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Demand for broadband access in Greece

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ABSTRACT

As broadband access networks are relatively new in Greece, it is really difficult and involves great risk to determine the potential market for broadband services. The intent of this paper is to add to the discussion of delivering fixed broadband lines to customers in Greece taking into account regulation issues, the strategic movements of the market key players and the commonly admitted inequality of broadband access availability between urban and rural areas. In addition, using time-series analysis and examining the correlations between the number of fixed broadband lines and specific demographic factors for the past three years (mid 2006–mid 2009), an attempt to estimate empirically the forthcoming demand for broadband lines is conducted. Population's income and effective competition are recognized as the strongest determinants of broadband development. In addition, it yields that demand for broadband will continue to have a positive trend for the years to come as people are becoming more and more familiar with new technologies, with youth being the pioneer to the use of innovative services that require broadband access.

1. Introduction

Broadband access is a vehicle that allows the delivery of an entirely new breed of media services and communications-oriented applications. It is these new services and applications that differentiate broadband from dial-up Internet access and give consumers a reason for subscribing to broadband. Audio and video being the obvious cornerstones of this high-speed revolution, speedy connections coupled with always-on access improve the consumer multimedia experience and change the types of business models that are viable in the interactive marketplace. Moreover, it is commonly accepted that broadband access constitutes a key factor in the effort of economic growth and performance enhancement. Broadband shrinks the world and enables telecommuting for collaborative projects across countries or across the globe and therefore infuses capital into the markets. Especially for developing countries, for every 10 percentage-point increase in high-speed Internet connections there is an increase in economic growth of 1.3 percentage points (World Bank Report, 2009). Likewise communities that had mass-market broadband experienced more rapid growth in employment and in the number of businesses, mainly in technology-intensive sectors, compared to communities without broadband (Europe's Information Society, 2008).

Although broadband is not deemed to be the replacer of traditional communication formats, broadband services cannot be delivered via traditional distribution systems. In order to be able to provide such services to the public, telecommunications companies need to invest substantial amounts of capital expenditure (excavation works for installation of new fiber optic cables within cities and between them, procurement and installation of new generation transmission equipment, provision assurance for new services, etc.). As a consequence, they may feel reluctant to do so when demand for the services

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or even worse the services themselves appear to be a "black box", as there is no guarantee for the respective investment depreciation. Not being the only factor, this approach can explain to a great degree the diversity in broadband diffusion between countries as it would be impossible to anticipate telecommunications companies to be willing to undertake such risks to the same level (Annemijn et al., 2006). On the other hand, not infrequently, investment is promoted for investment's sake, rather than its efficacy and this can lead to over investment which can be disastrous especially for companies with deficient economic figures. All these along with the fact that broadband access is prerequisite for diverse advanced and relatively new services (i.e. Voice over Internet Protocol [VoIP] services, very rapid data downloads, streaming IP Television, Video on Demand [VoD], etc.), accentuate the question of forecasting the demand which, though a complex procedure, is of high importance in the decision of a carrier to enter the market. Regarding private funded companies in particular, estimation of market potential is of high necessity since expected profits need to be estimated and as time goes by, hopefully, verified in order to ensure the necessary cash flow for earnings and further investments (Rappoport et al., 1999).

In most nations, provision of telecommunications services was initially performed by public companies (traditional Telecommunications Organizations, TOs) which owned the infrastructure networks. With the need for liberating the market being more and more exigent these companies were to play a significant role in the process of broadband development as they were considered incumbent to supply the infrastructure to new entrants. However, it was soon discovered that this could constitute an impede towards broadband evolution since the incumbent firms in some cases chose to exercise the option to delay and in that way raised the entry barriers for other companies (Alleman and Rappoport, 2007). Recognizing this effect, special actions were taken by regulator authorities in order to enhance the development of infrastructure-based competition as it was considered to be the road towards broadband development (Sohn et al., 2008, Trkman et al., 2008 and Preston et al., 2007).

Focusing on the European Union (EU) and taking into account the dissimilarity between a significant number of variables, perception of the impact of broadband on the national economy and corresponding actions were quite diverse among EU countries across time. Foreseeing this phenomenon and the actual creation of a new market, or better, a market comprising new services, European Commission issued laws and directives to be adopted by member state countries in order to establish the correct framework within which broadband development should take place. Thereafter, local regulation authorities were created in countries aiming to control the market through policies and legislative amendments towards the elimination of monopoly effects and the respective induction of new investments in the Information and Communication Technology (ICT) area.

This paper explores the Greek telecommunications market. It endeavors to provide an empirical estimation of the demand for broadband access lines based on a time-series analysis and taking into account that the era of broadband in Greece is still on an early stage in particular with regard to the short history of real competitive environment. It uses data by the National Regulator Authority and the companies that offer broadband services regarding the diffusion of sites (exchange offices) with broadband availability and the number of the corresponding subscribers focusing on how this number fluctuated during the period mid 2006–mid 2009. The only distinction between subscribers is that of having chosen the incumbent or another company (so called alternative operator) for broadband access. Integrated Services Digital Network (ISDN) is not considered as broadband connection therefore data concern exclusively Asymmetric Digital Subscriber Lines (ADSL) connections, both symmetric and asymmetric, without further analysis to different speed packages as companies offer a variety of choice for download/upload speed. For the sake of uniformity in data analysis, all DSL connections are considered as broadband independent of the respective download/upload speed. In addition, data are examined in separate for the 13 territories in which Greece is administratively divided in order to observe possible inequalities between different geographic areas and perform correlations with external variables such as income, age, level of education of each territory's population according to data by the National Statistic Service and the Observatory for the Greek Information Society. The 13 territories examined are shown below:

	Abbr.	Description
1	EMac & Thr	Eastern Macedonia & Thrace
2	Att	Attica
3	NA	North Aegean Islands
4	WGr	Western Greece
5	WMac	Western Macedonia
6	Epir	Epirus
7	Thes	Thessaly
8	Ion	Ionian Islands
9	CMac	Central Macedonia
10	Cre	Crete
11	SA	South Aegean Islands
12	Pel	Peloponnesus
13	CGr	Central Greece

The paper is organized as follows. Section 2 gives a brief review of methodology approaches and models found in literature, applied to estimate the demand of telecommunications services. It then discusses the evolution of the telecommunications market in Greece from the official liberalization up to now in regard to strategic choices and investments on broadband networks undertaken by telecommunications companies (the main operator, formerly state-owned Hellenic Telecommunications Organization, HTO and private companies). The role of the local National Regulator Authority (NRA) is also highlighted by means of initiatives taken in collaboration with the European Union, law establishments and penalty impositions to carriers. Section 3 presents the actual fluctuation of the demand for broadband access in the whole country and separately for each one of the 13 administrative territories in which Greece is divided, during the examined period (July 2006–June 2009), severally for HTO and the other carriers. Differentiation between territories is explained by socio-demographic characteristics in cases where results are statistically significant. Moreover, an attempt to predict the future demand trend is made in relation to socio-demographic factors, using a time-series model.

Section 4 provides some concluding remarks, whilst Section 5 presents the study's limitations and suggestions for future research fields.

2. Background

2.1. Review of literature

A significant number of efforts to determine the market size and estimate the demand for various types of telecommunications services can be found in the literature especially for developed markets. In general, it is difficult to predict the future demand for information and communication equipment due to its short lifecycle and consequently limited historical data. However, research focused on the prediction of the demand for telecommunications services and in particular for broadband services in terms of high speed Internet access and use, has taken place in countries where the broadband boom took place in the 90 s or the early 00 s.

The importance of demand forecast for telecommunications services for engineers and marketers is highlighted in telecommunications literature. Mc Burney et al. (2002) recognize that it constitutes the basic tool to guide technology choices and decisions, to develop technical designs and dimension the network and its elements, to identify geographic territories for prioritization and consequently for potential investors, lenders, regulation authorities to be convinced of the market potential. They present methods commonly used by marketers when developing forecasting demand models along with the challenges each technique can face. The paper concludes that simple forecasting models are better than complex ones, because they are more likely to be persuasive and suggests that forecasting models should be embedded in a formal process of iteration within a telecommunications company in order to increase the speed and agility of the company in responding to changes in its external environment.

Rappoport et al. (2002) pose the question of Willingness To Pay (WTP) and consider it as the underlying basis on any demand curve. They present an empirical method for using survey-based information to evaluate the demand for broadband services and get similar results with estimates from conventional choice-based models. However, it is admitted that the results of the study should only be viewed as suggestive since a significant number of other issues (e.g. availability, monopoly markets, etc.) have to be taken into consideration. In addition, Alleman and Rappoport (2007) differentiate demand for access from demand for content and raise discussion in a wide perspective, approaching the demand for telecommunications services as derived from the consumer's ability and willingness to pay for them in relation to other basic needs such as food, shelter, health care, etc. Without using a specific model but considering the increase rate of subscribers in services that require broadband access in association with the respective modification of ICT expenditure share of Gross Domestic Product (GDP), they highlight the importance of the last kilometre affair. Due to sunk costs engaged with this issue, the authors imply that it would be unwise to leave the market work in an absolute competitive environment as carriers would be unable to recover these costs by usage charges. Hence, it suggests that last kilometre's market structure should comprise one or two companies at most, with interconnection prices calculated and controlled by regulation authorities in contrast with the services based on broadband access, which should evolve in antagonistic framework.

A significant problem faced by researchers is that of insufficient data. Fildes and Kumar (2002) describe the research that has been carried out on the telecommunications demand forecasting scientific field recognizing that successful modeling of the constantly changing telecommunications market has been limited due the demise of the monopolistic national suppliers on the one hand and rapid developments of competitive new technologies on the other. They argue the accuracy of econometric approach diffusion models across the wide range of telecommunications applications as they require long data sets which are not available as a result of the short life cycle of the respective services. In order to overcome this problem and improve precision the use of simulation models is recommended, through a system dynamics philosophy incorporating expert judgement in a structured process.

A forecasting methodology designed for newly introduced technology for which limited data is available is presented by Lee et al. (2008) and applied to the home networking market for new construction in South Korea. The model begins with an algebraic estimation and then applies Bayes' theorem based on data collected by experts from home networking companies in order to predict the cumulative number of households to adopt the new technology. Furthermore, it performs a conjoint analysis to estimate the diffusion of the three types of home networking technologies (Power Line Communication, Wireless

Network and Ethernet Cabling, PLC, WN and EC, respectively) and the market share of each technology. At the end, a simulation analysis that incorporates hypothetical changes in the attributes of PLC technology is experimented and finds that this technology is quite sensitive to standardization and government support. Sohn et al. (2008) introduce a slightly different model and propose a negative exponential growth curve model that incorporates unobservable time-varying covariates by reversely estimating the unknown covariates. The proposed approach is then applied to technological forecasting of high-speed Internet access services (different line types of Assymetric Digital Subscriber Line and Very high bitrate Digital Subscriber Line, ADSL & VDSL, respectively) provided by the biggest telecommunication corporation in Korea and compared to actual data given by the company. It is found that the model achieves high levels of accuracy and, as expected, predicts the domination of VDSL over ADSL but the authors do not neglect to mention that the profitability analysis based on the demand forecasting should not be overemphasized since new types of high-speed Internet access services are continuously being provided to satisfy various customers' needs.

The consumers' profile is deemed to be directly associated with the demand for broadband. Cerno and Perez (2005) provide empirical evidence on the issue of broadband access and use in Spain, focusing on the user profile and the variations by region. The study separates access from use taking into account that usage is conditional on access and access is conditional on usage. Furthermore, it distinguishes broadband use depending on where it takes place (work, home internet café, etc.) and focuses on broadband access from home assaying to estimate demand through a probit model and finding, as in most countries, that it is positively related to income. The results conclude to the fact that although broadband use is considered as necessity, access from home is considered a luxury good.

Rappoport et al. (2003) also give serious consideration for the characteristics of the end users (age, income, education, ethnicity, rural/non rural resident) and describe two models. The discriminant model which correlates broadband demand with socioeconomic and demographic characteristics and the users' specific activity and the discrete choice model which is based on access price, value of time and opportunity cost in association with the self-selected discrete choice of broadband or dial-up access. Main conclusion is that the so-called digital divide is more likely to be a geographic phenomenon rather than a socioeconomic one, so broadband services availability is likely to fall behind in rural areas without substantial supply subsidy provided by the state. Concerning rural/urban differences in particular, a research related to the provision and use of broadband in the EU countries was conducted under European Committee's support (the Beacon project). Preston et al. (2007) draw on findings from this research examining various factors that influence broadband development and produce reports for each country with findings in various areas. They stress the fact that rural areas are in most cases not served at all with broadband and even when served, the supply is inadequate and consists of lower quality and higher prices. Consequently, it strengthens the opinion that the market itself is incompetent to deal with this issue since telecommunications companies are not willing to invest in modern infrastructure development in rural areas where expected profit is of high uncertainty and therefore, state intervention and specific policy recommendations and initiatives are necessary to redress market failures.

Garbacz and Thompson (2007) delineate the demand for telecommunications services in general and how it is influenced by a variety of socioeconomic and demographic factors such as income, population density, price, competition, etc. They use binary choice models so coefficient estimates may be interpreted as demand elasticities and conclude that a strong effect is expected on demand for variables reflecting income, poverty and schooling. Moreover, privatization of state monopolies and effective competition are likely to have a positive impact on demand, only in conjunction with a fair regulatory regime. On the other hand, Trkman et al. (2008) use an exploratory approach to identify the latent variables that influence broadband development, namely factors that cannot be observed directly, as well as the correlation between them. They present a correlation matrix between pairs of variables such as GDP, price of broadband connection, population density, etc. with quite high coefficients. In order to reduce the number of factors to the most significant ones, they form the variables into three groups and present a framework with 3 underlying factors that is enablers and means, usage of information services and ICT sector environment. The first factor is connected to economic variables (income, broadband service price, etc.), the second one is correlated with the use of specific services (e-commerce, e-transactions, etc.) and the third one is connected with indicators which show the state of ICT environment within a country (PC access, education level, number of phones, etc.). These factors confirmed the importance of distinguishing access from actual usage and furthermore explain the differences seen in broadband development between EU countries. The study finally indicates direct actions by local governments and various stakeholders to stimulate broadband demand (e.g. effective competition by promoting and giving emphasis on local loop unbundling, liberalization of infrastructure and network services, public–private partnerships, tax incentives for investments, etc.). Hu and Prieger (2006) correlate broadband entry with the respective demand. Among other factors such as income, race and entry by other firms, they define demand as the underlying constituent in a telecommunications company decision to enter in the market at specific geographic areas. Unsurprisingly, the paper determines that broadband availability is directly related to population income and race, with income being the basic motivation for a carrier to step into the area. It distinguishes demand from households and businesses and uses a structural model to estimate broadband demand for households and then a simple probit model for businesses. It finds that demand is positively associated with income and population density and negatively associated with the distance from the central office of the carrier, probably as a result of degrading transmission quality. Regarding race, it concludes to the fact that ethnicity is a determinant factor but does not matter independently of income, education and other area characteristics.

In regard to different modes of broadband access, Ida and Kuroda (2006) explore broadband market in Japan considering the four available alternative modes of connection (ISDN, ADSL, Cable TV and Fiber To The Home [FTTH]). Using conditional and nested logit discrete choice models, own-price elasticities of access demand for each type of connection are calculated and result to the fact that ADSL service is less elastic than the other three services, implying that market of ADSL is independent of the others. Furthermore, because of the fact that the ADSL constitutes almost the three quarters of the whole market, three different speed categories within the ADSL market (low, medium and high) are scrutinized. It is concluded that demand for medium-speed ADSL is less sensitive to price changes than the other two categories. However, as broadband evolution continues medium-speed users are likely to switch to high-speed rendering ADSL a substitute of FTTH. Focusing on Greece, Yannelis et al. (2009) estimates own-price elasticity of the demand for broadband as well as the cross-price elasticity between ADSL and ISDN services using an empirical analysis since both services are available to the majority of the Greek population and they both allow the user to navigate in the web without the telephone line being busy. Being conducted in the beginning of the ADSL epoch, the study does not include data from other telecommunications companies than the incumbent operator (HTO) as no competition prevailed at that time. It finds that demand for ADSL has periodic fluctuations with an expected downfall in ADSL sales during summer months, peaking in October when schools open for the new academic year. It concludes that demand for broadband is inelastic (especially for ADSL) and finds the cross-price elasticity of ADSL to be negative and therefore presumes that ADSL is complimentary to ISDN that is ISDN customers use ADSL over ISDN instead of switching to ADSL. However, taking under consideration the sharp and constant decline in the prices of ADSL from the time of the research until today, there is some doubt in validity of the study's findings in our days.

2.2. The case of Greece – telecommunications market particularities, set backs, delayed offset and initiatives – the role of stakeholders

Broadband penetration in Greece has been a topic of significant line of argument throughout the past years. Among European Union countries, Greece has lagged behind on broadband networks investments, as a result of manifold reasons (e.g. limited terrestrial infrastructure, public ownership of the main vendor, disputed telecommunication policy and late abolition of monopoly in telecoms). From the mid-1980s, the European Commission undertook a far reaching project for the liberalization of telecommunications services in all the member states along with other policy initiatives in order to maximize the development and use of Information and Communication Technologies (ICTs). As dictated by Act 2075/92, a National Regulator Authority (NRA) was established in order to supervise liberalized telecommunications market. However, Greece was the last member of the EU-15 community to incorporate into its legislation the liberalization of the telecommunications market that is to grant to companies other than the state-owned main operator (Hellenic Telecommunications Organization, HTO, "OTE" in Greek) the right to provide telecommunication services.

The liberalization of the market officially began, with significant delay in comparison with the other member states, in the beginning of 2001. At the same time, in order to embolden competition, the NRA (Hellenic Telecommunications and Post Commission, HTPC, "EETT" in Greek) adopted European Commission's Directive 98/10/EC. According to this directive, the company with significant market power or the biggest market share (HTO in Greece at that time) was compelled to provide universal service, that is ensure that all citizens within Greek territory would have access to a phone line. More importantly, because of the fact that such a company could actually dominate the market and in order to avoid strong monopoly effects, its tariffs for distinct services had to be cost oriented and finally approved by the regulator. Consequently, for any change to its prices for a variety of services, broadband included, HTO had to submit to the regulator a well justified annotation and was further obliged to provide for each retail service a corresponding wholesale one at lower cost. This was quite a severe point of argument between HTO and the NRA and constitutes one of the most important reasons for the delay in the development of the country in the ICT sector as the national authority and the most significant telecommunications company behaved as absolute enemies, often escalating their disputes to civil courts.

During this period, private companies that showed some interest in the first place in the telecommunications market seemed hesitant to invest on new technologies and initially settled on trying to build their own clientele by offering the same narrowband services (mainly voice) as the incumbent. They managed to do so by leasing high-capacity circuits from the existing incumbent's infrastructure with wholesale prices controlled by the regulator and using Voice over IP compression provided voice services at low prices. Competition rules were applied in the market but practically not on modern services neither with the spirit of investing. This resulted to lower telephony prices, nonetheless proved to be an insufficient incentive to the dispersion of market shares and led to unavoidable bankruptcies and merges among private telecommunications companies reducing the number to market key players to 4 or 5 at most from more than 10 in the very beginning. On the other hand, the incumbent's stance during this period was fairly obstructive and surprisingly, even more contrary to the notion of new investments, special projects for the sake of the "national goal" for successful Olympic Games in 2004 excluded, as it relaxed on the absence of real competition and remained content to preserve a significant market share through a well-known brand name. Taking into account that the major stock holder in HTO at this period was the Greek government, the incumbent's option to delay was quite controversial to public declarations for broadband necessity and probably relies among others, on political issues and the opposition to the regulator's actions.

So by mid 2005 Greece preserved the last place in the EU-15, in terms of both broadband penetration and annual increase in broadband penetration and consequently broadband development constituted a major challenge for the State and the National Regulatory Authority. The action plan towards this goal focused on the effective unbundling of the Local Loop principally on the conviction that the development of infrastructure-based competition, which had remained at an embryonic stage until 2005, would be the only path to broadband evolution. Towards this goal, the regulator established the concept of Physical Collocation in HTO's Local Exchanges by obliging HTO to prepare and provide space to other telecommunications companies within its premises (especially in big Local Exchanges, serving more than 10,000 subscribers) for the installation of their equipment. Simultaneously, LLU was promoted by enforcing HTO to provide the "last kilometer" to other operators and furthermore, to be bound to maintain it on a monthly fee set and controlled by the regulator. This action encouraged private providers to invest on broadband technology and favored the diffusion of sites where broadband access was available. As expected, though belatedly, this incurred a different approach to the issue of investing on broadband infrastructure by the incumbent and hence strengthened competition between HTO and alternative operators. Accordingly, this led to a sharp decrease in average retail prices in the order of 60% within years 2006–2008 and a parallel harsh increase of nominal access speeds as, in end 2005, over 80% of broadband lines had nominal access speeds of 384 Kbps and none exceeded 1 Mbps, while in March 2009 64% of broadband lines had nominal access speeds from 2 Mbps and above, up to 24 Mbps, while 37% had speeds at 10 Mbps and above (Newsletter, July 2009). Another important issue that Greek market had to face was the big difference in the availability of broadband between urban and rural areas. As presumed, all telecommunications companies invested in the beginning on areas of high density. Considering that more than 70% of the population in Greece is gathered in five big cities, the provision of high speed networks to a significant number of citizens especially in rural areas was doubtful, creating within Greek territory the phenomenon of digital divide. In order to attract companies to invest on small cities and non-urban or distant areas, the State used own and EU funds (Information Society in Greece, invitation 93 in Measure 4.2) to support the development of telecommunications broadband network infrastructure in less favorable areas by means of subsidy of the end subscribers, the interconnection of the companies equipment via optical fibers, etc. These actions stimulated market deregulation in these areas, increased competition and resulted to the minimization of domiciles without access to broadband in less than 8% in the beginning of 2009 with an obvious goal to decrease even more in the forthcoming period (Observatory for the Greek Information Society, August 2009).

Nevertheless, although fixed broadband penetration escalated to 15.6% in July 2009 and 17% in January 2010 from 2.7% in July 2006, Greece currently ranks 23rd in EU-27 far enough from the EU-27 average, which was 23.9% (Europe's Information Society, 2009 and Observatory for the Greek Information Society, January 2010). Considering the massive fiscal crisis in Greece and the cuts in salaries and public investments adopted by the Greek government in order to decrease the State's budget deficit, the distance between Greece's and the EU's average penetration rate, though diminishing during the past 2–3 years, is rather controversial as data are likely to change within year 2010.

In any case, it becomes apparent and accepted by all stakeholders that there are yet lots to be done towards the goal of digital convergence. On top of the agenda lies the already proclaimed and alleged to be submitted to public consultation, New Generation Access Networks project according to which, outdoor Cabinets (Fiber to the Cabinet) and buildings (Fiber to the Home) are going to be connected with the Central Office through new, fiber optic cables, providing ultra broadband circuits to end-users.

So, will demand be enough to absorb supply and induce more and more broadband lines and with even higher capacities? In what ways do socio-demographic characteristics correlate with the desire for a broadband connection? What will be the role of the incumbent and the alternative operators? What further measures are to be taken by the State authorities? In order to provide well-justified answers to these questions we begin with analyzing existing data regarding broadband lines and modeling the respective diffusion in the next section.

3. Data analysis and demand forecast

The availability of broadband lines in Greece has increased significantly during the last 3 years. As shown in Fig. 1, HTO has tripled the number of available broadband lines, from 496,000 in July 2006 to almost 1.5 million in June 2009. The number of the corresponding Local Exchange Offices (Points Of Presence, PoPs) offering broadband lines was also sharply increased, from 875 in July 2006 to 1457 in June 2009. Furthermore, Fig. 2 demonstrates the dispersion of broadband lines to the 13 administrative territories (see introduction for complete reference of the regions) in which Greece is divided. The emphasis given by HTO to the regions of Attica and Central Macedonia where resides more than half of the Greek population (big cities of Athens, Piraeus and Thessalonica) is prominent.

This dramatic shift in the supply side, combined with the effective unbundling of the local loop and the continuously improved public awareness, have led to a rapid increase of broadband lines, which escalated from 318,000 in July 2006 to well over 1.8 million in June 2009. Table 1 presents the actual number of broadband access lines separately for the incumbent operator (HTO lines) and alternative providers (LLU lines) indicating that competition has a clear positive effect on the demand for broadband lines.

Transforming the table into diagram in Fig. 3, we see that demand for BB lines by alternative operators and in total follows an almost perfect linear shape, which is rather expected, considering that the market experienced its childhood throughout the last 3 years. Situation is slightly different for the incumbent since the initial sharp increase is followed by the stabilization and the subsequent mild increase of BB subscribers, mainly as a result of the absence of competition until the beginning of 2007.

Henceforth, we try to explain changes in broadband demand as influenced by a number of socio-demographic factors such as education level, age, income, sex and marital status and estimate the demand for broadband for the years to come using a time-series diffusion model which we briefly describe at first.

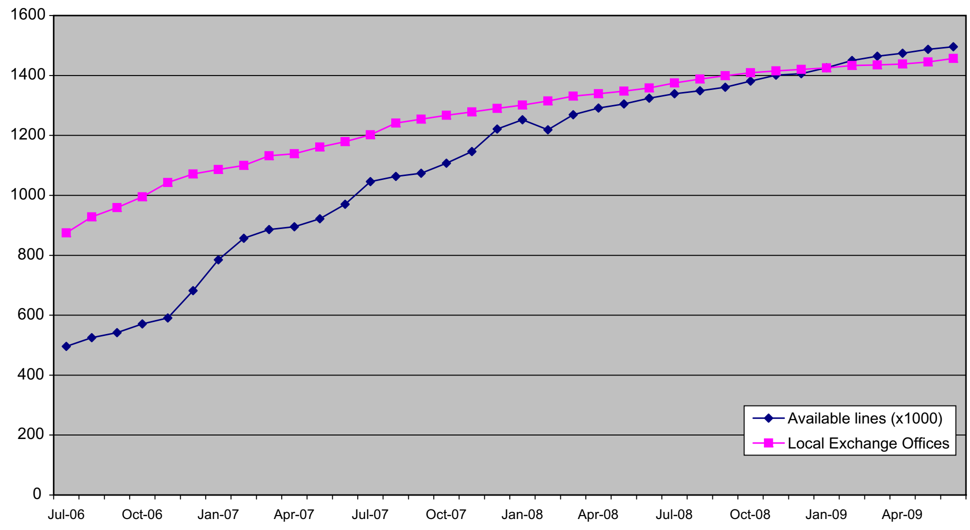

Fig. 1. HTO Broadband Availability PoPs and Lines.

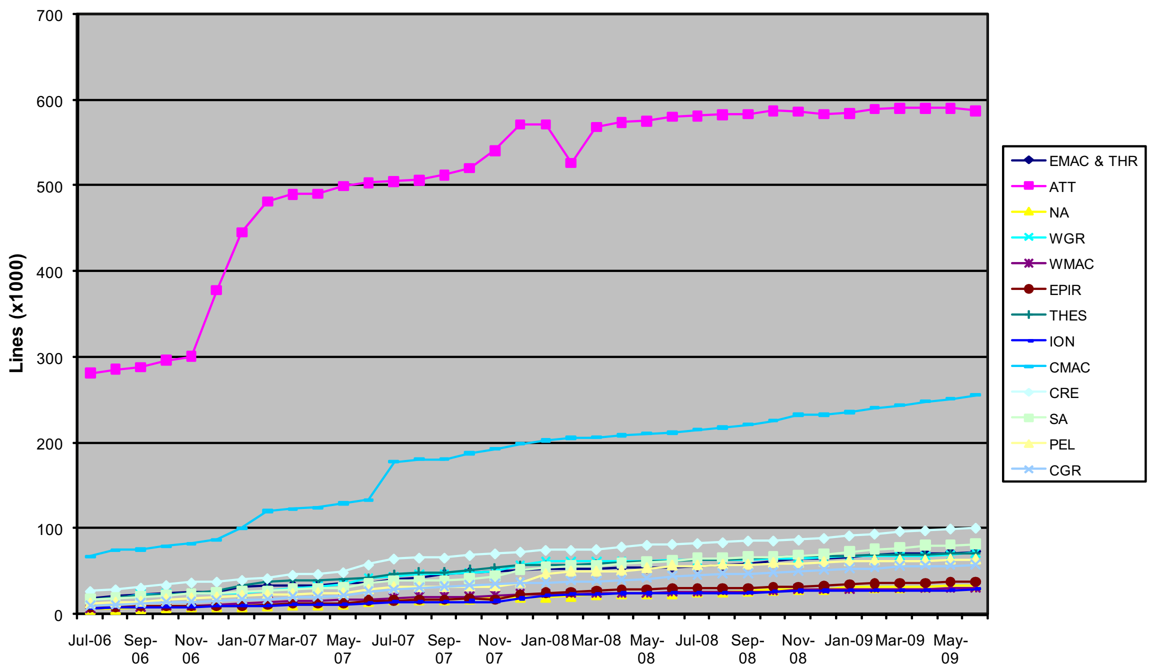

Fig. 2. HTO Broadband Availability by Region.

Table 1
Number of broadband lines.

	Jul-06	Sep-06	Dec-06	Mar-07	Jun-07	Sep-07	Dec-07	Mar-08	Jun-08	Sep-08	Dec-08	Mar-09	Jun-09
HTO	307	347	454	576	657	733	733	770	879	897	945	1008	1039
LLU	11	12	18	39	95	161	274	361	465	545	646	738	828
Total	318	359	472	615	752	894	1007	1131	1344	1442	1591	1746	1867

3.1. Correlations on time-series data

The model refers to the application of an econometric analysis to time-series data sets. Due to insufficient data regarding broadband subscribers' profile and characteristics, we use a causal method to find correlations between the number of

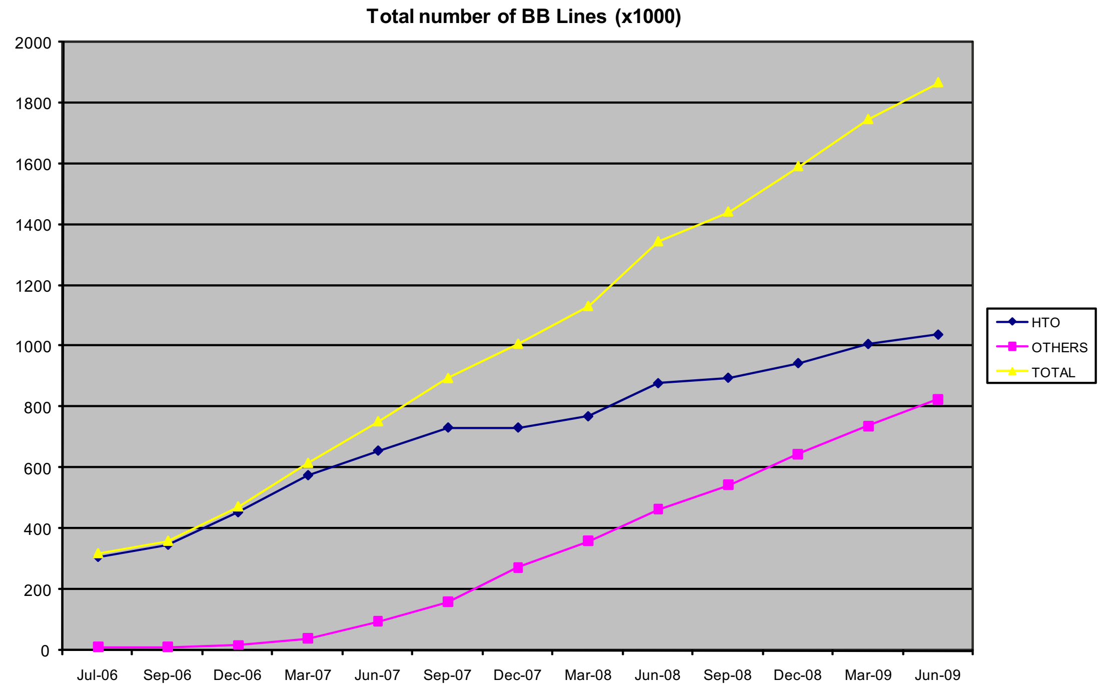

Fig. 3. Number of broadband lines (HTO and LLU lines).

broadband customers and socio-demographic factors, assuming that these correlations will continue to occur in the future (Lütkepohl and Krätzig, 2004).

In statistics, the covariance σ between two variables x, y can be represented as follows:

$$\sigma_{x,y} = E[(x - \mu_x)(y - \mu_y)]$$

For $\sigma = 0$, the variables are not correlated. If $\sigma > 0$, values above average of x correlate with values above average of y and vice versa, whilst if $\sigma < 0$, values above average of x correlate with values below average of y and vice versa. The level of correlation (i.e. how strong variables relate with each other) between variables x and y with expected values μ_X and μ_Y and standard deviations σ_X and σ_Y is indicated by the correlation coefficient:

$$R_{x,y} = \frac{\sigma_{x,y}}{\sigma_x \sigma_y},$$

where $\sigma_x = \sqrt{\mathrm{E}((x - \mu_x)^2} \;\&\; \sigma_y = \sqrt{\mathrm{E}\,(y - \mu_y)^2}$

The correlation coefficient contains covariation characteristics and ranges from -1 to 1. The closer the coefficient is to either -1 or 1, the stronger the correlation (negative or positive, respectively) between the variables (Mc Quarrie Allan and Chih-Ling, 1998).

The computation of the correlation coefficient is usually accompanied by the respective level of significance that is the probability of results being calculated by pure statistical accident. The level of statistical significance p is an estimation of the probability that the result has occurred by statistical accident. Therefore a large value of p represents a small level of statistical significance and vice versa. In the present study a threshold of $p = 0{,}05$ is adopted so we consider worthy of evaluation only correlation coefficients between variables for $p \leqslant 0{,}05$.

A time series is a set of observations generated sequentially in time (Box, Jenkins, and Reinsel, 1994). If the set is continuous, the time series is said to be continuous. If the set is discrete, the time series is said to be discrete. Let $X(t_1), X(t_2), \ldots, X(t_N)$ be the observations, which are made at times $t_1, t_2, \ldots, t_N$. Discrete time series, which are made between fixed interval T, are written as $\{X_1, X_2, \ldots, X_N\}$, to denote observations made at equidistant time intervals $t_0 + T, t_0 + 2T, \ldots, t_0 + NT$. If t_0 is adopted to be the origin and T the unit of time, one can regard X_t as the observation at time t.

The cross-correlation function CCF at delay "d" is defined as:

$$\mathrm{CCF}(\tau) = \int f1(t) f2(t - \tau)dt,$$

where τ is the shift of the second variable

For example, consider two real valued functions $f1$ and $f2$ that differ only by a shift along the x-axis. One can calculate the cross-correlation to figure out how much $f2$ must be shifted along the x-axis to make it identical to $f1$ (Electronic Statistics Textbook, www.statsoft.com).

In this paper, a distributed lags time-series analysis is used to describe the relationship between broadband lines and demographic variables. This is deemed as a specialized technique for examining the relationships between variables that involve some delay (Koyck, 1954). To this modeling approach, we consider demographic factors as independent variables that affect the dependent variable of broadband lines with some lag. The simplest way to describe the relationship between the two would be in a simple linear relationship:

$$N_t = \sum \beta_i * X_{t-i}$$

In this equation, the value of broadband lines N (the dependent variable) at time t is expressed as a linear function of x (specific socio-demographic characteristic) measured at times t, $t-1$, $t-2$, etc. Thus, broadband lines variable is a linear function of a specific socio-demographic characteristic which is lagged by 1, 2, etc. time periods. The beta weights (β_{i}) can be considered slope parameters in this equation. If the weights for the delayed (or lagged) time periods are statistically significant, we can conclude that the y variable is predicted (or explained) with the respective lag (Mc Quarrie Allan and Chih-Ling, 1998 and Boslaugh and Watters, 2008).

Therefore, based on time-series data and only for statistically significant correlation coefficient calculations, a regression forecast is performed in order to explore whether the correlation will change in the future. To achieve this, since demographic data is available for different age groups, distributed lag regression forecast is applied in order to examine the time-lagged correlations between the number of broadband lines and demographic characteristics. Any change (if existent) is discovered by comparing the values of the correlation coefficient (R) and the β parameter calculated by regression forecast before and after lag movement.

3.2. Application: correlations with socio-demographic characteristics and corresponding empirical demand forecast

Applying socio-demographic data provided by the General Secretariat of the National Statistical Service of Greece and data regarding the number of broadband lines from July 2006 to June 2009 provided by HTO and the National Regulator Authority. More specifically, we examine correlations that occur between broadband demand and the following factors:

(1) Education Level and Age
(2) Income
(3) Sex and Age
(4) Marital status and Age

Furthermore, in order to explore the effect of competition since data for broadband lines are available separately for HTO and the other providers for each territory, we examine Attica region. Attica comprises the two biggest cities of Greece (Athens and Piraeus) containing more than 50% percent of the total number of broadband lines. In addition, it is the first region within which alternative operators began to poach on, fact that resulted in the creation of a strong competitive environment.

3.2.1. Education level/age

It yields that the level of education plays an important role to the people's decision to buy a broadband access line as it explains covariations based on regression analysis results.

According to results shown in Table 2, groups of people with low level education (Junior high school graduates and lower) have bigger influence on broadband demand as high educated persons already or will definitely be users of new services anyhow, no matter their age. Table 3 depicts the correlation matrix, namely the estimation of relationships among the given variables (education level/age and total number of BB lines). Interpretation of the table for statistically significant variables reveals, among others, a positive correlation coefficient for people with very low education (R = 0687 and R = 0798 with high levels of accuracy, p = 0002 and p = 0, respectively) implying that as they grow up, they are likely to obtain a broadband line, possibly as a result of their essay to be kept up-to-date with the new era even though they lack basic knowledge. Results are converse for those that have finished junior high school, as their desire for broadband reduces as they grow up ($R = -0519$, p = 0033), probably due to the fact that they do not know much about new technologies and thus hesitate to use them.

As suggested by the regression analysis and the values of the Correlation Factors the demand for broadband is strongly related with the users' level of education. We perform time-series analysis by calculating the respective Cross Correlation Factor (CCF) through a regression forecast in order to investigate whether this relation will continue to occur. Due to limited space, we further analyze results about the CCF coefficient only for the variable of junior high school graduates.

Table 2
Values of beta standardized coefficient β (R = 0999, R^2 = 0997).

PhD	Masters degree	Univers. diploma	Technical education	High school	Junior high school	Element. school	Aband element with reading and writing ability	No. element without reading and writing ability
0.227	0.089	0.132	−0.512	1279 (excluded)	−0.427	−0.48	0.526	−0.462

Table 3
Correlation matrix for variables BB LINES, EDUCATION LEVEL/AGE.

		Total number of BB lines	PhD/ age	Masters degree/ age	University diploma/ age	Technical education/ age	High school/ age	Junior high school/Age	Elementary school/Age	Abandoned elementary education with reading and writing ability/Age	No elementary education without reading and writing ability/Age
Total number of BB lines	Pearson correlation	1	0.069	−0.302	−0.15	−0.304	−0.446	−0.519[a]	0.261	0.687[b]	0.798[b]
	Sig. (2-tailed)	–	0.792	0.239	0.565	0.235	0.073	0.033	0.312	0.002	0
PhD/Age	Pearson correlation	0.069	1	0.619[b]	0.871[b]	0.676[b]	0.442	0.01	0.476	−0.17	−0.236
	Sig. (2-tailed)	0.792	–	0.008	0	0.003	0.076	0.971	0.053	0.513	0.361
Masters degree/age	Pearson correlation	−0.302	0.619[b]	1	0.916[b]	0.975[b]	0.746[b]	0.22	−0.076	−0.399	−0.379
	Sig. (2-tailed)	0.239	0.008	–	0	0	0.001	0.396	0.772	0.112	0.134
University diploma/age	Pearson correlation	−0.15	0.871[b]	0.916[b]	1	0.948[b]	0.710[b]	0.139	0.165	−0.323	−0.335
	Sig. (2-tailed)	0.565	0	0	–	0	0.001	0.594	0.526	0.206	0.188
Technical education/age	Pearson correlation	−0.304	0.676[b]	0.975[b]	0.948[b]	1	0.822[b]	0.216	−0.048	−0.407	−0.389
	Sig. (2-tailed)	0.235	0.003	0	0	–	0	0.405	0.854	0.105	0.123
High school/age	Pearson correlation	−0.446	0.442	0.746[b]	0.710[b]	0.822[b]	1	0.564[a]	−0.143	−0.422	−0.419
	Sig. (2-tailed)	0.073	0.076	0.001	0.001	0	–	0.018	0.584	0.092	0.094
Junior high school/age	Pearson correlation	−0.519[a]	0.01	0.22	0.139	0.216	0.564[a]	1	−0.216	−0.375	−0.397
	Sig. (2-tailed)	0.033	0.971	0.396	0.594	0.405	0.018	–	0.404	0.138	0.115
Elementary school/age	Pearson correlation	0.261	0.476	−0.076	0.165	−0.048	−0.143	−0.216	1	0.346	0.138
	Sig. (2-tailed)	0.312	0.053	0.772	0.526	0.854	0.584	0.404	–	0.174	0.596
Abandoned elementary education with reading and writing ability/age	Pearson correlation	0.687[b]	−0.17	−0.399	−0.323	−0.407	−0.422	−0.375	0.346	1	0.935[b]
	Sig. (2-tailed)	0.002	0.513	0.112	0.206	0.105	0.092	0.138	0.174	–	0
No elementary education without reading and writing ability/age	Pearson correlation	0.798[b]	−0.236	−0.379	−0.335	−0.389	−0.419	-0.397	0.138	0.935[b]	1
	Sig. (2-tailed)	0	0.361	0.134	0.188	0.123	0.094	0.115	0.596	0	–

[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

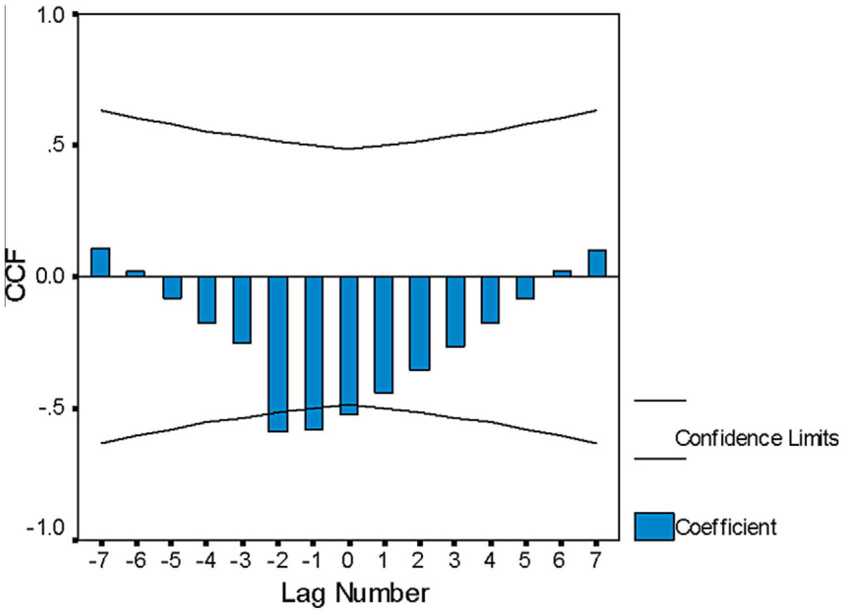

Fig. 4. Broadband lines and age of people having finished junior high school cross correlation factor coefficient.

Table 4
Correlation matrix for variables BB LINES, INCOME.

		Total number of BB lines	Population income
Total number of BB lines	Pearson correlation	1	0.998[a]
	Sig. (2-tailed)	–	0.04
Population income	Pearson correlation	0.998[a]	1
	Sig. (2-tailed)	0.04	–

[a] Correlation is significant at the 0.05 level (2-tailed).

As shown in Fig. 4, there is a significant negative correlation on lag number −2 and then a weak positive correlation on lag number 7. Since level of education drives demand, we create a new time series moved two lags further in order to demonstrate the future impact of high school graduates on broadband demand. It results that this influence will continue to occur being somewhat reduced though. The R's, adjusted R^2's and standardized β's are shown below:

Before lag movement: $R = 0526$, $R^2 = 0276$, $\beta = -0526$

After lag movement: $R = 0506$, $R^2 = 0256$, $\beta = -0506$

Taking into account the distribution of people to different age groups according to the latest population census data and the fact that demand has been continuously increasing during the past three years, the empirical outcome is that broadband demand will continue to have a positive trend for the years to come with more or less the same dispersion in groups of different education level.

3.2.2. Income

The population's income in Greece is increasing even at a slow rate, having a positive effect on broadband demand judging by the extremely high value of the correlation coefficient ($R = 0998$, $p = 0040$) in Table 4 as it denotes an almost perfect relationship between the variables. As expected, higher income means more money available for needs and likes other than the fundamental ones with high speed broadband lines being one of the most important contemporary modes of amusement as it is required for a variety of entertainment services. Time-series analysis and calculation of the Cross Correlation Factor (CCF) coefficient indicates that it is almost certain that this explicit association is will continue to exist as the value of the CCF coefficient is positive and very close to the absolute unit, as shown in Fig. 5.

3.2.3. Sex/age

With regard to the age of men and women, results presented in Table 5 uncover that no statistically significant covariations exist in broadband demand related with differences in the age of females ($R = -0370$, $p = 0131$). On the other hand, younger males are more likely to subscribe to broadband in opposition with older ones, as demonstrated by the negative value of the correlation coefficient ($R = -0545$, $p = 0019$), implying that boys are more interfered with new technologies both

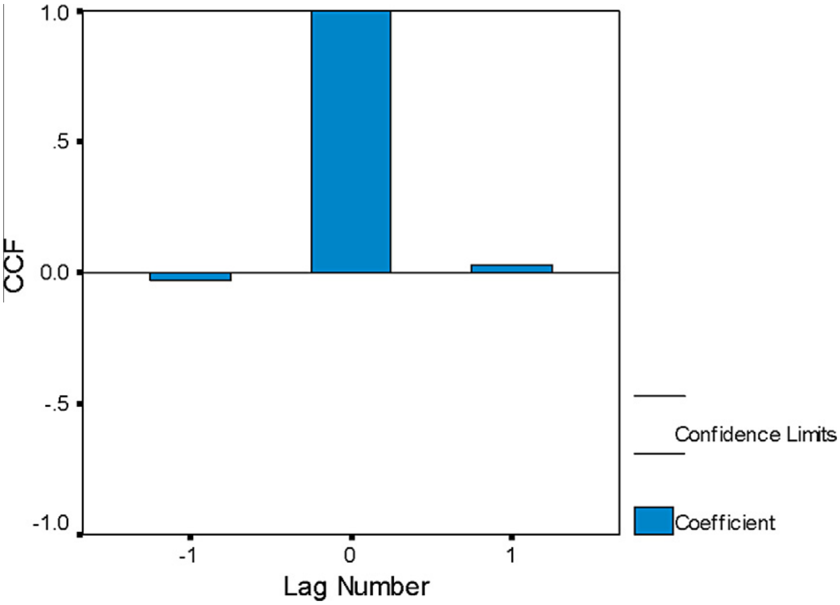

Fig. 5. Broadband lines and population income cross correlation factor coefficient.

Table 5
Correlation matrix for variables BB LINES, SEX/AGE.

		Total number of BB lines	Male/age	Female/age
Total number of BB lines	Pearson correlation	1	−0.545[a]	−0.37
	Sig. (2-tailed)	–	0.019	0.131
Male/age	Pearson correlation	−0.545[a]	1	0.975[b]
	Sig. (2-tailed)	0.019	–	0
Female/age	Pearson correlation	−0.37	0.975[b]	1
	Sig. (2-tailed)	0.131	0	–

[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

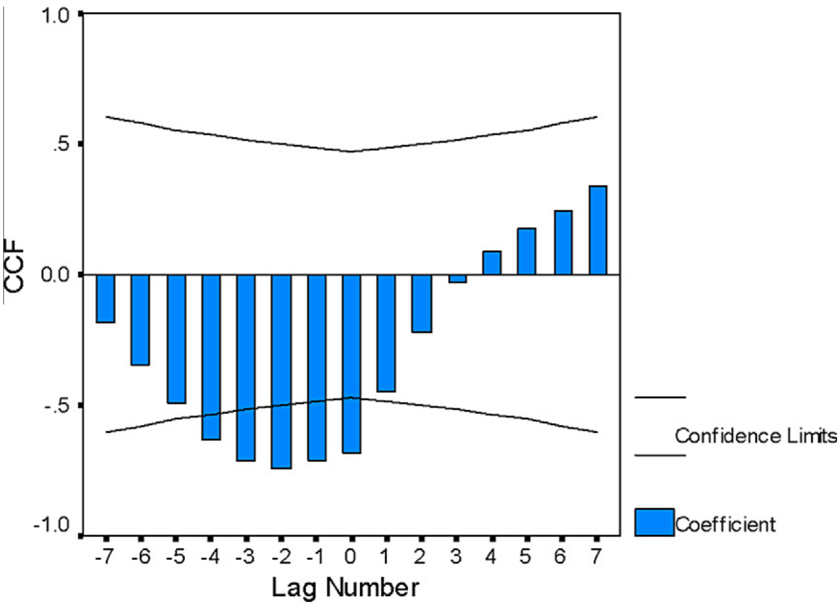

Fig. 6. Broadband lines and age of male persons cross correlation factor coefficient.

for educational (e.g. web searches for school homework) and entertainment use (e.g. multimedia/interactive gaming) than their predecessors.

We perform a distributed lags time-series analysis by calculating the respective Cross Correlation Factor (CCF) through a regression forecast in order to explore the future trend of the relation between the age of males and the demand for broadband lines. As demonstrated in Fig. 6, there is a significant negative correlation on lag number −2 and then a weak positive correlation on lag number 7. Since males drive demand, we create a new time series moved two lags further in order to demonstrate the future impact of young males on broadband demand. The R's, adjusted R^2's and standardized β's are shown below:

$$\text{Before lag movement}: R = 0684, R^2 = 0468, \beta = -0684$$

$$\text{After lag movement}: R = 0648, R^2 = 0420, \beta = -0648$$

It results that although a little diminished, this influence will continue to exist in the future, with male youth pioneering in the use of innovative services.

3.2.4. Marital status/age

Regarding the marital status of different age groups, we find in the correlation matrix of Table 6 that persons living alone, without further obligations have a strong influence on broadband demand. We discover a quite high correlation coefficient

Table 6
Correlation matrix for variables BB LINES, MARITAL STATUS/AGE.

		Total number of BB lines	Single/age	Married/age	Widow(er)/age	Divorced/age	Separated /age
Total number of BB lines	Pearson correlation	1	−0.912[b]	0.426	0.875[b]	0.274	0.18
	Sig. (2-tailed)	–	0	0.078	0	0.271	0.474
Single/age	Pearson correlation	−0.912[b]	1	−0.598[b]	−0.722[b]	−0.495[a]	−0.367
	Sig. (2-tailed)	0	–	0.009	0.001	0.037	0.134
Married/age	Pearson correlation	0.426	−0.598[b]	1	0.111	0.948[b]	0.908[b]
	Sig. (2-tailed)	0.078	0.009	–	0.662	0	0
Widow(er)/age	Pearson correlation	0.875[b]	−0.722[b]	0.111	1	−0.111	−0.199
	Sig. (2-tailed)	0	0.001	0.662	–	0.662	0.428
Divorced/age	Pearson correlation	0.274	−0.495[a]	0.948[b]	−0.111	1	0.963[b]
	Sig. (2-tailed)	0.271	0.037	0	0.662	–	0
Separated/age	Pearson correlation	0.18	−0.367	0.908[b]	−0.199	0.963[b]	1
	Sig. (2-tailed)	0.474	0.134	0	0.428	0	–

[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

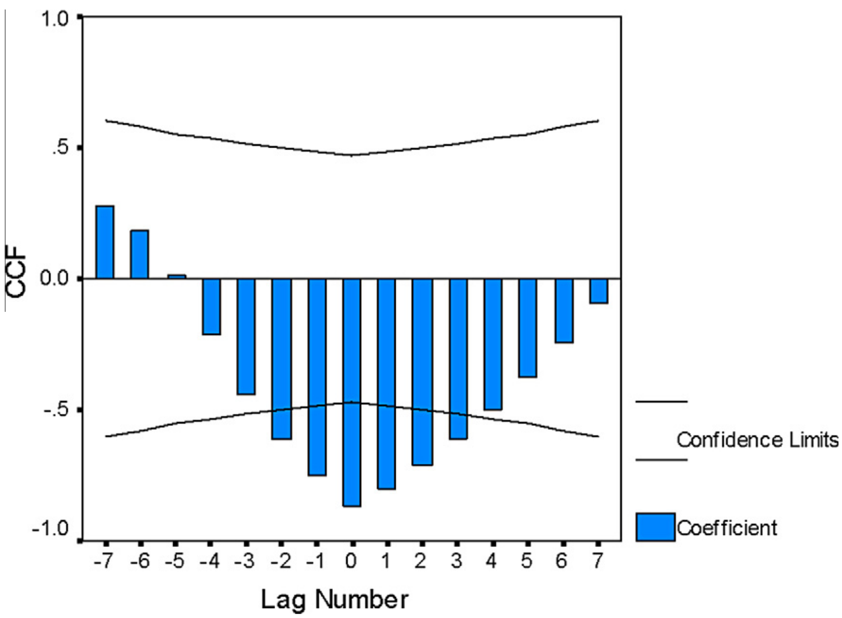

Fig. 7. Broadband lines and age of single persons cross correlation factor coefficient.

($R = -0912$, $p = 0$) in singles that are usually financial independent and have limited fixed expenses (shelter, food, etc.) which is rather expected considering that Greeks often live with their parents until they get married. The negative value indicates that demand for broadband by this group of people is likely to decline as time passes by, presumably as a result of change in the marital status. The other group that is deeply related with broadband demand is widowers/widows ($R = 0875$, $p = 0$). Nonetheless, the correlation coefficient is positive showing that demand increases as they grow older, supposedly because of the fact of having more free time and thus using the web for entertainment purposes.

Time-series analysis along with regression forecast infer to the continuation of the correlation in both groups. For illustration purposes though, we show results of the CCF calculation only for the group of singles in Fig. 7. We observe a weak

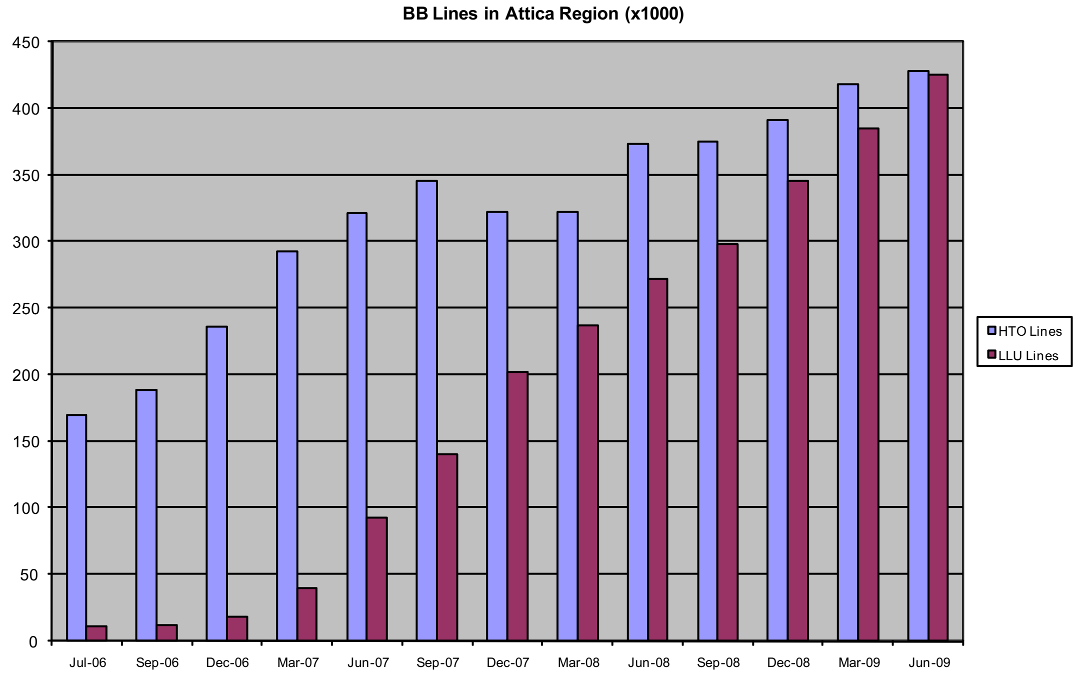

Fig. 8. Actual broadband lines in Attica (HTO and competitors).

Table 7
Correlation matrix for variables HTO BB LINES, SEX/AGE in Attica region.

		Total number of BB lines (HTO)	Male/age	Female/age
Total number of BB lines (HTO)	Pearson correlation	1	−0.435	−0.222
	Sig. (2-tailed)	–	0.071	0.376
Male/age	Pearson correlation	−0.435	1	0.970[a]
	Sig. (2-tailed)	0.071	–	0
Female/age	Pearson correlation	−0.222	0.970[a]	1
	Sig. (2-tailed)	0.376	0	–

[a] Correlation is significant at the 0.01 level (2-tailed).

Table 8
Correlation matrix for variables LLU BB LINES, SEX/AGE in Attica region.

		Total number of BB lines (LLU)	Male/age	Female/age
Total number of BB lines (LLU)	Pearson correlation	1	−0.708[a]	−0.835[a]
	Sig. (2-tailed)	–	0.001	0
Male/age	Pearson correlation	−0.708[a]	1	0.970[a]
	Sig. (2-tailed)	0.001	–	0
Female/age	Pearson correlation	−0.835[a]	0.970[a]	1
	Sig. (2-tailed)	0	0	–

[a] Correlation is significant at the 0.01 level (2-tailed).

positive correlation on lag −7 and then a substantial negative correlation on lag 0. Creating a new time series moved two lags further results the following values:

Before lag movement: $R = 0869$, $R^2 = 0756$, $\beta = -0869$
After lag movement: $R = 0879$, $R^2 = 0772$, $\beta = -0879$

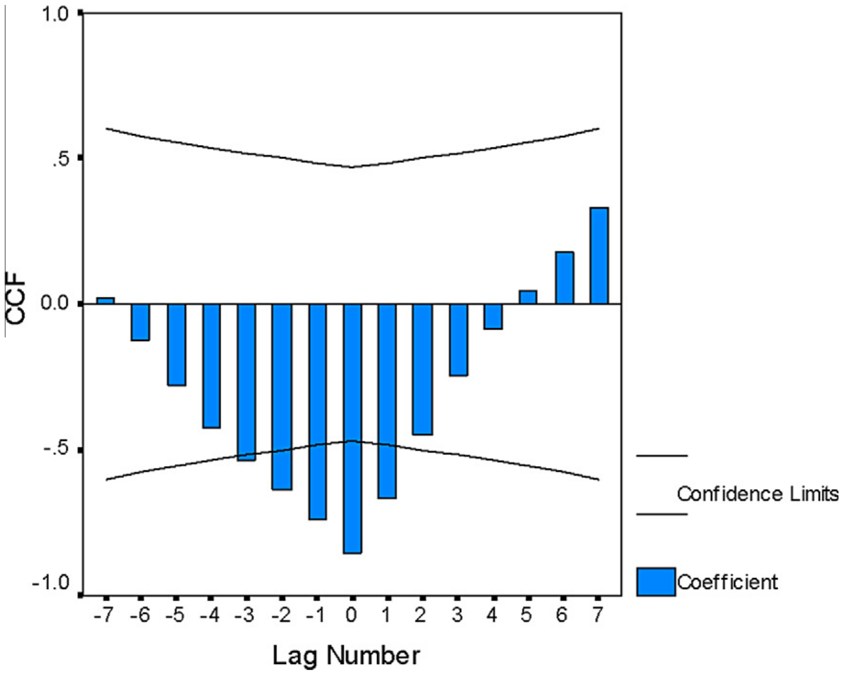

Fig. 9. Broadband lines (LLU only) and age of male persons cross correlation factor coefficient.

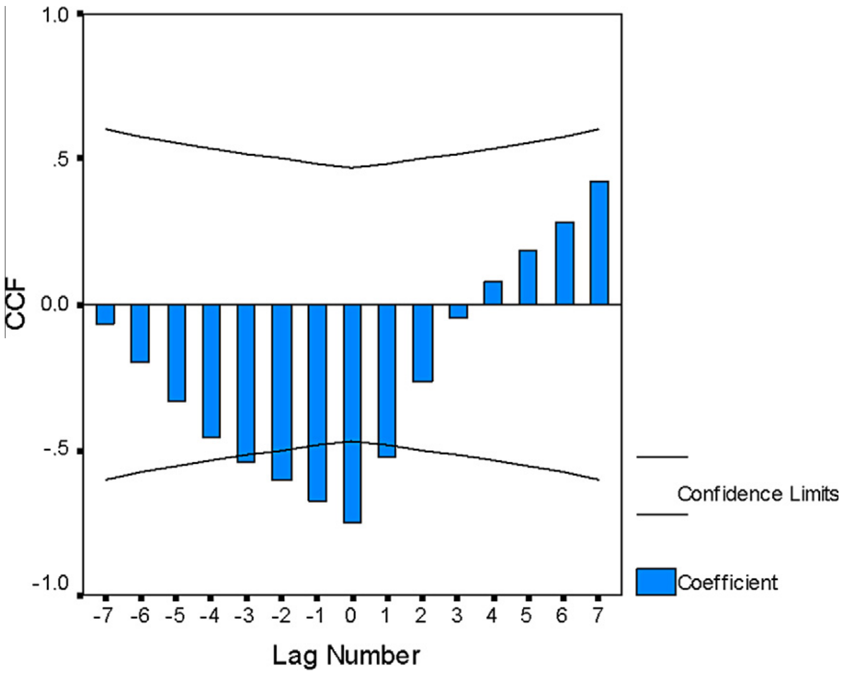

Fig. 10. Broadband lines (LLU only) and age of female persons cross correlation factor coefficient.

It is therefore concluded that demand for broadband lines will keep on increasing by single persons of low age which is expected if we take into account that young persons are more technology aware than older ones.

3.2.5. Competition – the case of Attica

Due to the high population and respective density of the territory of Attica, it was the first region in which alternative operators meddled and hence constitutes the ideal case to be examined in order to explore the impact of competition on the broadband market in terms of differentiation of the demand for broadband lines provided by the incumbent (HTO) and the alternative operators (LLU Lines). As highlighted by the diagram in Fig. 8, the increase in LLU lines in this region during the last two years is rather impressive, changing the telecommunication landscape and incurring imbalance in the companies' market shares.

Exploring the correlation between demographic characteristics and broadband lines provided by the traditional HTO in comparison with other carriers, we find that broadband lines provided by competitors are strongly related with sex and age. It is observed that demand by young males/females ($R = -0708$, $p = 0001/R = -0835$, $p = 0$, respectively in Tables 7 and 8) is higher than older which is another confirmation for the social phenomenon of lower possibility for change and new things adoption as age increases. On the other hand, the demand for HTO lines seems to be unaffected by external influences probably because of the fact that the decision of customers to obtain HTO-provided broadband lines is based to the powerful brand name of the company and not on other factors.

Calculation of the CCF separately for male and female gender results to the diagrams shown in Figs. 9 and 10. As demonstrated, in both cases, there is a significant negative correlation on lag number 0. Time series regression forecasts demonstrate that the relation will continue to be negative. It is therefore inferred that young males and females will continue to demand broadband lines provided by other than the incumbent carriers. For the purpose of continuity we quote below the values of the calculated correlation coefficient before and after the lag movement for each case.

Before lag movement Male/age variable: $R = 0675$, $R^2 = 0455$, $\beta = -0675$
After lag movement Male/age variable: $R = 0634$, $R^2 = 0401$, $\beta = -0634$
Before lag movement Female/age variable: $R = 0502$, $R^2 = 0252$, $\beta = -0502$
After lag movement Female/age variable: $R = 0458$, $R^2 = 0210$, $\beta = -0458$

4. Conclusions

Results of the study stiffen the already known positive relationship between broadband lines and income variable as they denote an almost perfect association among them. Same with all goods and services in the end, in the effort of estimating broadband demand, it comes down to price and income and more specifically that price relative to the price of basic needs (food, shelter, etc.). As far as level of education is concerned, demand is affected only by low level educated groups as in most cases persons with higher education are users of innovative services anyhow. Sex is a considerable factor as males influence demand more than females, especially in school ages. We presume that on-line gaming is a key element to the explanation of this phenomenon considering the increasing sales in the gaming machines market. The marital status variable plays quite an important role as singles and widowers/widows have in general more time and money to spend on entertainment (music/video downloads, Internet gaming, etc.), not excluding the possibility of using broadband lines for educational or tele-work purposes.

The role of a healthy competitive environment is not under question as it is deemed to be beneficial for the diffusion of broadband availability and the reduction of prices and the study's results support strongly this fact. Nevertheless, with new generation networks (FTTx, with x interpreted either to C for Cabinet/Curve or H for Home or B for Building) designated to dominate the broadband access market for the years to come and as the last-kilometer provision has non-trivial sunk costs; the market structure is likely to be monopolist or an oligopoly at best. Taking under consideration the privatization of HTO to a large extent as the State currently owns less than 20% of the firm's shares; the concession of the company's management to private funds is a matter of time. Assuming that this will result to a more flexible operation within the incumbent carrier, effective regulation and the role of the local NRA is of high importance as tariffs need to be estimated with precision and accepted by both sides. In any case, further strategic alliances between carriers are possible so the market landscape is quite vulnerable to changes and thus cannot be predicted accurately.

Time-series analysis and cross correlation factors calculations infer that the above relationships will continue to exist and thus demand for broadband will continue to have a positive trend examining the country as a whole and the various territories in discrete as no significant differentiation was discovered between them. Due to limited space in this paper, we have not demonstrated results and correlations separately for each geographic territory however they are available and can be presented if asked by e-mailing to the corresponding author.

5. Limitations – suggestions for future research

The demand for broadband services is affected by a variety of other factors such as the diversity of the services themselves, the opportunity to introduce innovative services, the local government broadband initiatives and the business plans of telecommunications companies. Although carriers usually offer bundle services (broadband access along with voice/

video/TV service, etc.), throughout the study we deal only with broadband access as it is considered to be prerequisite for the supply of any other service. It is worth to mention that the paper uses data and thus refers to fixed (DSL technology) broadband usage and does not take under consideration other modes of broadband access. This is due to the absolute absence of cable connections, the up to date small expansion of wireless high-speed connections (mobile, Wi-Fi, satellite) and the respective lack of data regarding end-users, thus presuming that the corresponding impact of such modes of access on the whole broadband market is yet relatively small in Greece. However, an increase in the number of such customers would undoubtedly affect directly the demand for fixed broadband lines. At the same time, new generation access networks (FTTx networks) are in the foreground, promising higher speeds and modern services. Coupled with budget constraints the question of estimating the demand for new forms of access and usage along with the diffusion of the services themselves remains a topic of interest for future research. After all, consumer demand is the driver of change.

Last but not least is the clear declaration of the statement that views and judgments expressed in this paper are absolutely impartial and reflect the authors' opinions and in no case those of companies implicated in the Greek telecommunications market.

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