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A multiple indicator model for panel data: An application to ICT area-level variation

Eva Ventura [a,b,*], Albert Satorra [a,b]

[a] Department of Economics and Business, Universitat Pompeu Fabra, Spain
[b] Barcelona GSE, Spain

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ABSTRACT

Consider the case in which we have data from repeated surveys covering several geographic areas, and our goal is to characterize these areas on a latent trait that underlies multiple indicators. This characterization occurs, for example, in surveys of information and communication technologies (ICT) conducted by statistical agencies, the objective of which is to assess the level of ICT in each area and its variation over time. It is often of interest to evaluate the impact of area-specific covariates on the ICT level of the area. This paper develops a methodology based on structural equations models (SEMs) that allows not only the ability to estimate the level of the latent trait in each of the areas (building an ICT index) but also to assess the variation of this index in time, as well as its association with the area-specific covariates. The methodology is illustrated using the ICT annual survey data collected in the Spanish region of Catalonia for the years 2008–2011.

1. Introduction

Previous studies have established that the widespread use of information and communications technologies (ICT) increases productivity and boosts the economic growth of territories. These technologies contribute to the improvement of productivity resulting from the adoption of more efficient business processes. Also, intensive use of ICT by the population contributes to further stimulate the economy through the introduction of new applications and services (see for instance Crandall, Lehr, & Litan, 2007; Garbacz & Thompson, 2008; Qiang & Rosotto, 2009). Thus given that ICT constitute a powerful tool to enhance economic performance, policy makers are concerned about narrowing (ideally eliminating) the inequalities of access to and use of ICT across the territory as a means of achieving economic and social convergence.

Statistical offices worldwide invest resources in surveys to ascertain the levels of information and communication technology (ICT) activity in the population. Often the aim is to inspect the levels of ICT in different geographical areas rather than the levels of ICT of individuals. It is therefore necessary to measure the level of ICT activity for each area and to monitor the area and time variation. In addition, it is important to investigate which elements are responsible for the observed differences in ICT activity across areas. That information will be valuable in order to design better policy interventions aimed for instance at enhancing ICT activity in some lagging areas.

Many authors have studied the so-called digital divide across countries or regions. A commonly accepted definition of the term "digital divide" is provided by the OECD (2001). According to this organization, "the term digital divide refers to the gap between

* Corresponding author at: Department of Economics and Business, Universitat Pompeu Fabra, Spain.
E-mail addresses: eva.ventura@upf.edu (E. Ventura), albert.satorra@upf.edu (A. Satorra).

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individuals, households, businesses and geographical areas at different socioeconomic levels with regard to their opportunities to access information and communication technologies and to their use of the Internet for a variety of activities". The digital divide is thus, in nature, a multidimensional concept. In a recent paper, Vicente and López (2011) identify two main types of contribution to the literature of the digital divide. The first type focuses on "measuring and quantifying the extent, evolution, and pace of the digital divide", while the second tries to explain "the determinants of ICT disparities". There are a considerable number of studies that examine the relationship between the ICT disparities and several socioeconomic characteristics at the cross-country, regional and even the individual level. Interested readers may consult the work of Vicente and López (2011) for a complete overview. Echoing their work and regarding the measurement issue, there have been many attempts to build composite indices capable of capturing the "multidimensionality of the digital divide" (Al-Mutawkkil, Hesmati, & Hwang, 2009, Bagchi, 2005; Corrocher & Ordanini, 2002; Cruz-Jesús, Oliveira, & Bacao, 2012; Dutta & Jain, 2004; ITU, 2009; Orbicom, 2003; Selhofer & Hüsing, 2002; Wolcott, Press, McHenry, Goodman, & Foster, 2001). Simple compound indices based on the arbitrary weighting of several indicators present certain disadvantages. New technologies are continuously emerging and have to be incorporated into the calculation of the index. Therefore, it is necessary to constantly update both the definition of the index as well as the weights used to calculate it. On the other hand, the weights are arbitrary and "could be the subject of political dispute" (Cruz-Jesús et al., 2012). Thus, a number of these studies rely on exploratory factor analysis to select the weights applied to a number of indicators to produce a single composite index (Al-Mutawkkil et al., 2009; Corrocher & Ordanini, 2002; Cruz-Jesús et al., 2012; Hanafizadeh, Saghaei, & Hanafizadeh, 2009; ITU, 2009; Soupizet, 2004; Vicente & López, 2011). Other authors use multivariate techniques such as multivariate analysis, cluster analysis and discriminant analysis to "explore the digital divide among old, new and candidate member states of the European Union" (Çilan, Bolat, & Coşkun, 2009; Cruz-Jesús et al., 2012). In this line, Vehovar, Sicherl, Hüsing, and Dolnicar (2006) argue that the multivariate approaches such as loglinear modeling, compound measures and time–distance methodology used to analyze the changes in the digital divide are a better alternative to "an oversimplified methodological approach to digital divide studies".

Much of the work performed on measuring and explaining the digital divide has been performed at the cross-country level. Research at the regional level has been conducted in large part for the United States (Atkinson & Andes, 2008; Chaudhuri, Flamm, & Horrigan, 2005; Grubesic, 2006; Horrigan, Stolp, & Wilson, 2006; Kolko, 2000; Mills & Whitacre, 2003; Progressive Policy Institute, 2002; US Department of Commerce, 2000); the European references are fewer (Billón, Ezcurra, & Lera-López, 2008, 2009; Vicente & López, 2007, 2011). There are a few studies that use microdata to determine the urban/rural digital gap (Chaudhuri et al., 2005; Mills & Whitacre, 2003; Noce & McKeown, 2008; US Department of Commerce, 2000), and others that use the individual and regional characteristics to explain the digital divide (Demoussis & Giannakopoulos, 2006; Horrigan et al., 2006; Schleife, 2010; or Cerno and Pérez-Amaral (2008) for Spanish data).

This paper presents a methodology that integrates in a single model both the measurement of the ICT activity for each area in each period, as well as the association of the ICT activity with the area-specific covariates. As we have already mentioned, the idea of an index based on factor analysis is not new. The approach in this paper is unique because the confirmatory factor analysis replaces the principal components approach. This permits us to assess the dimensionality of the index and to study its evolution in time for each of the areas. The geographical areas are meant to be the territories that differ in the level of contingency of several factors that we feel explain the digital gap among the areas. In previous works based on the principal components and exploratory factor models, the estimated factors are regressed into a series of explanatory variables to determine what may cause the differences among the regions or countries (see, for instance, Vicente & López, 2011). In contrast to this two-stage approach (fitting first an exploratory factor model for each year and then applying a regression to the extracted factors), our methodology considers the single-stage analysis for which the level of ICT activity is estimated and simultaneously regressed on the covariates. This single-stage approach leads to a more consistent and efficient estimation.

To illustrate our methodology, we use the ICT data collected in the administrative areas of the Spanish region of Catalonia. The Statistics Institute of Catalonia (Idescat) conducts repeated household surveys with the aim of ascertaining the time variation in the ICT at the area level. We combine several survey questions to produce a set of indicators representing the ICT activity at the individual level. These variables are then aggregated within each area to produce the indicators of the ICT activity at the area level.

The rest of the paper is organized as follows. Section 2 describes the data to be used. A confirmatory factor analysis with one factor for each year is developed in Section 3. Section 4 presents a multiple indicators dynamic panel data model whereby the factors are decomposed into a permanent and a time-varying component and related to the covariates. Section 5 presents the conclusions.

2. Data and construction of indicators

In this application, we use a household survey on the ICT conducted by the Idescat. The survey is a rotating panel, with five shifts of rotation on an annual basis. Here, we use four consecutive surveys, from 2008 to 2011.[1] The sample design is by means of a stratified two-stage sample. The strata are 41 Catalan administrative divisions, and the sample is uniformly distributed among them with 75 randomly-selected first-stage units (dwellings) in each administrative division. Within each dwelling, the second-stage unit is one person aged 16 or over (also randomly selected).

[1] The survey became biannual after 2011.