Technology in Society 33 (2011) 265–270

Contents lists available at SciVerse ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Digital divide gap convergence in Europe

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ARTICLE INFO

Article history:
Received 7 May 2011
Received in revised form 16 September 2011
Accepted 20 September 2011

Keywords:
Broadband diffusion
Digital divide gap
Digital convergence
Penetration

ABSTRACT

The diffusion of broadband in Europe is shaped by the penetration rates of the individual European countries. However, the contribution of each country to the total level of diffusion is not the same, due to the existence of a digital divide among the countries. The digital divide is still evident and although diffusion keeps increasing, not all countries have the same rate of broadband adoption. Based on the above, a methodology measuring the digital divide gap is presented in the context of this research, together with forecasts regarding broadband convergence. Evaluation of the methodology was performed for the European countries examined from 2001 to 2009.

1. Introduction

The proliferation of broadband services has introduced Internet access as a key concern for consumers and policy makers. The usage of services is connected to the economic growth and the level of broadband coverage has become one of the main characteristics of a developed country [1]. However, according to the OECD, less than 0.1 in every 100 people have access to a computer in developing countries, whereas in the developed world the corresponding proportion is 60 in every 100 people [2]. This ratio represents a “digital divide”, which refers to the ICT inequality among countries, in terms of ICT investments, PC skills, Internet skills and the availability of telecommunications networks. The digital divide is commonly related to the economic status of a country [3], since ICT services and products seem to be channeled more effectively in wealthy countries. However, poor countries could benefit from new technologies by exploring opportunities related to general development.

The European Commission (EC) keeps monitoring the persistence of the digital inequalities among member states and encourages initiatives in order to boost the usage of new technologies. Toward this direction, member nations applied a number of practices, including subsidization, aimed at enhancing ICT adoption. Despite these efforts, the digital divide is still evident and broadband diffusion varies substantially among countries. The lack of required infrastructure is assumed to be the main barrier causing low broadband penetration, as well as the major reason for broadband exclusion. Moreover, the EC promotes changes in policy frameworks, aiming to create positive circumstances for further broadband growth [4]. The enhancement of competition is associated with ICT adoption, quality improvement and lower prices. The main goal is the elimination of broadband penetration inequalities and ICT exclusion among the European countries.

To estimate the rate of digital convergence within European borders, the rate of fixed broadband penetration across a number of European countries (registered since 1998) can be analyzed together with the contribution of each country to the process of broadband diffusion. Nowadays, mobile broadband is widely established as well. Indeed, since 2006 there is a considerable growth in mobile broadband which varies among countries. For example, in Scandinavian countries mobile broadband penetration exceeds 100% while in some countries in central Europe the broadband penetration is less than 30%. Moreover, in

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doi:10.1016/j.techsoc.2011.09.001

several cases from the group of the developing countries mobile broadband penetration is higher than fixed broadband penetration (www.worldbank.org). This is not a surprising, since the content and targets of the digital divide gap change and will keep changing over time, according to the different needs of users and the different technologies used. Internet access has progressed from laptops to mobile phones and smartphones. Product life-cycle forms the different cycles of the digital divide gap indicating that among the parameters that influence this divide, the technologies and different socio-economic factors should also be taken into account in such an analysis.

In this analysis, the data used for evaluation purposes corresponds to the cumulative penetration of xDSL, FTTB and cable connections across the participating countries. Such an analysis is helpful in highlighting the flaws of governmental and European Commission practices regarding telecommunications policies and providing directions for more efficient approaches. Since Europe is affected by the recent economic crisis, decision-makers should focus on broadband adoption, as it is a foundation for long-term economic growth.

Some of the older Members States and especially the Scandinavian countries are the leaders in broadband diffusion, whereas the Balkan and Mediterranean countries are lagging behind. Apart from the technical or economical characteristics, there is a group of other important factors which play a crucial role in the process of broadband growth. These are mainly the social differentiations among countries, such as income, urbanization and PC skills. In addition, human resources from the marketplace, such as marketing professionals and engineers, regularly monitor end-users' needs aiming to maximize their satisfaction. They also address the demand for new content and provide more user-centered practices, offering more attractive services. Moreover, as multinational businesses exploit the new challenges offered by the new technologies and the Internet, they can leverage further broadband development. Although the analysis of the impact of these factors on broadband adoption could lead to useful insight, it is beyond the scope of this article.

The rest of this paper is structured as follows: In Section 2 a conceptual overview of the digital divide is presented. In Section 3 the proposed methodology for analyzing available data is explained. In Section 4, the results of this analysis are presented and discussed. Finally, conclusions reached from previous sections and proposals for extensions of the methodology are presented in Section 5.

2. The digital divide gap

2.1. Conceptual overview

"Digital Divide" was established as a term in 1990s, in order to describe the perceived growing gap between those who have access to and the skills to use ICT and those who have limited or no access at all [5]. The digital divide gap is usually examined among different groups of people within the borders of a country [6]. The methodology used to measure the digital divide is based on appropriate mathematical or econometric approaches with corresponding assumptions regarding the proxies used to estimate it. In this paper, the digital gap is assumed to be driven and reflected by the differences in broadband penetration among European countries.

Initially, the term "convergence" was used to describe integrated telecommunications services offered by telecom operators. The most well-known contemporary telecom convergence is the so called "triple-play", which consists of telephone, xDSL and Video on Demand services. Such services are very popular in countries where broadband penetration is nearing saturation, such as Korea and Japan [7].

However, in the context of this paper, convergence means the process of homogenization of broadband diffusion, based on the status of the penetration rate for neighboring countries. As penetration rates are still continuously increasing, even in countries where during the previous years broadband penetration was near zero, it is possible that all countries will eventually reach the same level of saturation.

The European Commission and the other decision-makers in Europe have attempted to address the problem of inequality among countries, as much as within them. Through regulatory changes they have tried to promote competition among telecommunication operators, that will in turn increase broadband diffusion [8]. In addition, there are a number of policy decisions regarding the enhancement of digitalization. The EC decided upon a policy framework for all Member States in order to benefit from ICT potentials [9]. This framework followed the strategic instrument for an "Information Society for all" in 2003 [10]. However, the goals from these actions were not achieved even some years later. To address this, the EC in [11] developed a new strategy which will last until 2020, combining a number of key factors such as trust and security. This strategy focuses on the needs of each individual member country. Moreover, the EC aimed at 100% broadband coverage by the end of 2013, together with the upgrade of the available bandwidth to 30 Mbps by 2020 [12].

2.2. Literature review

Despite the fact that the digital divide attracts the interest of both the scientific community and the EC, the way it is approached varies substantially. The ICT adoption, as well as broadband penetration, are directly related with economic development [13,14]. Moreover, the level of an information society is criteria for a country's accession into the European Union [15]. As Ferrer et al. [16] showed, the use of ICT in primary education contributes to the improvement of academic results. In this regard, the most significant output of this study is the fact that students with lower socio-economic and cultural status improve their performance more than advantaged pupils.

However, despite the impact of the digital divide socially, politically and economically, according to Corrocher and Ordanini [17] there is still a lack of theory supporting the existing measurement of the digital divide. They proposed a synthetic index of digitalization and

presented the results of its application over ten developed countries. Falch [18] suggested that income affects broadband penetration rate, as subscribers are concentrated in countries with high GDP (Gross Domestic Product). The differentiation may also depend on a variety of factors such as gender, age, income etc, as stated in Refs. [19,20]. In a recent work of Horrigan [1] it is highlighted that age together with education level play a crucial role to the usage of broadband services. A higher population density may lead to a higher level of broadband adoption as well, since people living in such areas usually don't face digital exclusion [21,22]. On the other hand, the provision of broadband services in rural areas, where potential users are fewer than in urban areas, is limited [23]. However, the availability of broadband access in rural and remote areas boosts the willingness of service adoption [24].

A general view of the digital divide could reveal that a digital gap is still evident among whole countries, mainly due to social disadvantages and lack of digital infrastructure [25]. This work, exemplified by Jeffery (2007), examines the impact of ICT usage on economic growth and the elimination of poverty. Moreover, even if equality among people is well established in the developed countries it seems that race, income and education can affect broadband adoption negatively, as stated in Prieger and Hub (2008) [26]. Preston and Cawley [8] indicated that the policy framework could be an obstacle for further development in rural and low population density areas.

Finally, the growth of broadband diffusion should be based on specific strategies, orientated to non-users, even in countries with high penetration rates [27]. In addition, Billon et al. [28] studied a number of parameters affecting ICT adoption in both developed and developing countries and proposed policy suggestions aimed to the improvement of the adoption process.

2.3. Broadband penetration in Europe

Despite the targeted actions initiated by the EC and the member states, there are still large differences in the corresponding broadband penetration rates. Some of them take up broadband services faster than the other, mainly due to the lack of adequate infrastructure. However, as Bouckaert et al. [29] showed, differences in penetration also result from the access regulation, causing limited infrastructure competition. Furthermore, despite the actions aiming to strengthen the required skills regarding the effective usage of ICT, there is still room for improvement that could lead to a higher broadband adoption [30].

Broadband penetration rates together with the mean broadband rate are illustrated in Fig. 1, for each considered quarter term. The dataset was extracted from Eurostat and the term penetration describes the number of connections over population (i.e. over the 28 European countries considered) [31,32]. The dataset consists of 28 quarter terms, from December 2001 up to December 2009.

According to the results, it can be observed that the mean penetration rate of the countries considered is increasing at a non-constant rate that ranges, from 0.3% to 1.4% per quarter term. Moreover, it is evident that there are many fluctuations, since some of countries are in their early stage of broadband evolution, while others have already achieved saturation. This uneven distribution of diffusion rates reveals that there is digital divide gap among these countries.

The aim of this work is to determine the level of the digital divide and forecast the time of digital convergence based on the proposed methodology analyzed in the next section.

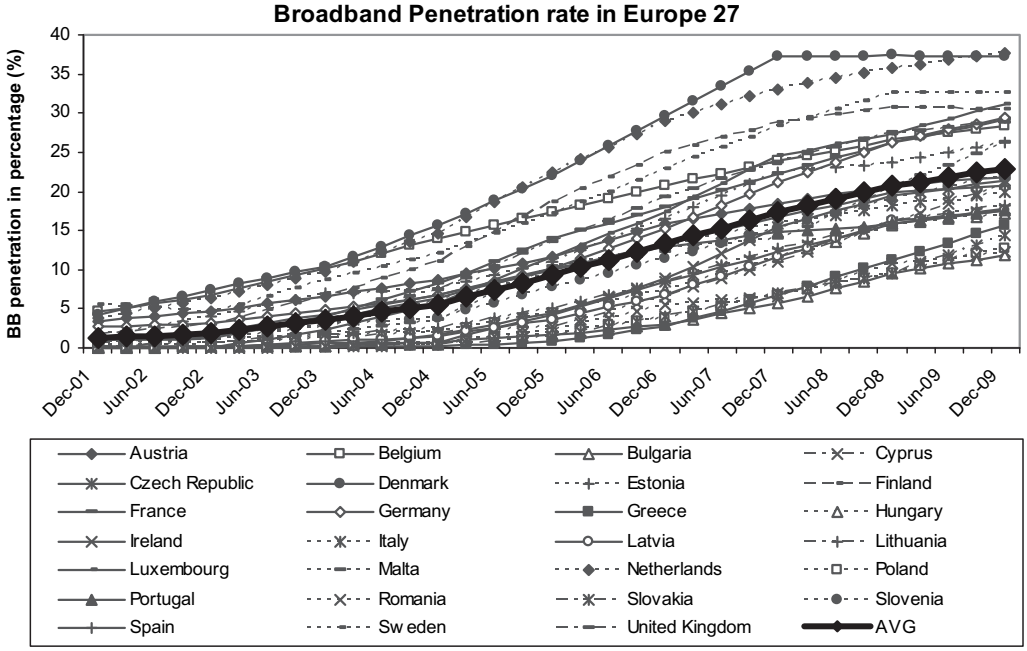

Fig. 1. Broadband penetration rate of considered countries together with the mean penetration rate.

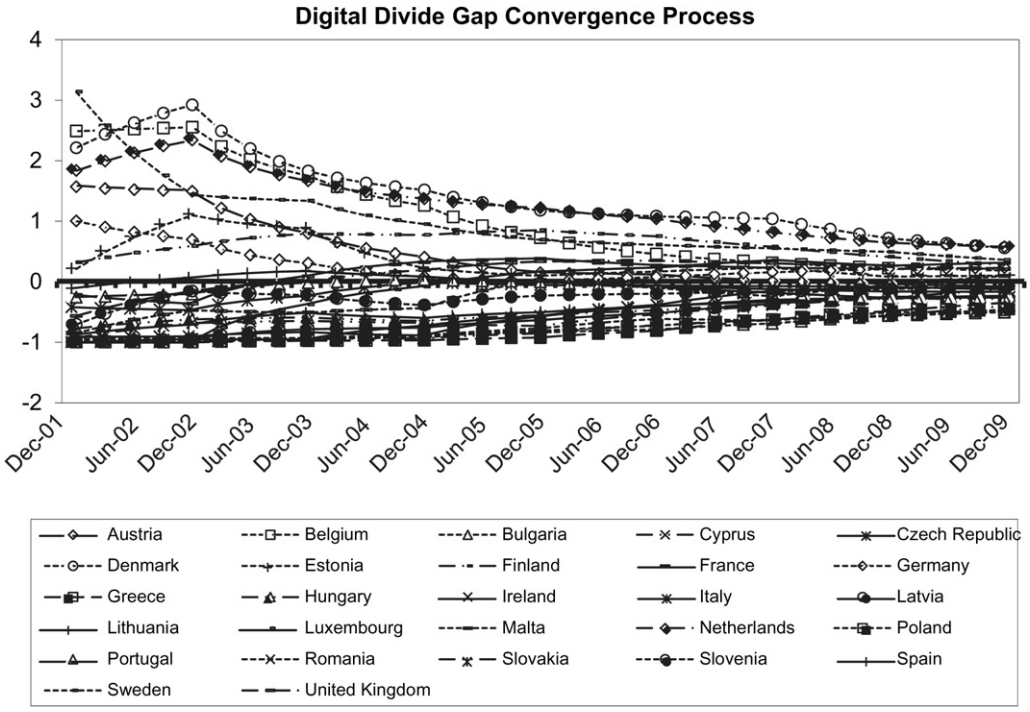

Fig. 2. Relative to the mean penetration for all considered countries from December 2001 to December 2009.

3. Methodology

The development of the proposed methodology is presented in this section in terms of the assumptions made and the mathematical framework used.

For each quarter term, t, and for each one of the considered countries, i, the proportion of its penetration over the mean penetration rate is calculated. The results are plotted against time and depict the relative penetration, *RP*, of each country considered and for each period of time. The formulation for calculating the *RP* is described by Eq. (1).

$$RP_{(i,t)} = \frac{\frac{x_i}{p_i} - \frac{x_T}{p_T}}{\frac{x_T}{p_T}} \tag{1}$$

where x_i is the cumulative diffusion rate of each country at time t, and x_T is the total penetration of the countries considered, in the same time period, in terms of subscribers. Furthermore, p_i is the population of each country and p_T is the total population across all of the countries.

In addition to the above calculations, the width of $RP_{(i,t)}$ in each quarter term is calculated, according to Eq. (2).

$$\Delta(RP_{i,t}) = RP_{\max,t} - RP_{\min,t} \tag{2}$$

Further analysis includes the forecasting of the future values of $\Delta(RP_{(i,t)})$, which describes the future process of digital convergence. The corresponding results for both the estimated and the forecasted values of $\Delta(RP_{(i,t)})$ are plotted against time, in order to provide an estimation regarding the time of full convergence. Forecasting is based on appropriate mathematical functions originated from two representative function families, the exponential and the polynomial. These functions are able to estimate the process of the *RP* width and provide accurate forecasts, regarding the digital divide convergence.

4. Evaluation results

According to the proposed methodology described in the previous section, the results illustrated in Fig. 2 indicate that the digital divide gap indeed declines.

The calculated $RP_{(i,t)}$ values for all the European countries considered tend toward zero, which means that countries tend to equally contribute to the total broadband diffusion in Europe. It is also obvious that broadband adoption differs substantially across European countries. Countries that lay above the *X*-axis tend to increase their penetration rate faster than countries which appear below. During the first quarter term taken into consideration, September 2001, the majority of the considered countries had the same level of broadband diffusion which was less than 4% across the population. However, some countries exploit the opportunities offered through the Internet more efficiently. The development of the necessary infrastructure for broadband provision gave advantages in countries that

Table 1
R-squared, RSS, MSE and MAE of two chosen mathematical functions.

Model	R^2	RSS	MSE	MAE
Polynomial	0.957	1.07	0.032	0.13
Exponential	0.977	0.58	0.018	0.09

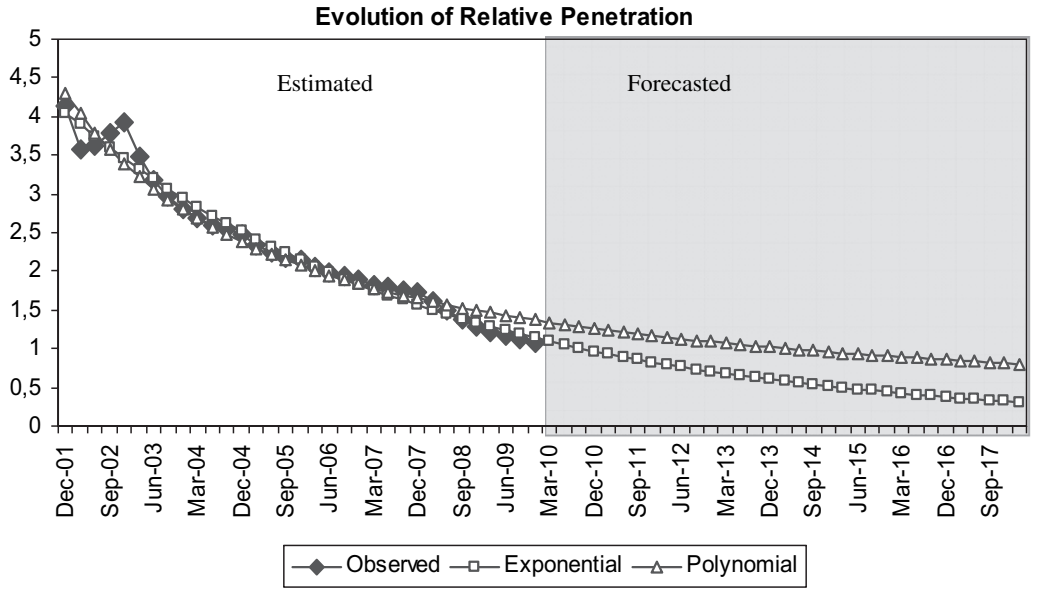

Fig. 3. Evolution of relative penetration over time. The white portion refers to the estimated values and the gray to the forecasted.

invested in the required networks. However, although the time lag of this situation is an interesting aspect to study, it is beyond the scope of the present work.

Apart from the estimation of the relative penetration, $\Delta(RP_{(i,t)})$ is also calculated, in order to examine the process of convergence of this width. Two mathematical functions are used in order to provide reliable results, regarding the future progress of this process, described by the following equations:

$$P = \frac{1}{\alpha + \beta * x} \tag{3}$$

$$E = \exp(\alpha + \beta * x) \tag{4}$$

The statistical accuracy of these functions (Eqs. (3) and (4)) is based on the *R*-squared (R^2), the Mean Square Error (MSE) and the Mean Absolute Error (MAE). The Residual Sum of Squares (RSS) is also calculated. The threshold for R^2 to be accepted is set to 95%, whereas respective values for MSE and MAE are set to be lower than 0.05. Results are presented in Table 1.

Both functions provide quite acceptable results and therefore can be expected to provide reliable forecasts as well. A visual representation of the above findings is illustrated in the graphs of Fig. 3. According to these graphs, it is obvious that both functions provide accurate fittings for the actual observed values.

The plots of the approximate findings that forecast the digital divide convergence are presented in Fig. 3. The polynomial function seems to be more pessimistic, as the corresponding plot tends to keep an almost constant distance from zero, whereas the exponential function tends to be closer to the *X*-axis. However, both forecasts imply that European countries will come closer, in terms of broadband diffusion. Thus, based on the exponential model, the homogenization is expected to be met after the 67th quarter, which coincides not before the first quarter of 2018. Of course, this result reflects the current dynamics of the system, based on the level of influence of the factors that affect the process, which leads to huge differentiation in broadband penetration rates among countries.

Beyond the differences in broadband penetration, the considered countries have significant differences in social, economical and technological conditions as well. For example, in December 2009, which is the last quarter term taken into account in this research, the leading country, Denmark, had a diffusion level of 36.7%. At the same time the last country, Bulgaria, had reached only 10.1%. Both percentages reflect broadband penetration rate across the population. On the other hand, in 2009, GDP for Denmark was about 27.7K euros, while in Bulgaria it was 10.7K euros. Though, the diffusion and the convergence process should be regarded as a part of the general inequality constraints.

5. Conclusions and future directions

The main focus of this research was to outline the process of digital divide convergence to develop a methodology for mathematically describing this phenomena. This methodology was developed based upon the calculation of the relative penetration, which was estimated as the mean penetration rate of the countries studied in proportion to each country's penetration rate. For this purpose, this work utilizes an updated dataset from 2001 to 2009. The results correlate with the findings of the literature regarding the evolution of broadband diffusion validating the methodology developed [33,34].

Apart from the estimation of the process of digital divide convergence, forecasted estimates regarding the time of full convergence were also provided. According to the results, full convergence among the countries

considered is expected in 2018 under the stated conditions. However, this research considered countries with largely varied levels of maturity in terms of broadband diffusion. Thus, it is quite possible to come up with different results if the countries considered were clustered into subsets based on the level of broadband penetration. The methodology developed provides a basis for alternative phenomenological analysis which could incorporate other conditions.

As the digital divide gap convergence remains an open problem there are many issues for further research. Extensions of the proposed methodology include the study of the process of digital convergence at a micro, instead of the macro level presented in this work. To achieve this, the main factors that affect broadband diffusion on a micro-economic level should be more accurately described mathematically. These factors could include economic, social or technological measurements and may even include business factors such as marketing analysis and impact. Analysis could be performed by measuring the efficiency of broadband adoption, in the form of an output-to-input ratio. In this way useful information and additional opportunities for collaboration between analysts and decision-makers could be revealed. Importantly, this type of methodology helps decision-makers understand the process and relative timing of convergence under specified conditions.

Appendix

The European countries considered for evaluation are presented in Table 2, in a decreasing order according to broadband penetration rate in December 2009.

Table 2
Countries' ranking based on broadband penetration rate of the fourth quarter-term (Q4) 2009.

Rank	Country	Rank	Country
1	Denmark	15	Spain
2	Netherlands	16	Slovenia
3	Norway	17	Ireland
4	Switzerland	18	Hungary
5	Iceland	19	Italy
6	Sweden	20	Latvia
7	Finland	21	Czech Republic
8	United Kingdom	22	Portugal
9	Belgium	23	Greece
10	France	24	Romania
11	Germany	25	Croatia
12	Estonia	26	Poland
13	Lithuania	27	Slovakia
14	Austria	28	Bulgaria

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