - High speed demand by US households**




*Source: VANSTON & HODGES, 2004*

Despite the simplicity of the models and their apparent disadvantages, we can derive that their capacity to forecast the diffusion of BB and Next Generation technologies such as UBB in the telecommunications industry is rather good. As data for UBB technologies become more widely available, it will become possible to test further the robustness of these models in practice. In the meantime, the use of these models for forecasting purposes can be quite satisfactory as it became clear from the review of the empirical literature above.

## ■ Conclusions and policy recommendations

Broadband technologies and services are ubiquitous in most developed and developing economies, although many differences still exist. UBB is still in its infancy and many countries struggle to promote its deployment and use. Various models and incentives are offered to bring this technology and applications into existence and some countries are more successful than others.

Economists use an array of models to forecast the deployment of this technology and its possible applications. Diffusion models and their variants are the most widely used for that purpose but other models such as econometric analyses and Delphi methods are equally used. In the past, diffusion models were able to predict relatively accurately the deployment of new technologies (TV, cable, internet, etc.). The advent of BB and UBB technologies poses a challenge to these models. Nonetheless, the review of the empirical literature has shown that these very models can also be used to explain the deployment and diffusion of broadband and UBB technologies despite the fact that these technologies are different from the previous ones and more evasive (less tangible than, let's say, a TV set). In applying these models in practice, special attention should be given to factors such as regulation and competition which seem to contribute to the predictive accuracy of the models in explaining the diffusion of UBB technologies.

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## Appendix: UBB deployment and economic growth

A number of studies have examined the relationship between broadband penetration and economic development for a number of countries and regions. Nonetheless, the lack of sufficient empirical data for long periods of time, limits the possibilities to do econometric studies and therefore most empirical studies are ad hoc and quite anecdotal (FORD & KOUTSKY, 2005, p. 4). Earlier studies (RAPPOPORT, KRIDEL & TAYLOR, 2002) have shown that the availability of broadband connections have led people to use it more intensively compared to dialup connection. This change in behaviour of firms and individual consumers has an impact on productivity and on the economy as whole. Few studies (FORMAN, GOLDFARB & GREENSTEIN, 2005; BRESNAHAN, BRYNJOLFSSON & HITT, 2002; and BRYNJOLFSSON & HITT, 1996) examined these changes of firm behaviour and they found that firms which integrate intensively IT into new business processes have the highest payoffs in terms of productivity increase [15] compared to firms which simply adopt the broadband technologies. As far as the effects of broadband on individual workers' productivity are concerned, Autor, LEVY & MURNANE (2003) found that broadband enables workers who perform nonroutine problem-solving and complex communication tasks to increase their productivity (broadband is viewed as a complementary factor of production), but as far as routine process is concerned, broadband has a negative effect on the demand of these workers (broadband and routine type jobs are viewed as substitutes). The net effect on employment depends on the mix of different types of jobs in the economy.

As far as the impact of broadband deployment on residential demand is concerned, it seems that the effects are both direct and indirect. On the one hand, broadband at home may be used for recreational (leisure) purposes which enhance well-being, on the other hand, it may augment the possibilities for teleworking, allow remote employment, give more flexible working hours or even to use productively the non-traditional working hours. E-commerce (teleshopping), telemedicine and telebanking are other activities that may be pursued using broadband at home, reduce the time spend on these activities and leave more time for leisure. Broadband at home may also increase the quality of the labour force through distance learning and other educational activities. From a social point of view, broadband at home allow for a greater participation in community and civic activities. The effect of these activities on employment is not clear yet (CRANDALL & JACKSON, 2001) but there are more and more studies that are trying to quantify them. For instance, GILLETT *et al*. (2006) created testable hypotheses and examined empirically the impact of broadband deployment on productivity and economic growth by concentrating their analysis mostly on employment opportunities, wealth, community participation, skills and quality of labour force. Using biennial business Census US data [16] they were able to test the impact of broadband deployment on five key indicators of business activity: (1) total employment, (2) wages, and (3) the number of business establishments (used as a rough proxy for firms), as well as indicators of industry mix along (4) sector and (5) size dimensions. Although their analysis is not as complete as it should because of data restrictions, nonetheless, their preliminary results confirm the

[15] These firms by developing and integrating complex "e-business" applications, such as CRM and ERP, they develop a competitive advantage compared to simple broadband adopters.

[16] The 2002 data was the most recent available at the time of writing of their article.

theoretical allegations that "the economic impacts of broadband are both real and measurable" (GILLETT *et al.*, 2006, p.16). On a broader scale, more recent studies examined the same relationship of broadband deployment and economic growth for several countries and regions considered to be the hubs of broadband and innovation (USA, Canada, Australia, Scandinavian countries, etc.) and they found that this relationship is real but its effect differ from country (region) to country. For instance, experts from Gartner examined the relationship between GDP per capita and broadband penetration for the US economy and they found that an increase of broadband penetration from 30% to 50% would increase GDP by 10%.

The Centre for Economics and Business Research CEBR in 2003 [17] realized a study for the U.K. economy. Assuming annual productivity gains [18] between 0.1% and 0.6% (due to broadband use) and increased investment in broadband deployment and higher consumption expenditures, the impact of broadband deployment on GDP for the U.K. economy is estimated to be £12billion annually by 2007 and £22 billion by 2010.

**Table 2 - Sample of empirical studies examining the correlation between broadband and economic growth**

| | *Study* | *Results* |
|---|---|---|
| Micro Studies | | |
| | FORMAN *et al.* (2005) | Firms integrating the IT have the highest payoffs in terms of productivity increase. |
| | GILLETT *et al.* (2006) | The economic impacts of broadband are both real and measurable. |
| Macro Studies | GARTNER (2002) USA | An increase of broadband penetration from 30% to 50% would increase GDP by 10%. |
| | CEBR (2003) U.K. | The impact on GDP of the U.K. is estimated to be £12billion annually by 2007 and £22 billion by 2010. |
| | TASMAN Australia (Victoria) | The average contribution of broadband to Victoria's GDP growth is estimated to be between 0.47% and 0.82% for the period 2004-2015. |

TASMAN in 2004 [19] assumes three broadband take-up curves (early/mid/late adopters) and various productivity gains (0.06% for Primary agriculture, vs. 0.47% for Communication) with the highest gains realized in 2008 (the year of fastest projected broadband growth). The impact on GDP for the state of Victoria is estimated to increase by AUS$1.5 billion to AUS$2.5 billion by 2008 but the gains are lower after that year, situated between AUS$0.6bn to AUS$1.4bn in 2015 [20]. Overall, the average contribution of broadband to Victoria's GDP growth is estimated to be between 0.47% and 0.82% for the period 2004-2015.

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17 www. cebr.com

18 The productivity gains vary by year and they vary between 0.1% and 0.6%.

19 Multimedia Victoria (2006), "Economic Impacts of Broadband in Victoria", Broadband Access Office. http://www.mmv.vic.gov.au/broadband/Economicbenefits, accessed on 22 May 2006.

20 These gains are relative to the no broadband adoption case.