Information Technology Availability and Use in the United States: A Multivariate and Geospatial Analysis by State

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Abstract

Exploratory empirical studies of the digital divide exist for various nations including the United States. The contribution of this paper is to enhance understanding of factors associated with availability and utilization of information and communication technologies (ICTs) at the state level in the US. In our conceptual model of technology utilization, eight dependent technology availability and utilization factors are posited to be associated with twelve independent socio-economic, demographic, innovation, and societal openness factors. Technology utilization variables are spatially analyzed to determine extent of agglomeration or randomness, and regression residuals are examined to eliminate spatial bias. We find that societal openness, urbanization, and ethnicities are significantly associated with higher ICT utilization. We report interesting findings for social media communication technologies of Facebook and Twitter. Implications for policymakers at both federal and state levels are discussed.

1. Introduction

Inequality in ICT availability, access, and utilization is sometimes termed as the Digital Divide. Digital divide has been defined in [31] 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 need.

In this study, we focus on the digital divide in the United States, the subject of several previous studies [1,2,30]. Our overall research question is: what factors determine ICT adoption and utilization for US states and how do ICT adoption and utilization vary geographically.

The goals of this paper are to induce a conceptual model that examines recent influences on ICTs for the 50 states in the United States, explore the spatial distributions of use of technologies, examine the extent spatial agglomeration of ICTs, and empirically test the conceptual model. The following specific research questions will be addressed:

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, political, demographic, innovation, and societal openness factors with access 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 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 [38], Japan [29], and India [37]; and county-level [2] and city-level [16,25] studies of socio-economic influences on technology levels and digital divide exist for the US. However a systematic nationwide study of the digital divide and its correlates at the state level does not exist for the US, the world's largest economy and information society.

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 US states possess authority to develop their own digital policy and shape ICT adoption, consumption, and usage in its regions. Another contribution 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 and identify clusters of high utilization and low utilization states. We further use a GIS to

978-1-4799-2504-9/14 $31.00 © 2014 IEEE
DOI 10.1109/HICSS.2014.411

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quantitatively analyze the geographic patterns and extent of spatial autocorrelation error in studying the nation's digital divide. In addition, the regression residuals are evaluated for spatial autocorrelation in order to examine geographical similarities and outliers in technology levels for states and exclude regression findings that are geographically biased. The study provides theoretical, empirical, and methodological advances that are relevant to IS and systems sciences researchers and practitioners, and to state IT planners and policymakers.

The remainder of this paper is arranged into sections on review of prior literature, conceptual model, methodology, findings, discussion and implications, and concluding remarks.

2. Literature Review

Digital divide differences have been studied for nations worldwide [4,21.29,34,35,40,53], states/provinces/economic areas within nations [29,37,38,50], individuals within nations [30], and cities [16,25]. 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 differences [12,35,44], but so far there is a lack of theoretical models that have received widespread support by researchers. One framework, "the networked readiness index," advocated for the world by the World Economic Forum, considers three major factors of environment, readiness, and usage that influence ICT readiness [12], yet that model has been little cited in academic studies. Adoption/diffusion theory [41] provides detailed explanations of how technologies are adopted and diffused, but it has had limited application in the digital divide literature.

However, there is a significant empirical literature developed that strives to explain influences on access, adoption, and use of technologies. It is sometimes atheoretical and at other times utilizes a wide variety of theories that include social reproduction theories [1,6,25] and the framework of institutional factors in technology utilization and innovation [24]. The empirical findings for nations and states/provinces have identified significant relationships of utilization of information technologies with factors of education, age structure, economic forces, democracy, and innovation.

For the United States, studies have examined a variety of digital divide questions based on national and regional surveys of individuals and households [6,45], as well as studies at the county [2], selected city [25], selected state [3], and national [20] levels. In addition, multi-national comparative studies of the digital divide [7,9,32,49] have often included the United States.

A fine-tuned analysis of social capital and its role in shaping the digital divide [6] concluded that education, geographic location, and generation of birth (i.e., age) are consistently evident in access, general use, and online communication using the Internet in the US. The same study further noted that rural residents' access and use the Internet the least compared to their urban and suburban peers. Overall, [6] argues that digital have-nots are often on the wrong side of social inequalities. The findings of [6] are corroborated by [25] which used a case study of two US cities in the state of Georgia to contend that the digital divide will persist in the absence of remediation of social, economic, and locational inequities.

The spatial distribution of broadband for the entire US in 2004 at the zip code unit of analysis was studied in [20]; this study is notable for its use of Geographic Information Systems (GIS) for mapping broadband providers, broadband core and periphery, as well as islands of broadband availability and inequity nationwide. Insights about underlying spatial phenomena were provided by estimating measures of spatial autocorrelation within a GIS for islands of broadband availability and inequity. The emphasis on geography/location among the main aspects of the digital divide [6,20,25] justifies our use of GIS-based analysis (clustering and spatial association) of the dependent variables.

Important determinants of ICT adoption and utilization from prior studies are urban, Asian ethnicity, labor force, college education, higher education government funding, R&D, newspaper, magazine, and book publishers, and societal openness. Urban location has been related to technology utilization for Japanese prefectures [29], and regions of China [17]. In the U.S., online communication was associated with urban location [6], while broadband was shown to be most heavily concentrated in metropolitan and urban regions [20]. Broadband availability and competition were shown to be related to Asian population in U.S. core and peripheral areas [20], although another study found inverse association of online households and Asian ethnicity in metropolitan areas [1].

For labor force, in U.S. counties payroll and receipts for most technology sectors studied were related to professional and service labor force [2], while for Japanese prefectures, ratio of working age to total population related to internet use and mobile phone subscriptions [29]. In China, employment in the market economy (non-state-owned units) was associated with internet and PC use [38]. College education is a well-known correlate of technological utilization and accessibility for states/provinces and nations [1.6,29,32,37,49,50,53]. Explanations include that more educated people understand technology better and have greater occupational use for it. Higher education government funding was associated with PCs, ICT expenditure and ICT infrastructure for a sample of 72 nations [34]. It has not previously been studied for U.S. states or counties. We reason that it constitutes intermediate support in a state for education improvement, which is widely confirmed as a technology correlate. Innovation and R&D are known correlates of technology utilization in the U.S. [2], Japan [29], Asia [39], and worldwide especially in developed nations [36]. A reason is that localities with many enterprises and people engaged in R&D tend to need and use ICT.

In studies of China [38], India [37], and Japan [29], newspaper, magazine, and book publishing have been significantly related to a variety of technology utilization indicators. This is because the distribution of information represents a more open society related to great internet connectivity and that localities with high publishing also have high web content generation. For China and India, tests showed that the largest metropolis had by far the greatest influence on this relationship [37,38]. Societal openness as measured by indicators of freedom and democracy has been a significant correlate of technology use [4,21,34,40,53]. This is intuitive: free, democratic, and law-abiding social entities tend to electronically exchange more information and ideas.

Overall, it is evident that while digital divide studies for the United States at the national level or for selected cities, counties, or states exist and many technology determinants are known for nations, states, and provinces, a systematic examination of social, political and demographic influences on technology differences and geographical patterns at the U.S. state level is missing in the literature. Our research attempts to fill this gap.

3. Conceptual Model

Models of influences on technology access, adoption, and use at the level of nations and states/provinces have included a variety of factors. A study, based on U.S. individual and household characteristics, posited that individual internet use in metropolitan areas is influenced by the internet use of people in geographic proximity; that people in segregated ethnic enclaves will have similar online use patterns typical of the ethnic group; and that housing density and people's socializing interactions will moderate online use [1]. Accordingly, individual internet use for a metropolitan area is predicted based on income, education, age structure, and families with children.

Use and accessibility of ICTs in Chinese provinces and Indian states have been related to social, economic, and political characteristics, which included education, fixed-asset investment, private sector employment, cooperative society membership, exports, infrastructure, publishing, science/education/cultural expenditures, and innovation [37,38]. This relationship was screened for spatial randomness, so the effects of geographic proximities are implicit within valid model findings, rather than external. A study of 164 EU subnational regions proposed a model to assess the influence of GDP, unemployment, science/technology resources, population density, age, services employment on an ICT factor determined by factor analysis of three internet variables, non-use of computer, and people who ordered personal good/services online [50]. The model is also controlled by variables of Nordic/non-Nordic region and Native-English-speaking/non-native English speaking.

Based on these prior studies, a conceptual model of ICT utilization and availability for U.S. states, seen in Figure 1, is posited in which demographic, economic, educational, government-support, innovation, and societal openness factors are related to each of eight technology utilization and availability factors. The relationships are screened for spatial proximities. Model relationships which result in spatially random errors are regarded as valid. If errors in a relationship are spatially auto-correlated, it implies that the geographic forces are exogenous to the conceptual model [26]. Throughout the U.S., metropolitan clusters of high and low intensities of technology use have been observed [11,16], which further justifies the inclusion of screening by ICT levels for geographic proximities.

The literature that justifies inclusion of particular independent variables was detailed in the literature review section. Income, that has been significant in many prior digital divide studies was excluded due to multi-collinearity, in particular college education per capita and median household income are highly correlated (Pearson correlation = 0.693 (significance level less than 0.001)). Average age was excluded because of its scarce appearance in the prior literature.

The eight *Technology utilization and availability outcome factors* are % of persons with desktop/laptop in household, % of persons with internet access at home, % of households with broadband adoption, % of persons in cellphone-only households, mobile wireless high-speed devices per capita, % of persons in fixed-phone only households, Facebook users per capita, and Twitter users per capita. They are justified by their inclusion in many prior studies (among others, [3,5,7,10,11,12,13,14,16,34]).

4. Methodology

Different sources of data were used to obtain values of various dependent and independent variables. Among independents, variables such as population and employment estimates, demographics such as education and income, economic variables such as gross state product, publication estimates such as annual sales revenue of book publishers, and crucial innovation related variables such as research and development estimates by state, and patents awarded by state were obtained from a variety of federal government sources such as the US Census Bureau's Population Census [48] and American Community Survey (ACS), Bureau of Economic Analysis (BEA), and the National Science Foundation (NSF) [28]. Variables related to societal openness were obtained from two sources: a report that estimates freedom indices at the state level in the US based upon combining scores for fiscal, regulatory, and personal freedom [43], and an elections performance index [33] that examines election administration performance across all 50 states and the District of Columbia. Most independent data were obtained for the years 2008 – 2010, although in a couple of instances the sources extended back to the year 2006 to ensure completeness of data for variables such as gross state product and sales revenue estimates of newspapers and periodicals. On the dependent variable side, sources of data included the 2010 U.S. Population Census, and reports from reliable federal sources such as the Federal Communications Commission (FCC) [15], U.S. National Telecommunications and Information Administration (NTIA) [30], and National Center for Health Statistics (NCHS) [5], and trusted independent sources such as Internet World Stats [22] and the DCI Group [10] (for Facebook and Twitter). Most dependent variable estimates were from 2010; in two instances (for mobile wireless devices and subscribers), the most recent complete data were from the year 2008. Most variables were re-estimated on a per capita basis (percentages or per 100 population) and descriptive statistics of all variables were calculated.

Dependent variables are mapped using a geographic information system (GIS). Moran's I statistic [14,20,26] is calculated for a variable's spatial pattern to indicate the extent to which states agglomerate spatially into "hotspots" of states that are high-valued states in ICTs or " low spots" of low-valued states. In other words, we were able to identify overall extent of clustering of states. We measured this by Moran's I statistic, which varies between 1 and -1. Index levels close to zero indicate a random geographic distribution of states, whereas values near +1 indicate like-valued states group together, while -1 indicates a high-valued state is surrounded by a low-valued one, and vice versa. In applying this method, care was taken to resolve contiguity issues for the states of Hawaii and Alaska.

Moran's I statistic is applied first to each dependent variable, in order to judge if that variable is randomly distributed or not, and if not random, whether states are surrounded by similarly-valued spatial neighbors or by differently-valued neighbors. Later in the study, Moran's I is applied to the residuals of the regressions. These findings answer Research Question 4. If the regression model accounts for the geographic forces, then the Moran's I test should be significantly close to 0 (i.e. random). Otherwise, the model does not capture the spatial forces.

A further exploratory method known as K-means cluster analysis is applied to identify groups of states that are most similar based upon all eight technology utilization dependent variables (see Table 2). OLS regression is conducted for the eight dependent variables based upon 12 independent variables [46]. All independent variables are tested for multi-collinearity using the variance-inflation factor to assure that multi-collinearity was not present. The OLS regression diagnostic tests of Joint Wald Statistic [52], Koenker (BP) Statistic, and Jarque-Bera Statistic [42] are applied to evaluate that regression assumptions are met. Moran's I tests if spatial autocorrelation of residuals is non-significant, indicating lack of spatial distribution bias for the residuals. More details about the research methodology employed in this paper can be found in Author [37,38].

5. Results

The presence of agglomeration of states for the eight ICT variables is measured by the Moran's I statistic, and is summarized in Table 1. Findings show that all the dependent variables except Facebook and Twitter have highly significant spatial autocorrelation. We reason the lack of spatial autocorrelation for the social media variables may be due to their appeal to a more youthful user base of consumers that is not limited or bound in its social media use to ICT-intensive geographies. Comparison of the US ICT clusters in 2010 with a similar agglomeration study of ICT in China in 2006-2009 [38] shows that the level of spatial autocorrelation in Chinese provinces is three quarters of that for US states, and half of the US level if the municipalities of Beijing and Shanghai are excluded. The reason the US is more agglomerated is unknown, but we speculate it might be due to China's relatively more centrally planned economy and urban residential and migration restrictions which might lower the potential for provincial ICT agglomeration. In China, web page volume is not spatially agglomerated, which may reflect less government control and prevalence of virtual rather than geographic concentrations of users.

For broadband in the U.S., at the zip code level there is a high level of agglomeration, due in part to socioeconomic and demographic differences [20]. When broadband providers were mapped by zip code, they were predominantly located in the large metropolitan areas. This clustering was confirmed by very high Moran's I values ([20], figure 2).

K-mean cluster analysis reveals distinctive geographical clustering of states, based on all eight dependent variables. Cluster results for selection of 4 clusters are mapped in Figure 2, with characteristics given in Table 2. They are characterized as follows:

Cluster 1. "Selected non-Metropolitan." Technology access/use levels are intermediate. Most of the states are more rural, and are low to medium in their proportion metropolitan.

Cluster 2. "Northeast, California, Hawaii, Alaska." Technology levels are high and resemble Cluster 3. Most states are in the Boston-Washington megalopolis and California, which are regarded politically as "blue states."

Cluster 3. "Western, Sunbelt Cluster." This highest cluster overall in ICT access/use is similar to Cluster 2, but higher in cell-phone-only and fixed-phone-only households, and in Twitter use. It comprises twenty states mostly in the Rocky Mountain region, and some in the upper and western Midwest, as well as Georgia, Maine, and the Sunbelt states of Arizona, Texas, and Florida. The states tend to be large in land area, while only three in are in the East.

Cluster 4. "South, non-Sunbelt states, Indiana, New Mexico." The cluster has the lowest technology access/use levels, with broadband adoption in the home at 57 percent, and computer in the household at 72 percent. These states tend to have lowered educational and income levels, with few large metropolitan areas.

Overall, the cluster analysis identifies four clusters, each internally based on similar ICT characteristics. They are mostly agglomerated as geographical regions. This is expected by Tobler's Law, which states that geographic units that are similar in characteristics will tend to be in proximate locations [26]. The higher technological clusters (2 and 3) tend to be in the Northeast, prosperous Sunbelt states, Pacific Northwest, and Rocky Mountain areas, while the lower technology clusters (1 and 4) are in more rural, mostly interior parts of the country. The conceptual model testing by OLS regression indicates that, for the full sample, societal openness and urban factors are the most important in their association with ICT dependent variables. As seen in Table 3, the societal openness factors of freedom index and election performance index are significant influences on all technology factors except mobile high-speed wireless devices and Twitter users, which are dominated by associations with ethnicities, Asian for the former and Hispanic for the latter. Urban is significant for three of eight technology factors, namely mobile wireless devices, Facebook, and Twitter. Other significant determinants are education, important for cellphone-only, and R&D, positively associated with internet access and inversely associated with and fixed-phone-only households.

Findings meet the OLS diagnostic tests entirely for five of eight regressions, and indicate minor problems for Facebook (Jarque-Bera test significant at 0.5 level) and Twitter (Koenker test significant at 0.5 level). Because in studies of China [38] and India [37], large metropolitan states/provinces had profound impact on findings, another regression test is performed that excludes the eight U.S. states with urban percent at 90 or higher. For the less-urban sample, there are again significant associations for societal openness for 6 of 8 states, although election performance index is the main determinant, versus freedom index for the whole sample. As in the whole sample, for less-urban states, societal openness is the dominant independent group. A striking difference is that ethnicity replaces urban as the second strongest group. Particularly, it is positive for Asian and mixed for Hispanic. Findings were moderate for higher education, R&D, and urban, and strong although mixed for publisher sales.

The diagnostic tests for this sample indicate minor problems are present for 8 percent of tests, namely the Koenker statistic is significant for cellphones and Twitter, so we consider all these findings valid.

In short, the less urban subsample yielded somewhat consistent findings to the full sample, a result which contradicts the large shift in determinants for China and India when heavily metropolitan provinces/states were excluded [37,38].

6. Discussion

The present findings on agglomerated geographical areas of technology utilization are partly supported by prior studies in the literature, yet they also reveal new insights. For the U.S. the clusters are somewhat even in size, ranging from 8 to 20 states each, whereas in China [38] and India [37], there were unique 1-state clusters for high-technology. For instance for China, the Beijing and Shanghai municipalities both stood out as unique clusters, with technology levels 3-fold to 20-fold higher for than the lowest clusters. In contrast, for the U.S., ratios of low to high clusters vary from 1.2 to 1.7. The difference is partially due to Beijing and Shanghai being classified as municipalities, i.e. highly urban, yet Beijing has substantial rural zones within it. More important as a cause is that the U.S. states have more nationwide evenness in ICT use than the Chinese provinces. For India, Delhi stands out as a unique high-technology state, in a cluster by itself, with technology levels 4- to 10-fold higher than the lowest cluster in the north central/northeast part of the country.

This may be partially explained by the fact that unique metropolitan states and provinces in China and India skew the high-low ratios more than for the US ones, even though the US states overall are more agglomerated (as shown earlier). Another reason might be higher economic barriers in provision of technological capacities between U.S. states, including differences in state regulations and taxation barriers, whereas in China the distribution of ICT capacities is more centrally controlled with fewer inter-provincial barriers.

The testing of the model of digital divide in the U.S. indicates the major variable groups associated with higher ICT levels are education and societal openness. For a sample of developing nations, [4] hypothesized that social openness and democracy impact diffusion of mobile phones, internet hosts, internet use and pc use, but the findings supported only limited, mixed effects for civil liberties index and political rights index on internet use. In [21], a democratic political regime was posited to be related to internet use, yet extensive testing for mostly developed nation's demonstrated only slight positive effects for democracy.

In a more convincing study, "political openness" was hypothesized to foster more acceptance of technology since technology stimulates competitiveness [40]. Using a variable on political openness of institutions from the Polity III dataset, the factor consistently was correlated with internet hosts. Correspondingly, for a world sample and for developed nations [35], the factor of societal openness, legal framework, and government support related strongly to a socioeconomic level factor and in turn to technology utilization factor. The first factor comprised the indicators of freedom of press, property rights, and government ICT prioritization. Accordingly, our strong positive findings for societal openness's link with ICTs within the highly developed US correspond to literature that has emphasized developed countries.

In the case of developing nations, for China and India, a constraint at the provincial and state levels is that variables are not available that directly measure leading openness variables such as freedom, democracy, and judicial independence. Nevertheless, for Chinese provinces, number of published books was significant for technology utilization and can be viewed as a proxy for societal openness; however it is tied to Beijing and lost significance when Beijing was excluded [38]. For Indian states, likewise newspapers and periodicals was a leading correlate of technology use, but not when Delhi was excluded [37]. In China, government control of the internet, including often censorship and even closures [27,47] are associated with a society that compared to the U.S. has reduced freedom, civil liberties [18] and judicial independence [13].

In concert with our positive findings that higher education is related to higher ICT use levels, literature has extensively supported the relation of education to levels of ICTs, both at national and state/provincial units of analysis. The inverse relationship of education on fixed-phone-only households reflects that these households tend to trail in educational levels.

Other significant correlates for ICT factors are urban, ethnic, service occupation, and R&D variables. Percent urban is the most important correlate of Facebook users, an effect not present for the other ICTs. Similarly, for Japanese prefectures, proportion farm population reduced Facebook subscriptions [29]. We reason that Facebook is more characteristic of metropolitan and urban areas, where it spreads more rapidly as an innovation.

The positive relationship of Hispanic ethnicity to Twitter use, corresponds to findings for a national sample of U.S. counties in which Latino percent is related to both receipts and payrolls for motion picture-sound, since Twitter use can be considered somewhat as a form of entertainment [2]. The relationship of Asian ethnicity to mobile wireless high-speed devices is supported by a Pew Foundation finding that mobile wireless connectivity of Asian Americans at 77 percent is twenty percent higher than the total U.S. population [47]. The findings are corroborated by studies of the U.S. which discerned that creative and technological activities are more prevalent in ethnically diverse metropolitan areas [16].

The relationship of service occupation employment with Twitter use is consistent with a study of U.S. counties which found that service employment was related to receipts and payrolls of the broadcasting/telecommunications and motion picture-sound industries [2]. The inverse relationship of Facebook use to service employment is unexplained.

Explanations for the less-urban subsample follow these for the whole sample, with two exceptions. The positive correlation of publisher annual sales with Facebook users reflects research on China [38] and India [37], in which publishing was positively associated with web-intensive variables, such as broadband, domain names, and web pages in China; and with broadband, internet, and mobile phone subscribers in India. There is an unexplained inverse relationship of LN of Internet access at home with service occupations.

Returning to our paper's conceptual model, it appears largely robust for the empirical results. For the labor force factors, findings suggest that service labor force is important, whereas construction labor force could be dropped and replaced by knowledge workforce. This may reflect that the 21st century U.S. economy is much more a service and knowledge economy. Likewise, newspaper, magazine and book publishers, important proxies for innovation in prior studies, can be dropped and replaced by an indicator of electronic content.

The exploratory K-means cluster analysis of all eight ICT variables show distinctive agglomerations of states to be evident for the U.S. This is further confirmed by positive, significant measures of spatial autocorrelation for the technology variables, as seen in Table 1.

The model is strongly supported by OLS regression analysis tests, both for the entire country sample (N=50) and less-urban subsample (N=42). Spatial influences are embodied in the model, as seen by the random spatial autocorrelation of the residuals for half of the variables, and only one variable with highly significant spatial autocorrelation. The model's socioeconomic variable groups which are especially associated with the dependent variables are societal openness and education, and are backed by conceptual frameworks and empirical findings in the literature, particularly for developed nations or sub-national units within developed nations. In summary, the conceptual model is strongly supported for U.S. states.

6.1 Implications of the study

State governments are often challenged to develop, sustain, and achieve success with policies for technological development. A notable success is the Georgia Enterprise Technology Services (GETS), which is recognized as a notable statewide policy and program. It led in the state's technology transformation including public-private partnerships, and a $1 billion+ in investment [19]. In our study, Georgia's success is seen in its inclusion in a cluster with other high-technology states, rather than in the low-tech South cluster. To foster technology use and availability, in addition to the policies of very detailed and careful state planning, commitment to invest, and public-private partnerships suggested by the Georgia example, our results support the recommendations that states should (1) invest and support higher education, (2) strive to emphasize freedom, openness, and transparency to the public in the state, (3) emphasize R&D for newer forms of technology, and (4) favor inclusion in technology initiatives of ethnically diverse segments of the population.

A second notable example of public-private relationship is Virginia, a state in which Virginia Information Technologies Agency (VITA) formed in 2003 has worked with outsourcer Northrup-Grumman to upgrade 97 percent of executive branch agencies to a robust, secure, and flexible 21st century infrastructure for ICT services, governance, procurement, emergency response and GIS [8,51]. The path required successfully resolving difficulties with its outsourcer in 2010. Consistent with our findings, Virginia's initiative emphasized R&D and openness of state-related information.

This research also has implications for systems sciences researchers and professionals in emphasizing spatial analysis as a useful tool for state governments and the federal government to understand how states compare with each other; which regional agglomerations are present; what their distinctive characteristics are; and how technology is advancing throughout the U.S. Although this paper focuses on statewide geographies, systems sciences researchers can similarly apply spatial analysis and its theories to study societal changes in technologies and determinants of digital divides for other geographies, such as nations, trade areas, and metropolitan regions, as long as appropriate data are available or could be collected.

7. Conclusion

This research has developed a conceptual model for information technology utilization and availability for the states in the U.S. and tested it. An initial finding is that six ICT variables for desktops/laptops, internet, broadband, cell phones, fixed phones, and mobile wireless devices are highly agglomerated by state in regional clusters, whereas social media variables of Facebook and Twitter are randomly distributed. Subsequent cluster analysis for the combined eight ICT variables reveals four distinctive clusters throughout the country. They are characterized into technology profiles that reveal most states in high-technology clusters, some in a mid-America cluster at intermediate level, and a southern cluster plus New Mexico and Indiana at a low level.

The leading determinants of technology utilization and availability for the full sample are societal openness, followed by urban, R&D, and service occupations. For a less-urban subsample, the determinants are societal openness and ethnicities, followed by education, and publisher sales. Societal openness corresponds to some studies for developed nations, and its prominence in the US may reflect an advanced and very open society. The impact of ethnicity has been little studied, although some researchers have stressed its influence in the U.S. [12,16]. Education is widely known in numerous studies as a correlate of ICT use. Other correlates have been reported in particular studies for other nations.

The research questions are all answered by the study. In particular, the geographical patterns are confirmed to be present through high spatial auto-correlation and are defined nationally through cluster analysis leading to four distinctive clusters. The strongest associations with ICT use and access are for societal openness, urbanization, and ethnicities; and the regression models account entirely for spatial auto-correlation in half of the regressions.

Policies recommended to state and federal governments to improve information technology utilization and access are support of higher education, effort to increase society openness and public transparency, support of ICT initiatives for ethnic groups in society, financial investment in technology infrastructure, and public-private partnerships.

8. References

[1] Agarwal, A., A. Amines, & K. Prasad, "Social interactions and the 'digital divide': Explaining variations in internet use," Inform. Systems Res. 20(2), 2009, 277-294.

[2] Azari, R., and J.B. Pick, "Technology and society: Socioeconomic influences on technological sectors for United States counties", International Journal of Information Management, 25(1), 2005, pp. 25-37.

[3] Azari, R., and J.B. Pick, "Socio-economic influence on information technology: The case of California," in Marian Quigley (ed.), Information Security and Ethics: Social and Organizational Issues, Hershey, PA, Idea Group Publishing, 2004, pp. 48-72.

[4] Baliamoune-Lutz,, M. "An analysis of the determinants and effects of ICT diffusion in developing countries", Inf. Technology for Development, 10, 2003, pp. 151-169.

[5] Blumberg, S.J., J.V. Luke, H. Ganesh, M.E. Davern, M.H. Boudreaux, "Wireless Substitution: State-level estimates from the National Health Interview Survey, 2010-2011," National Health Statistics Report No. 61, National Center for Health Statistics, U.S. Department of Commerce, Washington, D.C, 2012.

[6] Chen, S.J. "The implications of social capital for the digital divides in America", The Information Society, 29, 2013, pp. 13-25.

[7] Chen, S.J., and B. Wellman, "The global digital divide – within and between nations", IT & Society, 1(7), 2004, pp. 39-45.

[8] Commonwealth of Virginia. "Virginia information technologies agency marks 10th anniversary", Chester, VA: Virginia Information Technologies Agency.

[9] Corrocher, N., and A. Ordanini, "Measuring the digital divide: a framework for the analysis of cross-country differences", J. Information Technology, 17, 2002, pp. 9-19.

[10] DCI Group, "Digital America," Report. DCI Group, Washington, DC, 2011.

[11] DeVol, R.C., K. Klowden, A. Bedroussian, and B. Yeo, "North America's high tech economy", Report. Milken Institute, Santa Monica, CA, 2009.

[12] Dutta, S., and A. Jain, "Networked readiness and the benchmarking of ICT competitiveness," in Dutta, S., Lopez-Carlos, A., and Mia, I. (eds.), The Global information technology report. Palgrave Macmillan, NY, NY, 2006.

[13] Dutta, S., and B. Bilbao-Osorio. "The Global Information Technology Report 2012", World Economic Forum, Geneva, Switzerland, 2012.

[14] ESRI Inc, "How spatial autocorrelation (Global Moran's I) works," May 20, 2013, ESRI Inc., Redlands, CA.

[15] FCC, "14th annual report and analysis of competitive market conditions with respect to mobile wireless," Federal Communications Commission, Washington, DC, 2010.

[16] Florida, The Rise of the Creative Class – Revisited, Basic Books, New York, NY, 2012.

[17] Fong, M.W.L."Digital divide between urban and rural regions in China", Electronic Journal of Information Systems in Developing Countries, 36(6), 2009, pp. 1-12.

[18] Freedom House, Freedom in the World 2011. Freedom House, New York, NY, 2011.

[19] Georgia Technology Authority, "Technology Transformation Overview", State of Georgia: Atlanta, GA.

[20] Grubesic, T.H. "A spatial taxonomy of broadband regions in the United States", Information Economics and Policy, 18, 2006, pp. 423-448.

[21] Guillen, M.F., and S.L. Suarez, "Explaining the global digital divide: Economic, political, and sociological drivers of cross-national Internet use", Social Forces, 84(2), 2005, pp. 681-708.

[22] Internet World Stats. "United States of American Internet and Facebook users stats," available on 6/6/13 at www.internetworldstats.com.

[23] Kauffman, R.J., and A.A. Techatassanasoontorn, "Is there a digital divide in digital wireless phone technologies?" Journal of the Association for Information Systems, 6(12), 2005, pp. 338-382.

[24] King, J.L., V, Gurbaxani, K.L. Kraemer, F.W. Mcfarlan, K.S. Raman, and C.S. Yap, "Institutional factors in information technology innovation", Information Systems Research, 5(2), 1994, pp. 139-169.

[25] Kvasny, L., and M. Keil, "The challenges of redressing the digital divide: a tale of two US cities," Information Systems Journal, 16, 2006, pp. 23-53.

[26] Longley, P.A., M.F. Goodchild, D.J. Maguire, and D.W. Rhind, Geographical information systems and science, John Wiley and Sons, Hoboken, NJ, 2011.
[27] Martinsons, M.G. “State censorship of the Internet in China”, Communications of the ACM, 48(4), 2005, p. 67.
[28] National Science Board, “Science and Engineering Indicators 2012,” Nat, Science Found., Arlington, VA, 2012.
[29] Nishida, T., J.B. Pick, and A. Sarkar, “Japan’s Prefectural Digital Divide: Multivariate and Spatial Analysis,” Unpublished manuscript, 2012.
[30] NTIA, “Digital Nation: Expanding Internet Usage,” National telecommunications and Information Admin., U.S. Dept. of Commerce, Washington, DC, 2011.
[31] OECD, “Understanding the digital divide,” Report, Organization for Economic Co-operation and Development, Paris, France, 2011.
[32] Ono, H., and M. Zavodny, “Digital inequality: A five country comparison using microdata”, Social Science Research, 36(3), 2007, pp. 1135-1155.
[33] Pew Charitable Trusts, “Measuring state elections performance.” Washington, DC: Pew Charitable Trusts. Available June 6, 2013, at www.pewstates.org.
[34] Pick, J.B., and R Azari, “Global digital divide: Influence of socioeconomic, governmental, and accessibility factors on information technology”, Information Technology for Development 14(2), 2008, pp. 91-115.
[35] Pick, J.B., and R. Azari, “A global model of utilization of technology based on governmental, social, economic, and business investment factors,” Journal of Management Information Systems, 28(1), 2011, pp. 51-85.
[36] Pick, J.B., and T. Nishida, “Digital divides in the world and its regions: A spatial and multivariate analysis of technological utilization”, unpublished manuscript, 2013.
[37] Pick, J.B., T. Nishida, and A. Sarkar, “Broadband utilization in the Indian States: Socio-Economic correlates and geographic aspects,” in Jyoti Choudrie and Catherine Middleton (eds.), Management of Broadband Technology Innovation, Routledge, Oxford, England, in press, 2013.
[38] Pick, J.B., T. Nishida, and X. Zhang, “Determinants of China’s technology utilization and availability 2006-2009: A spatial analysis,”The Information Society,29(1), 2013, 26-48.
[39] Quibria, M.G., S.N. Ahmed, T. Tschang, M.-L. Reyes-Macasaquit, “Digital divide: determinants and policies with special reference to Asia”, J. Asian Economics, 13, 2002, pp. 811-825.
[40] Robison, K.K., and E.M. Crenshaw, “Post-industrial transformations and cyber-space: a cross-national analysis of Internet development”, Soc. Sci. Res., 31, 2002, 334-363.
[41] Rogers, E. Diffusion of Innovations, 5th edition, Free Press, San Francisco, 2003.
[42] Rosenshein, L., L. Scott, and M. Pratt, “Finding a meaningful model”, ArcNews, ESRI Inc., Redlands, 2013.
[43] Ruger, W.P., and J. Sorens, “Freedom in the 50 states”, Report, Mercatus Center, Arlington, VA,.
[44] Simon, J.S., “Critical success factors for electronic services: Challenges for developing countries”, J. of Global Information Technology Management 7(2), 2004, pp. 31-53.
[45] Sipior, J.C., B.T. Ward , and R. Connolly, “The digital divide and t-government in the United States: Using the technology acceptance model to understand usage,” European J. of Information Systems, 20, 2011, pp. 308-328.
[46] SPSS Inc. SPSS Statistical Software, SPSS/IBM, Chicago, IL, 2013.
[47] Talbot, D., “China’s internet paradox”, Technology Review, 113, pp. 62-67, 2010.
[48] U.S. Census Bureau, U.S. Population Census of 2010, U.S. Census Bureau, Washington, DC, 2013.
[49] Vicente, F., and F. Gil-de-Bernabé, “Assessing the broadband gap: From the penetration divide to the quality divide”, Technological Forecasting and Social Change, 77(5), 2010, 816-822.
[50] Vincente, M.R., and A.J. Lopez, “Assessing the regional divide across the European Union-27”, Telecommunications Policy, 35, 2011, pp. 220-237.
[51] VITA. “About VITA”, Chester, VA: Virginia Information Technologies Agency.
[52] Wald, A. “Test of statistical hypotheses concerning several parameters when the number of observations is large”, Transactions of the American Mathematical Society, 54, 1943, pp. 426-482.
[53] Yates, D.J., G.J. Gulati, and J.W. Weiss, “Different paths to broadband access: The impact of governance and polity on broadband diffusion in the developed and developing worlds,” Proceedings of 44th Hawaiian International Conference on System Sciences, IEEE, 2011.

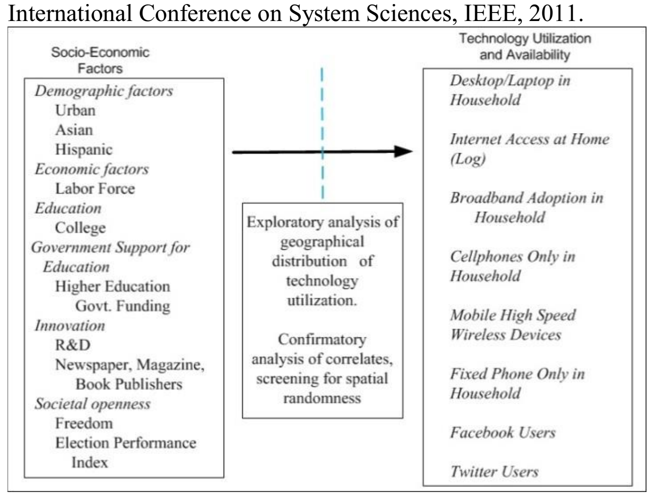

Figure 1. Conceptual Model

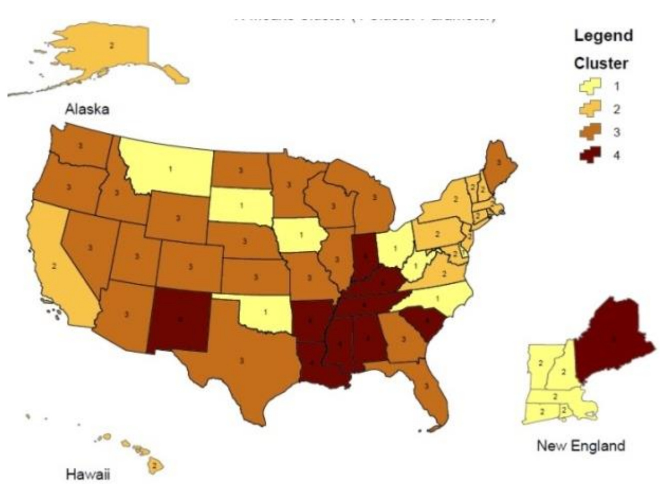

Figure 2. K-Means Clusters for the US 2010

Table 1. Spatial Autocorrelation of Dependent Variables, US 2010 and China 2009, as measured by Moran's I Statistic

		Moran's I values for United States, N=50, 2010							
	Desktop/ Laptop in Household	Log of Internet Access at Home	Broadband Adoption in Household	Persons in Cellphone-Only Household	Mobile Wireless High-Speed Devices	Persons in Fixed-phone-only Household	Facebook Users	Twitter Users	AVERAGE
	0.547***	0.471***	0.457***	0.621***	0.230***	0.648***	-0.004	0.069	0.381
		Moran's I values for China, N=31, 2009							
PCs per 100 Urban Families	PCs per 100 Rural Families	Internet Users per 100 pop.	Broadband Subscribers per 100 pop.	Mobile Telephone Subscribers per 100 pop.		Urban Fixed Phone Subscribers per Capita	Number of Domain Names per 100 pop.	Number of Web Pages per Capita	AVERAGE
0.346***	0.206*	0.264**	0.272**	0.205*		0.252**	0.615***	0.086*	0.285
		Moran's I values for China, N=29, Excluding Beijing and Shanghai, 2009							
0.343***	0.239**	0.137	0.258**	0.061		0.143	0.236**	0.177*	0.199

(Source for China, author, 2013a)

Table 2. K-Means Cluster Composition and Characteristics, US 2010

Dependent Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Ratio of High to Clusters
Desktop/Laptop in Household	78.30	83.30	82.20	71.90	1.16
Internet Access at Home	63.30	69.00	68.10	56.70	1.22
Broadband Adoption in Household	64.16	72.12	71.20	57.06	1.26
Persons in Cellphone-Only Household	26.18	18.76	30.90	31.89	1.70
Mobile Wireless High-Speed Devices	17.20	23.60	22.50	17.00	1.39
Persons in Fixed-phone-only Household	31.22	23.43	36.15	36.54	1.56
Facebook Users	32.40	40.80	41.90	31.10	1.35
Twitter Users	0.64	0.82	0.89	0.72	1.39

Table 3. Standardized Regression Results by Dependent Variables, 50 States, US 2010

		Dependent Variable							
Category	Independent Variable	Desktop/ Laptop in Household	Log of Internet Access at Home	Broadband Adoption in Household	Persons in Cellphone-Only Household	Mobile Wireless High-Speed Devices	Persons in Fixed-phone-only Household	Facebook Users	Twitter Users
Demographic	Urban			0.443***		0.348*		0.474***	0.239
Demographic	Asian					0.435**			
Demographic	Hispanic								0.318*
Economic	Employed Civilian Workforce								
Economic	Service Occupation Employment					-0.337*		-0.305*	0.304*
Economic	Construction Industry Employment								
Education	College Graduates			0.186	-0.326**				
Education	Higher Education Government Funding				0.272*				
Innovation	R&D Expenditures	0.269	0.306*				-0.336**		
Innovation	Publisher Annual Sales (Newspaper, Periodical, Book, Directory)					-0.302*			
Societal Openness	Overall Freedom Index				0.521***		0.515***		
Societal Openness	Election Performance Index	0.283*	0.403**	0.284*				0.299*	
	Regression adjusted R square and significance level	0.125*	0.241**	0.338***	0.456***	0.267**	0.416***	0.276***	0.316***
	sample size (N)	50	50	50	50	50	50	50	50
	OLS REGRESSION TESTS								
	Joint Wald Statistic	68.001***	119.742***	126.765***	74.671***	36.264***	51.921***	19.350***	31.827***
	Koenker (BP) Statistic	5.494	23.908***	6.145	2.534	4.364	1.232	4.336	9.584*
	Jarque-Bera Statistic	8.545	30.123***	0.688	0.490	0.263	1.185	8.879*	1.246
	SPATIAL AUTOCORRELATION OF RESIDUALS								
	Moran's Index	0.273**	0.199*	0.197*	0.038	0.242**	0.191*	0.112	0.031

* signif. at 0.05 ** signif. at 0.01 *** signif at 0.001