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Driving factors during the different stages of broadband diffusion: A non-parametric approach

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ABSTRACT

A number of socio-economic factors influence broadband diffusion and are assumed to be responsible for the different levels of adoption among countries. Most of the approaches met in literature do not take into account the different stages of the diffusion process and they are parametric. They are based on the construction and study of econometric models, which include all the influential parameters. Regression functions are defined prior to the analysis and they are usually linear in nature. However, this increases the complexity of the system, since the less influential variables are derived during the final stages of the analysis. On the contrary, non-parametric methods can achieve dimension reduction during the early stages, while they do not require a definition of the regression function.

The present work studies the effect of a wide range of social, economic and political factors over the broadband diffusion process, following a non-parametric approach and comparing the results with these of the parametric. Based on criteria from information theory the link function between the level of penetration and the rest variables is derived, providing highly accurate results. The evaluation of the methodology was performed over countries from the wider European area. It is proven that the different stages of broadband diffusion process, defined by the inflection point, are affected by different factors.

1. Introduction

The level of broadband diffusion is considered as an important indicator for a country, related directly to its development, due to the varied capabilities offered by the information and communications technologies [1]. In the area of the European Union (EU) the different levels of broadband penetration among member countries raise entrepreneur and political considerations. The main obstacle for a wider and faster broadband adoption used to be the lack of infrastructures or the limitation of transmission data traffic [2]. EU noticed this necessity and decided to subsidize initiatives regarding the deployment of broadband infrastructures [3], since infrastructures' competition enhances broadband development [4]. A number of studies were published during the last years, aiming to understand the development of broadband adoption by revealing common influential factors [5]. The initial purpose of these researches was the evaluation of the forecasting approach [6–9]. Forecasting methodologies were also used in order to estimate digital divide convergence among countries. As EU declared an "information society for all" through policy framework adopting in June 2005 [3], digital convergence became one of the main issues of relevant studies [10].

In line with the early studies regarding the factors fuelling broadband demand among and within countries, a number of social, economic, demographical and other factors have been extensively studied in literature. These factors are considered as the driving determinants of the broadband diffusion process. Depending on the factors in each examined case, results provide useful information to telecom operators and to policy makers for a more effective strategy deployment. Apart from the identification of the most important determinants, the usage of different statistical analyses and tools could lead to different conclusions as well.

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In addition, results provided by different studies are affected by the time that the corresponding research took place. Due to the dynamic nature of the broadband diffusion process these results usually reflect only the present situation. Furthermore, results are depending on the geographic areas considered in each study. Thus, an obvious digital gap is identified among OECD and European Union member countries, in terms of broadband penetration rate. Despite the renew Lisbon strategy, stated in 2007 and aiming for 30% broadband penetration in EU until 2010, a digital gap among member states still exists [11,12]. Apart from the level of penetration, differences among countries include, but are not limited to, prices, availability and broadband connection speeds.

The contribution of this work is, firstly, to use a non-parametric regression in order to identify the a priori unknown nature of the relation between the dependent and the independent variable. Secondly is to assume that the influence of socio-economic factors (independent variables) over broadband diffusion (dependent variable) differs during the two main stages of the diffusion process.

Most of the studies regarding the estimation of broadband diffusion are usually based on an econometric analysis, aiming to relate diffusion with a number of external factors which are assumed to affect it. The corresponding econometric models are mainly linear in nature, incorporating either the values of the variables or their logarithms. However, this assumption does not always hold since in many cases the linear relation between the dependent and the independent variables is not the most appropriate to describe their dependence, in terms of estimation accuracy. These cases are better to be described by other functional forms, such as exponential or sinusoid. A very useful tool for identifying the nature of their relation is a non-parametric method. Non-parametric methods do not require the prior knowledge of the econometric model; the regression function is constructed during a later step of the analysis. Another benefit of the non-parametric approach is the identification of the less influential variables, which are excluded from further consideration. The procedure is known as “dimension reduction” and is performed during the early stages of evaluation of the methodology. This is in contrast to the conventional econometric method, where possible variable elimination occurs at a final step, according to the derived results.

In addition to the above, most of the analyses focus on describing the total response of the independent over the dependent variables. For this, they use the available dataset as a whole when evaluating the econometric model. Nevertheless, there is quite often the case that the data must be clustered, in order to reveal the peculiarities of particular segments and allow important information to be derived. The main assumption of this work is that the different stages of the broadband diffusion process are affected by different factors. Therefore, instead of using the whole data to describe the influence of the socio-economic variables over broadband diffusion, the data are appropriately divided into two groups and two separate analyses are consequently performed. Data segmentation is performed according to the inflection point of the diffusion process in each country. The data used in the analysis describe the European area, aiming to build a methodology which consists of two steps.

The first step corresponds to the development of a non-parametric approach aiming to study the driving factors of broadband diffusion in each stage of the process. In addition to this, dimension reduction is performed, based on sliced inverse regression — SIR [13].

During the second step, results of the influential variables are evaluated based on appropriate statistical measures. Hence, the validation of the accuracy of the proposed dimension reduction is provided, without the regression model being specified yet. In order to identify the models that better describe the diffusion process, local polynomial regression (LPR) has been used. Based on criteria from the information theory, such as the Akaike information criterion (AIC) [14] and the Bayesian information criterion (BIC) [15] the best model has been chosen.

The present analysis is based on a large dataset consisting of statistics over a number of European countries. The participating variables were considered over a prolonged period of time. In addition, the study is conducted at the macro level which means that results do not reflect specific countries' behavior but the total response. Moreover, separation of the dataset into two groups is performed based on the inflection point (IP) of the broadband diffusion process in each country. IP provides a crucial turning point in the evolution of diffusion. Before that point, the parameters affecting broadband penetration are expected to be different from those after IP, mainly because of the fact that the maturity level is changing. Besides, it seems that different regression models could be more suitable for describing, in terms of accuracy, the process during its different stages. Estimation of the IP of each country is based on the non-symmetric Gompertz model [16] and the process is described later in this paper.

Finally, in order to boost the selection of non-parametric approach, parametric regression was also conducted in this work, allowing the comparison of results. In the following sections the appropriate theoretical framework is presented, together with the development of the methodology.

2. Background

There are mainly two approaches used regarding the study of the driving factors of broadband adoption. They correspond to either regression analysis based on statistical data or surveys' outputs based on questionnaires [17].

Most of the existing studies are associated with the OECD countries, probably due to the availability of data. The main categories of derived statistics are based on social, economic, political, demographical and technological factors [18]. Such kind of data is used in a number of studies in order to measure the digital divide [19] or to rank countries according to their broadband performance [20]. Zupan [21] forecasted the maturity of electronic commerce in Slovenia and predicted a rapid growth in the following years, which is directly related to the corresponding broadband penetration rate. Furthermore, new indexes measuring broadband in terms of performance, efficiency and adoption level are suggested [22,23]. Nevertheless, indexes are also developed for policy usage, mainly taking into account liberalization and competition levels [24]. An extensive study was also performed by