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United States digital divide: State level analysis of spatial clustering and multivariate determinants of ICT utilization

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ABSTRACT

This study analyzes factors associated with availability and utilization of information and communication technologies (ICTs) for U.S. states. We construct an exploratory conceptual model of technology utilization in which eight dependent ICT availability and utilization factors are posited to be associated with fourteen independent socio-economic, demographic, innovation, social capital, and societal openness factors. Technology utilization variables are spatially analyzed to determine extent of agglomeration, and regression residuals are examined to eliminate spatial bias. Findings indicate social capital, education, societal openness, urbanization, and ethnicities are significantly associated with ICT utilization. We suggest important implications for policymakers at state and federal levels.

1. Introduction

Information and communication technologies (ICTs) such as computers, the internet, mobile telephones, and fixed-line telephones provide individuals, organizations, and nations with access to information and means to communicate with each other. Traditional ICTs along with innovative social media technologies such as Facebook and Twitter have changed the landscape of information processing and communication. ICTs have been recognized to have seminal impact on social and economic development. Despite the tremendous growth in ICT availability and utilization in recent years, differences persist among nations, states, and cities. This inequality in ICT availability, access, and utilization is sometimes termed the Digital Divide. OECD [45] defines digital divide as "the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies and to their use of the Internet for a wide variety of activities." Differences in ICT adoption and usage vary due to social, economic, and political factors, and they also vary geographically. The possession of ICT access at a high level has been viewed by the United Nations and other observers as a basic human right [73].

In this study, we focus on the digital divide in the United States, the subject of several previous studies [1,2,7,8,24,44,54,70]. According to the International Telecommunication Union (ITU), the United States ranks seventeenth among 157 nations worldwide in 2012 in terms of the ICT Development Index (IDI) which combines 11 indicators into one single measure to track progress made in ICT access, use and skills, and includes indicators such as the number of fixed- and mobile-broadband Internet subscriptions, households with a computer, and literacy rates [31]. The U.S. ranks below other developed and heavily industrialized economies such as the United Kingdom, South Korea, and Japan, and nations such as Sweden, Denmark, Iceland, Switzerland, and Singapore, but ranks slightly above nations such as Germany and France. Given that the United States is a large and increasingly diverse nation in terms of social, political, economic, and demographic attributes, it is expected that ICT adoption and utilization among the U.S. states will vary. This motivates our research. Our overall research question is: what factors determine ICT availability and utilization for U.S. states and how do ICT availability and utilization vary geographically.

The goals of this paper are to develop a theory for recent influences on ICT availability and use for the 50 states in the United States; explore the spatial distributions of use of technologies; examine the extent of spatial agglomeration of ICTs; empirically test the theory of social, political, and economic influences on ICTs; and provide policy, planning, and decision-making recommendations to state and national policymakers in the U.S. The following specific research questions will be addressed:

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1. Are geographical patterns of ICT access and use present for the U.S. states as measured by spatial auto-correlation?
2. Is there significant geographic clustering of states based on the access and use of ICTs?
3. What are the associations of socio-economic, demographic, governmental, innovation, and societal openness factors with availability and use of ICTs?
4. Can a regression model of these associations on access and use of ICTs account for the influence of the geographical proximity of states?

The assumptions associated with these questions include the framework that the dependent ICT-access variables that are associated with the independent variables, and not the converse. We are not studying, for instance, how an innovation is associated or related to a set of technology variables. In applying a theoretical model, to be discussed later, we assume that the variables chosen are appropriate to represent the model. Since we utilize OLS regression, we have its standard assumptions, which include that the model is linear, residuals are independent of serial correlation, error distribution is normal, and the errors have homoscedasticity with respect to the predicted values. We test that the independent variables are not subject to multicollinearity. For testing of spatial auto-correlation, we assume that neighboring states have some positive, neutral, or negative influence on each other that can be examined by comparing values of an ICT attribute.

The research has some novel features when compared to existing literature on the digital divide in the US. First, this paper induces a theoretical model of the socio-economic correlates of the digital divide at the state level for the United States. State level models of the digital divide exist for nations such as China, Japan, and India. In the U.S. at the county level [2] and city level, research has been done on socio-economic influences on technology levels and digital divide [21,36]. However at the state level in the U.S., a systematic nationwide study of the digital divide and its correlates and geographical influences does not exist.

While the state is certainly not the smallest geographic unit for the United States, examining gaps in ICT adoption and usage at the state level is important since U.S. states possess the authority to develop their own digital policy and shape ICT adoption, consumption, and usage within their boundaries. A contribution of this study is the use of spatial analysis and mapping methods to supplement traditional multivariate analysis. We exploit the visualization capability of a geographic information system (GIS) to develop descriptive understanding of technology adoption patterns, otherwise difficult to discern from numerical tables, and identify clusters of high utilization and low utilization states. We further use a GIS quantitatively to analyze the geographic patterns and extent of spatial agglomeration of technology levels. In addition, the regression residuals are evaluated for spatial autocorrelation to determine if a regression model does not account for geographic associations, in which case regression findings that are geographically biased are treated with caution. The study provides theoretical, empirical, and methodological advances that are relevant to quantitative socio-economic and planning science researchers, government and business practitioners, and to U.S. federal and state IT policymakers.

The remainder of this paper is arranged into sections on review of prior literature on digital divide, conceptual model and its justification, research questions, methodology, exploratory analysis of geographical patterns of technology levels, regression analysis findings, discussion and policy recommendations, limitations, and concluding remarks.

2. Literature review

Digital divide differences have been studied for nations worldwide [3,27,49,50,57,85], states/provinces/economic areas within nations [2,43,50,52,80], Europe as a region comparable to the U.S [28,29,35,37,80], individuals within nations [44], and cities [21,36]. Studies have consistently found differences in use of information technologies at these units of analysis. Theories and models have been posited to account for the technological differences [17,18,50,58,63,77], but so far there is a lack of well-accepted theoretical models that have received widespread support by researchers.

One recognized theoretical framework, the Networked Readiness Index (NWI), considers the four major sub-index factors of environment, readiness, usage, and impacts that influence networked readiness [17,18], yet the framework has been little cited in academic studies. Each sub-index in turn consists of 2 or 3 "pillars," each defined by multiple variables. Its shortcomings for digital divide research are that it is classificatory and does not postulate relationships between variables, its base of over 50 variables is cumbersome for many quantitative models, its choices of variables and sub-indexes are not validated, and its component variables are changed over time [18]. Furthermore, the NWI is readily calculated with data available for nations, but much of those data would not be systematically collected at the sub-national level, such as states or provinces. With prominent support from the World Economic Forum, NWI is visible and in use by some national governments and businesses, but its slight acceptance by researchers reflects some difficulties in applying it to quantitative models and in procuring its data below the national level.

A second recognized theoretical model, adoption/diffusion theory [58], provides detailed explanations of how technologies are adopted and diffused. The model posits how, over time, an innovation is diffused, with support from concomitant communication channels and change agent(s). In digital divide research, it has the drawback that it concentrates on innovative rather than accepted technologies, does not inform on why an innovation is diffusing, does not provide the basis for determining correlates of levels of ICT use, and is designed for longitudinal rather than cross-sectional analysis. It does mention geographical diffusion of innovations, but does not provide theoretical support for spatial autocorrelation or cluster analysis. Its limited acceptance for digital divide studies stems from fairly narrow focus on an innovation being adopted and diffused over time, rather than on comparative levels and correlates of the full spectrum of accepted technologies through innovative ones.

A third recognized theoretical model of digital technology access [76,77] centers on four means of access to ICTs: motivational access, material or physical access, skills access, and usage access. Gradually, its focus is shifting from the first two to skills and usage. Access is included in a broader circular causal model that starts with personal characteristics leading to resources; then to access; then to participation in society; economy, and institutions; then to positional characteristics of education, household, nation; and finally back to resources [76].

Although van Dijk's elaborate theory is known in Europe especially for understanding the digital society, it has not been widely accepted for digital divide research due to several shortcomings including: (1) the circular model shifts between units of analysis, so it becomes hard to operationalize, (2) the model is highly complex, with about 30 sub-entities, which although rich, are challenging to apply quantitatively; (3) it does not include the well-known digital divide factors of societal openness, participation, and social capital; (4) geography is not a key part of the model.

However, there is a body of empirical literature that strives to explain influences on access, adoption, and use of technologies. It is