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Spatial Analysis of the Global Digital Divide

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ABSTRACT

The global pattern of social, economic, and political influences on technology utilization is analyzed through a combination of linear regression and spatial analysis. The conceptual framework is based on prior research findings on the global digital divide, including non-spatial determinants and on geographic differences. The theory posits that higher levels of technological utilization are based on known factors and it further provides that significant geographic differences will be present in world regions. The paper tests the theory by first conducting ordinary least squares (OLS) regression. For the world, the most significant determinants are tertiary education, innovation capacity, judicial independence, and foreign direct investment. For each regression equation, the spatial autocorrelation of the residuals are tested for significant spatial autocorrelation. After determining that geographically weighted regression cannot be applied, based on residual spatial mapping, OLS regression is performed for three world UN-defined regions and two sub-regions. Findings reveal distinctive determinants for these regions and sub-regions. The paper contributes insights to the global digital divide literature stemming from the geospatial analysis methods.

Keywords. Technology, digital divide, technology utilization, regression, geography, spatial autocorrelation, policy.

INTRODUCTION

The world has a digital divide that reflects a large range of technology accessibility, utilization, and effects for countries. The impact of technology differences is evident today in manifestations related to grassroots political unrest, economic export capacity, provision of technical services, and virtual collaboration. At the same time, geographical differences remain, and might be even greater with increasing technology utilization. High technology use is associated with creative and economically productive cities, regions, and nations (Florida 2005; Warf, 2001); with high social and economic levels, and scale of research and development (Warf, 2001; Pick and Azari, 2011); and with capital investments, foreign direct investments, and other investments of organizations and of nations.

Because of the growth in technology in nations, it is essential to understand better the influences and associations of technology utilization with underlying social, economic, and policy attributes of countries. With this understanding comes enhanced ability for governments to plan and stimulate productive use of technology.

There have been numerous studies of the influences on technology utilization at the country level (Baliamoune-Lutz, 2003; Guillén and Suarez, 2005; Obyeiwu, 2002; Ono and Zavodny, 2007; Robison and Crenshaw, 2002; Simon, 2004; Pick and Azari, 2008, 2011). The research has mostly utilized ordinary least squares (OLS) regression, with sample sizes in the range of 30 to 80 nations. Other approaches have included the panel data econometrics model analysis for within-nation drivers to explain technology diffusion (Kauffman and Techatassanasoontorn, 2005), Gompertz diffusion model (Baliamoune-Lutz, 2003), and structural equation modeling (Pick and Azari, 2011).

Among the weaknesses encountered by prior studies have been reduced data quality for developing nations, varied geographical sizes and shapes of nations, cultural differences, and lack of screening for spatial autocorrelation. Spatial autocorrelation refers to the tendency of like attributes to also be located close together geographically (Longley, Goodchild, Maguire, and Rhind, 2011). If technology companies all cluster together in one location, and another place has no technology companies, then geography is playing an influential role in the association of the attributes. However, geography is largely ignored in OLS regression, so the significance levels of effects may be overstated (Longley, Goodchild, Maguire, and Rhind, 2011).

The present study examines the worldwide digital divide, taking into account geography. It includes map analysis that reveals where high or low utilization countries are clustered together and measurement of the strength of geographic clustering for regression residuals. If there is significant spatial autocorrelation, separate OLS regressions are conducted for world regions that are determined to have clustered residual values, which yields more accurate findings of effects. If technology levels are randomly distributed spatially, then the worldwide regression findings can be relied on from a geographic standpoint.

The findings of the paper indicate influences on technology utilization worldwide and in some cases for world regions. The data are recent, from 2008-2009. The paper is organized into sections on conceptual theory based on prior literature, research questions, methodology, findings, discussion, and conclusion.

CONCEPTUAL MODEL DEVELOPMENT

Prior studies provide a basis for developing a conceptual model. Regression studies of samples of developed nations, developing nations, and of both combined, have posited that a group of social, economic, political, infrastructure, regulatory factors influence one or more indicators of technology utilization, access, or rate of adoption (Robison and Crenshaw, 2002; Baliamoune-Lutz, 2003; Quibria, Ahmed, Tschang, and Reyes-Macasaquit, 2003; Simon, 2004; Guillén and Suárez, 2005; Chinn and Fairlie, 2006; Ono and Zavodny, 2007; Pick and Azari, 2008). Other approaches that are not as directly useful are an econometrics model analysis of panel data for within-nation drivers to explain technology diffusion (Kauffman and Techatassanasoontorn, 2005), Gompertz model of internet diffusion which models impacts of demand-side independent factors on technology adoption, based on an S-shaped curve (Kiiski and Pohjola, 2002), structural equation modeling (Pick and Azari, 2011), and a purely conceptual path model (Simon, 2004).

The present conceptual model (see Figure 1) posits that for countries, social, economic, and political factors are associated with technology utilization outcomes. The model controls for the potential problem of geographic clustering of like-valued outcome attributes. This section provides justification for this model, based on prior literature and, in instances with limited prior research, on induction by the authors' reasoning (Stebbins, 2001).

Social influences on technology utilization are based on the underlying aspect that education, occupation, labor force participation, age, and other social characteristics influence use of technology. At the country level, education has been frequently shown to be influential in technology utilization (Robison and Crenshaw, 2002; Ono and Zavodny, 2006; Chinn and Fairlie, 2007; Pick and Azari, 2008, 2011). Quibria, Ahmed, Tschang, and Reyes-Macasaquit (2003) reason that higher education is especially important for achieving technology utilization, a finding corroborated empirically by the significance of math and science education and of scientific publications (Pick and Azari, 2008). Another social attribute, less frequently included, but influential at the country level, is women's participation in the labor force (Pick and Azari, 2008, 2011). In many countries, women's labor force participation is considerably lower than men's (World Bank, 2010). As women enter or remain in the labor force, they may gain training and confidence in their use of technology, leading to a higher country rate of women's labor force participation and thus greater per capital technology use. For social factors, the present model posits that higher (tertiary) education and female labor force participation influence technology utilization.

Economic influences at the country level on technology utilization from prior research have included integration in the global economy (Onyeiwu, 2002), income (Baliamoune-Lutz, 2003; Quibria, Ahmed, Tschang, and Reyes-Macasaquit, 2003; Chinn and Fairlie, 2006), international trade openness (Baliamoune, 2003), and foreign direct investment (Pick and Azari, 2008, 2011). Important innovation-related factors of prior significance include technology readiness (Pick and Azari, 2011), R&D productivity (Pick and Azari, 2008), and innovation through R&D (Quibria, Ahmed, Tschang, and Reyes-Macasaquite, 2003). In many studies, income has been highly correlated with education, leading investigators to use one or the other to avoid multi-collinearity. Since education has been more important overall in prior studies, we include it but not income. Among other important prior economic determinants included in the present model are foreign direct investment, capacity for innovation, and availability of scientists and engineers as influential on technology utilization.

Political characteristics of empirical importance in earlier research have included democracy and freedom (Guillén and Suárez, 2005; Baliamoune-Lutz, 2003); freedom of the press (Pick and Azari, 2011); rule of law, property rights, and enforcement of contracts (Quibria, Ahmed, Tschang, and Reyes-Aacasaquit, 2003). Authors have reasoned that a democratic, free, and lawful society fosters more communication of ideas and collaborative activity. Recent examples that illustrate this aspect are the rapid spread of Facebook in the 2000s to spur technology utilization, and the importance in 2011 of the internet and mobile technology related to grass-roots democratic upswings in the Middle East. In a society, not only the citizenry, but the government can also spur technology utilization. Two examples are Estonia (Dutta, 2007), in which successive Estonian national administrations pushed ICT as a priority with notable national technology utilization outcomes, and Singapore (Warschauer, 2001; Wong, 2003), in which the national government provided well-funded programs of training and infrastructure throughout the country, spurring technology use. Prior studies have demonstrated government prioritization of ICT to be influential (Pick and Azari, 2008, 2011). The present model posits freedom of the press, judicial independence, reduced government regulation, and government prioritization of ICT to influence technology utilization.

The five outcome variables in the model are ones commonly used in prior literature at the country level (Kiiski and Pohjola, 2002; Robison and Crenshaw, 2002; Baliamoune-Lutz, 2003; Quibria, Ahmed, Tschng, and Reyes-Macaqsaquit, 2003; Guilén and Suárez, 2005; Chinn and Fairlie, 2007; Pick and Azari, 2008, 2011). They consist of personal computers, internet users, broadband internet subscribers, secure internet servers, and mobile telephone subscribers, all per capita. The five utilization attributes cover major platforms of technology use today worldwide. They are contemporary since four of the five refer to internet or mobile environments, yet all are available and used in the developing world.

The conceptual model screens for geographical clustering of like-valued outcome attributes. In other words the model may be consistently over-predicting or consistently under-predicting outcome values for one or more geographic regions within the overall geographic area of study (Rosenshein, Scott, and Pratt, 2011a). The section on methodology will describe in detail the technique of spatial autocorrelation, used to measure spatial clustering of outcome attributes, and will justify the further step of conducting separate regressions for regions.

RESEARCH QUESTIONS

Based on the conceptual model, the study's research questions are the following.

Research Question 1. Which of model's social, economic, and political factors influence the five technology utilization variables for the world as a whole, disregarding spatial effects?

Research Question 2. For each significant world regression identified from Research Question 1, is significant spatial autocorrelation present?

Research Question 3. For those world regressions with significant spatial autocorrelation, what world regions have regression residuals that are spatially over-estimated or spatially under-estimated?

Research Question 4. Which of the model's social, economic, and political factors influence the five technology utilization variables for major world regions with residuals identified in Research Question 3 as spatially over-estimated, spatially random, or spatially under-estimated regions?

The overall results for the study provide an exploratory test of the conceptual model.

METHODOLOGY

The data were collected from recent worldwide compilations by the World Bank (2010), World Economic Forum (2010), and International Telecommunications Union (2009). These volumes provide country data respectively for 2008, 2008, and 2009. A combined data set was completed that resulted in data for 114 countries. The details on the definitions, sources, year, and measurement of the five dependent and nine independent variables are given in Table 1. As partly justified in the limited space for this paper's literature review, the dependent and independent variables are factors present in both developed and developing nations, although some were previously more significant in influencing technology utilization in developed countries, while others were more significant in developing nations.

For the initial regressions, multi-collinearity tests were run on an initial set of fourteen independent variables. Nine variables were further tested for multi-collinearity with the world sample and found not to have it present. Ordinary least squares (OLS) method is applied and the regression residuals mapped and examined for spatial randomness. Each world regression was estimated with all nine independent variables included and also by stepwise regression. In the case of each regression the same significant variables appeared with similar significance levels of coefficients. For this reason, the stepwise results only are used for the global sample. Further on, when regressions are run for regions, stepwise regression is utilized because the smaller sample sizes in the range of N= 30 to N=50 prevent all nine attributes to be forced to enter.

Spatial autocorrelation tests were applied on the residuals, using the Moran's I statistic (Longley, Goodchild, Maguire, and Rhind, 2011; ESRI, 2011) and exploratory regression (Rosenshein, Scott, and Pratt, 2011). Moran's I is an inferential test, with the null hypothesis that the regression residuals in this case are randomly distributed. It is interpreted by both its p value for statistical significance (in this case $p = 0.05$ or less is the cutoff), as well as by the z-score for the probabilities. If the z-score is positive, the high values of the residuals are more clustered than expected randomly; if the z-score is negative, the spatial pattern is more dispersed, i.e. high values are more separated than randomly distributed from neighboring high values and low values are more separated from neighboring low values than in a random pattern (Longley, Goodchild, Maguire, and Rhind, 2011; ESRI 2011).

A further check on the validity of Moran's I for each of the regressions for the world sample is done by exploratory regression (Rosenshein, Scott, and Pratt, 2011). Exploratory regression constructs OLS regressions for all possible combinations of independent variables, and produces summary tables of models that pass standard tests which includes Moran's I. This gives a picture of the broader amount of randomness of residuals of models, that put in context the results for the specific OLS regression chosen. It can be used as a check on the Moran's I specific residual results for the specific

OLS regression chosen, versus a larger university of possible models. In particular, if 0 percent of residual regressions are random, then the Moran's I of our result reflects even stronger overall autocorrelation results involving all combinations of independent variables. A software extension to ArcGIS10 software for exploratory regression is used in the calculations (Rosenshein, Scott, and Pratt, 2011).

If there is significant autocorrelation, there are several possible alternative way to continue the analysis. (1) additional variables can be added. This would be appropriate if there were prior studies providing guidance on which variables to add to reduce autocorrelation. However, there are not prior studies. (2) Geographically weighted regression (GWR) could be applied (Charlton and Fotheringham, 2009). GWR estimates a different regression equation for the data within all the smaller sub-areas that are part of the whole geographic area under study. The sub-areas are determined by geographic algorithm involving kernel, bandwidth, distance, and number of neighbors (Fotheringham, Brundsdon, and Charlton, 2002; ESRI, 2011). The problem for a sample of 114 nations is that the highly varied boundary shapes, distances across nations, and number of neighbors for countries around the world would lead to highly inconsistent GWR results. Hence this alternative is ruled out for the study sample. (3) The residual maps can be examined for correspondence of clusters of over-estimation, randomness, and under-estimation, and approximate world regions chosen for separate regional OLS regression analysis. This is the approach followed. The United Nations categories of world regions are utilized (United Nations Statistics Division, 2011) to select sub-areas. If there is significant spatial autocorrelation for the world, this paper discards the world results, and interprets instead the dependent variable depending on several results for appropriate world regions indicated by the clustering on mapped residuals.

FINDINGS

Results of OLS stepwise regression for the world (Table 2) support that the most important attributes are tertiary education, capacity for innovation, and judicial independence and freedom of the press. Of lesser importance are foreign direct investment and females in the labor force. The overall regression results are highly significant. For mobile telephones, the results are more highly dominated by tertiary education enrollment, with no effects from capacity for innovation or judicial independence, or freedom of the press.

The autocorrelation findings of the residuals for the five regression equations are given in Table 3. There is clearly spatial autocorrelation present for the residuals of the regressions for mobile telephone subscribers (Moran's I = 0.21 with p value of 0.003 and strong positive Z value) and secure internet servers (Moran's I = 0.16, with p value of 0.026 and strong positive Z value). Also for both of these, 0 percent of exploratory regressions (i.e. all combinations of independent variables) were random. For mobile telephone subscribers, residuals are overestimated in Europe, underestimated in Africa/South America, and random in Asia.

From the map of regression residuals for secure internet servers is shown in Figure 3. It is evident that for Asia, there is nearly uniform underestimation of server utilization, with the strong exception of Australia. In Europe also there is strong underestimation of server utilization with the exception of the United Kingdom and several countries in Scandinavia. On the other hand, the regressions for Latin America and Africa mostly overestimate server utilization.

The maps of residuals for the two other variables with significant residual autocorrelations, internet users and mobile telephone subscribers, likewise show regional clustering of overestimation and underestimation corresponding to the regions, although differently. For internet users, residuals are underestimated for Asia, overestimated for Europe, and random for Africa/South America. For mobile telephone subscribers, residuals are overestimated in Europe, underestimated in Africa/South America, and random in Asia.

For dependent variable of broadband internet subscribers, the spatial autocorrelation as measured by Moran's I is insignificant (p=0.054). About a quarter of exploratory regressions support insignificance of p> 0.10, which increases support for non-significance. The map of residuals shows strong underestimation of broadband internet subscribers in Asia, but random patterns in Europe and in Africa/South America.

Spatial autocorrelation results for residuals of dependent variable personal computers per capita strongly indicate randomness. Examining the world residual map in Figure 1, Europe and Africa/South America are random, while Asia has moderate weighting towards underestimation of residuals.

Based on the spatial autocorrelation analysis, the world sample results are regarded random for the dependent variables, personal computers and broadband internet subscribers, and spatially autocorrelated for internet users, secure internet servers, and European mobile telephone subscriptions. For the former two, the world results are discussed, but not for the latter three since they are regarded as invalid. This analysis points strongly for the need to conduct separate OLS regressions for the three world regions, which appear in Table 4. The regional regressions were conducted utilizing stepwise regression analysis, since sample varies from 27 to 48, which precludes forcing all nine attributes into the estimations.

Ninety three percent of the regional OLS regressions in Table 4 are highly significant, with the exception of mobile telephone subscribers in Europe, for which no variable coefficients were significant. That finding strongly points to the need to introduce new independent variables to reflect the dynamics of mobile phone subscription in Europe. The discussion section interprets the findings considering prior studies, summarizes outcomes of research questions, examines the benefits of the methodology, offers policy implications, and addresses limitations of the investigation.

DISCUSSION

For the world, the findings for valid regressions of personal computers and broadband internet subscribers reveal tertiary education and capacity for innovation to be dominant. Higher education's role is consistent with prior studies (Pick and Azari, 2008, 2011), while innovation and R&D were important determinants (Robson and Crenshaw, 2002; Ono and Zavodny, 2006; Chinn and Fairlie, 2007; Pick and Azari, 2008, 2011). Another related indicator, scientific publications is shown to be the dominant influence on varied technology utilization factors (Pick and Azari, 2008). For personal computers, judicial independence is significant, which is consistent with literature on the importance of democracy as a factor (Quibria, Ahmed, Tschang, and Reyes-Aacasaquit, 2003), while for broadband subscribers, foreign direct investment (FDI) is significant. FDI's greater role with broadband versus personal computers may reflect the newness of broadband in developing areas of the world, and the need for foreign investment to get it started.

For the three continental regions, the regional regressions are nearly all significant. For Europe, the two consistent dominant determinants are judicial independence and capacity for innovation. Judicial independence is more prominent in Europe than in the other regions. This might relate to present day Europe's emphasis on fair and democratic use of the internet and other technologies. The European Commission emphasizes internet and information rights, with many directives, policies, and actions that reflect strong emphasis on high standards and legal rights for information use, an example being "eYou Guide to Your Rights Online" (European Commission, 2011). Second in importance is capacity for innovation, a correlate found for all three regions to be associated with broadband or internet dependent variables. That makes sense, since innovation today has transitioned from personal computers to the broadband internet. For internet users, tertiary education was the most important. For example, in some eastern European nations that were residual from the Soviet Union breakup, higher education has grown. In the case of Estonia, the past two decade advance in education since the breakup has contributed to a rapid increase in technology utilization (Dutta, 2007).

In Asia, the strongest influence on technology utilization, which applies to all the dependent variables, is tertiary education, followed by foreign direct investment that applies to all except internet servers. Many parts of Asia have modernized their higher education over the past decade including China and countries in central and eastern Asia. Since education has been widely reported as a determinant of technology use (Robison and Crenshaw, 2002; Ono and Zavodny, 2006; Chinn and Fairlie, 2007; Pick and Azari, 2008, 2011), so this finding reflects more educated, knowledgeable and information seeking Asian citizenry. FDI is important in poorer and middle-level Asian nations, which have attracted moderate to large FDI. The investments spur technology use directly through building of technology manufacturing and services and indirectly by stimulating other sectors such as finance, design, engineering, and defense that emphasize technology. Judicial independence is of secondary importance, which contrasts with Europe.

For Africa and South America, the key determinants of internet use are education, capacity for innovation, and foreign direct investment. Education and FDI have been reported in a prior study for developing countries (Pick and Azari, 2008), while another investigation (Baliamoune-Lutz, 2003), based on 1998-2000 data for 47 developing nations, did not report either factor as significant. This difference might be due to Baliomoune-Lutz's decade earlier date, and to the distinction between the composition of the present regional sample of Africa and South America and that of Baliamoune-Lutz's developing nation sample.

A further sub-regional test was done to compare findings for African versus South American nations (see Table 5). Although the sample size for Latin America of 18 countries is small for OLS regression, nonetheless the comparison shows contrast. Surprisingly, for Africa the most important relationship for broadband internet, internet users, and mobile telephones was an inverse one with percent of females in the labor force. This might be culturally explained, i.e. that some of the north and central African nations, which have greater religious constraints for women joining the labor force, the economies are encouraging technological development and use. In Africa, for personal computers, servers, and mobile telephones, judicial independence is significant. This factor is unexpected based on the literature, but has been demonstrated in northern Africa, where countries with somewhat stronger legal systems, such as Egypt, have higher levels of technology use, while the reverse is true in poorer central African nations. In Latin America, capacity for innovation, education, and/or availability of scientists and engineers were important for personal computers, broadband, and internet, much more so than in Africa. For internet users and internet servers, judicial independence is significant, and FDI only so for mobile telephone subscribers. Latin America's leading economies of Chile, Brazil, and Mexico, all with significant technology and IT sectors, have strong higher education capacities, while the reverse is true for poorer nations including Bolivia and Ecuador. The results of disaggregating of the Africa/South America sample into its components demonstrates that the developing world sub-regions are distinctive in technology utilization determinants.

Research question outcomes

Based on the empirical findings, the research questions are answered as follows.

Research Question 1. The significant technology utilization determinants for the world as a whole are tertiary education, capacity for innovation, and judicial independence, with FDI of lesser influence.

Research Question 2. Spatial autocorrelation analysis demonstrates that significant spatial autocorrelation is present to regression residuals for the dependent variables of internet users, internet servers, and mobile telephone subscribers. Residuals for personal computers and broadband subscribers are seen to be random.

Research Question 3. For regressions for internet users, residuals are underestimated for Asia, overestimated for Europe, and random for Africa/South America. For regressions for mobile telephone subscribers, residuals are overestimated in Europe, underestimated in Africa/South America, and random in Asia, while for regressions of secure internet servers, residuals are underestimated for Europe, underestimated in Asia, and mostly overestimated in Africa and Latin America.

Research Question 4. For the three regions, disaggregated and analyzed separately by regression, the most important factors were: *Europe* – judicial independence and innovation capacity; *Asia* – tertiary education, innovation capacity, judicial independence, and foreign direct investment; *Africa/South America* – tertiary education, innovation capacity, and foreign direct investment; and *Africa* – judicial independence and an inverse effect for females in the labor force.

Limitations

The research study has several limitations. The worldwide data sources allow only a sample of 114 nations, due to governmental limitations on data collection. A larger future sample would enable more powerful analysis methods, as well as enlarged sub-regional samples for areas such as Latin America. The conceptual models are presently few in the field of the global digital divide, so the present conceptual framework needs to be constructed in an exploratory manner. This constraint can be improved as more worldwide studies are conducted. The limitation on use of geographically weighted regression when there are spatially autocorrelated residuals, is an accident of the world's very irregular country boundaries and shapes, which preclude using geographically weighted regression methods. Future studies could undertake the methodological challenge to develop GWR-like methods for irregular size and shaped polygons.

Since the unit of analysis is the nation, population sizes across nations vary, which might introduce some inconsistency in interpreting the data. However, that limitation would apply to many other studies of ICT in nations (for example, Robison and Crenshaw, 2002; Baliamoune-Lutz, 2003; Guillén and Suárez, 2005; Pick and Azari, 2008, 2011), and to numerous studies in the social sciences of government data collected for nations and sub-national units such as states, counties, and provinces. The present paper has the intent to be inclusive of nations worldwide. In a future study, population size ranges could be controlled yielding samples that are more similar in population size.

Language, which is not included as an independent factor in this study, may influence internet usage. However, it would be difficult to validate a language variable, since the world's leading spoken first languages are Chinese (20.4 percent of world population), Spanish (5.5 percent), English (5.5 percent), and Arabic (3.7 percent) (Lewis, 2009). There are at least 3 million first-language speakers in 31 countries for Chinese, 44 countries for Spanish, 112 countries for English, and 57 countries for Arabic (Lewis, 2009). In these countries, the internet and web vary in their dominant language. Hence, a further research on internet and web language dominance would be need to be carried out before a meaningful language dummy variable, such as English speaking or Chinese speaking, could be added to future country-based studies of the global digital divide.

In this study, is assumed that the number of personal computers is proportional to users i.e. ad one-to-one ratio. This is not entirely true because users can share personal computers or one user might have two or more personal computers. Mobile phone and broadband subscribers likewise might not be in a one-to-one ratio with users, due to group subscriptions or one person having multiple subscriptions. A favorable aspect is that these ratios might vary little from nation to nation. Another aspect is that in poor nations, 3-G mobile devices if available and affordable, might account for a higher proportion of internet use than in developed nations. Determining the extent of user's internet access with 3-G or 4-G mobile devices mode by country developmental level is beyond the scope of the present study. However, such a study would be useful in the future and might alter the interpretation of the internet usage dependent variable.

CONCLUSION

This study has analyzed global patterns of the effects of social, economic, and political influences on technology utilization. The findings demonstrate significant influences especially tertiary education, capacity for innovation, judicial independence, foreign direct investment, and women's labor force participation. The study screened the global regression residuals for spatial autocorrelation, finding it to be significant in 60 percent of worldwide regressions. Consequently regional and sub-regional regressions analysis was conducted that were more suitable to dependent variables with auto-correlated residuals. For those variables, the study points to a significant benefit from shifting from global regression analysis to separate analysis in world regions in instances of significant spatial autocorrelation of regression residuals.

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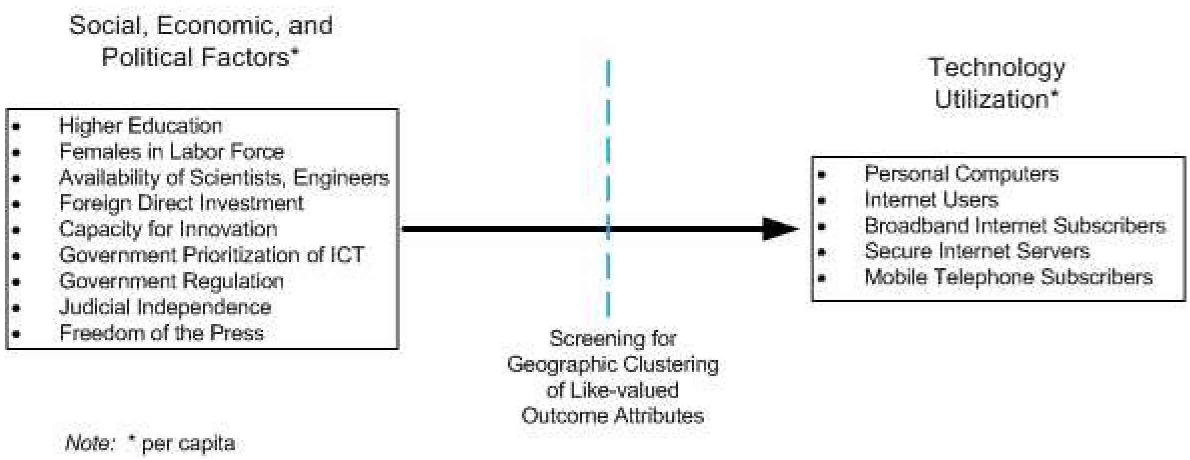

Figure 1. Conceptual Model

Variable	Dependent or Independent	Definition	Year of Data Collection	Data Source	Measurement
PCs	Dep.	personal computers per 100 population	2008	WEF	numerical
Broadband Internet Subscribers	Dep.	broadband internet subscribers per 100 population	2008	WEF	numerical
Internet Users	Dep.	internet users per 100 population	2008	WEF	numerical
Secure Internet Servers	Dep.	secure internet seervers per milllion population	2008	WEF	numerical
Mobile Telephone Subscribers	Dep.	mobile telephone subscribers per 100 population	2008	ITU	numerical
Tertiary Education Enrollment Rate	Indep.	gross tertiary education enrollment rate	2007	WEF	numerical
Availability of Scientists and Engineers	Indep.	extent to which scientists and engineers are available	2009	WEF	Likert 1-7 Scale
Capacity for Innovation	Indep.	extent of conduct of formal research and pioneering in products and services	2009	WEF	Likert 1-7 Scale
Burden of Government Regulation	Indep.	extent of burden for business to comply with government administrative requirements (regulations, permits, reporting)	2009	WEF	Likert 1-7 Scale
Freedom of the Press	Indep.	Extent the press is free	2009	WEF	Likert 1-7 Scale
Judicial Independence	Indep.	Extent the country's judiciary is independent of influences from government, citizens, or firms	2009	WEF	Likert 1-7 Scale
Government Prioritization of IT	Indep.	Extent of priority the government places on information and communication technologiese	2009	WEF	Likert 1-7 Scale
Foreign Direct Investment	Indep.	Foreign direct investment	2008	WB	numerical

WEF = Data from World Economic Forum (2010)
WB = Data from World Bank (2010)
ITU = Data from International Telecommunications Union (2009)

Table 1. Definitions and Sources of Variables

Figure 2. Regression Residuals for Personal Computers,

corresponding to regression equation in Table 1, WORLD, column 1

Figure 3. Regression Residuals for Secure Internet Servers,

corresponding to regression equation in Table 2, WORLD, column 4

	PCs per 100 Pop.	Broadband Internet Subscribers per 100 Pop.	Internet Users per 100 Pop.	Secure Internet Servers per 100 Pop.	Mobile Telephone Subscribers per 100 Pop.
Tertiary education enrollment rate	0.231***	0.364***	0.479***	0.219***	0.711***
Availability of Scientists and Engineers					
Capacity for Innovation	0.454***	0.488***	0.318***	0.338***	
Burden of Government Regulation					
Freedom of the Press		0.152***			
Judicial Independence	0.263***		0.232***	0.382***	
Government Prioritization of Information Technology					
Percent of Females in the Labor Force		0.090*		0.122*	-0.131*
Foreign Direct Investment (per 1000 pop.)		0.154***	0.101*		0.171**
Regression adjusted R square and significance level	0.706***	0.851***	0.815***	0.668***	0.574***
sample size (N)	110	114	114	112	114

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

Table 2. Standardized Regression Results for Dependent Variables, 2008-2009, for world nations, developed nations, and developing nations

	PCs per 100 Pop.	Broadband Internet Subscribers per 100 Pop.	Internet Users per 100 Pop.	Secure Internet Servers per 100 Pop.	Mobile Telephone Subscribers per 100 Pop.
Moran's I	0.005	0.140	0.156	0.164	0.215
p value	0.855	0.054	0.026	0.027	0.003
Z score	0.183	1.929	2.229	2.218	2.964
Exploratory regressions - percentage with Moran's I > 0.10	61.11	27.03	25.93	0.00	0.00

Table 3. Measures of spatial autocorrelation of residuals for OLS regressions of 2008-2009 world sample of countries
Regressions correspond to those for world in Table 1.

Europe

	PCs per 100 Pop.	Broadband Internet Subscribers per 100 Pop.	Internet Users per 100 Pop.	Secure Internet Servers per 100 Pop.	Mobile Telephone Subscribers per 100 Pop.
Tertiary education enrollment rate			0.473***		N.S.
Availability of Scientists and Engineers					N.S.
Capacity for Innovation	0.450*	0.436**	0.298**		N.S.
Burden of Government Regulation					N.S.
Freedom of the Press					N.S.
Judicial Independence	0.421*	0.534***	0.225*	0.878***	N.S.
Government Prioritization of Information Technology					N.S.
Percent of Females in the Labor Force					N.S.
Foreign Direct Investment (per 1000 pop.)			0.266**		N.S.
Regression adjusted R square and significance level	0.676***	0.854***	0.839***	0.763***	N.S.
sample size (N)	31	31	30	31	

Asia

	PCs per 100 Pop.	Broadband Internet Subscribers per 100 Pop.	Internet Users per 100 Pop.	Secure Internet Servers per 100 Pop.	Mobile Telephone Subscribers per 100 Pop.
Tertiary education enrollment rate	0.551***	0.547***	0.473***	0.633***	0.402**
Availability of Scientists and Engineers					
Capacity for Innovation		0.370***	0.298**		
Burden of Government Regulation					
Freedom of the Press					-0.391**
Judicial Independence			0.225*	0.356**	0.459**
Government Prioritization of Information Technology	0.279*				
Percent of Females in the Labor Force					
Foreign Direct Investment (per 1000 pop.)	0.386**	0.364***	0.266**		0.429***
Regression adjusted R square and significance level	0.666***	0.857***	0.839***	0.745***	0.661***
sample size (N)	27	30	30	30	30

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

Table 4. Standardized Regression Results for Dependent Variables, 2008-2009, For nations in Europe, in Asia, and in Africa and South America Combined

	Africa and South America				
	PCs per 100 Pop.	Broadband Internet Subscribers per 100 Pop.	Internet Users per 100 Pop.	Secure Internet Servers per 100 Pop.	Mobile Telephone Subscribers per 100 Pop.
Tertiary education enrollment rate	0.423***	0.476***	0.274		0.590***
Availability of Scientists and Engineers					-0.206
Capacity for Innovation			0.257*	0.240*	
Burden of Government Regulation			-0.257*		
Freedom of the Press	0.223				0.330***
Judicial Independence	0.311*				
Government Prioritization of Information Technology					
Percent of Females in the Labor Force					-0.263*
Foreign Direct Investment (per 1000 pop.)		0.361**	0.364*	0.619***	
Regression adjusted R square	0.348***	0.564***	0.546***	0.505***	0.602***
sample size (N)	47	48	48	48	48
* signif. at 0.05					
** signif. at 0.01					
*** signif at 0.001					

Table 4 (cont.). Standardized Regression Results for Dependent Variables, 2008-2009, For nations in Europe, in Asia, and in Africa, and in South America Combined

Africa

	PCs per 100 Pop.	Broadband Internet Subscribers per 100 Pop.	Internet Users per 100 Pop.	Secure Internet Servers per 100 Pop.	Mobile Telephone Subscribers per 100 Pop.
Tertiary education enrollment rate	-0.408				
Availability of Scientists and Engineers					
Capacity for Innovation					
Burden of Government Regulation					
Freedom of the Press					
Judicial Independence	0.385*			0.471**	0.408**
Government Prioritization of Information Technology					
Percent of Females in the Labor Force		-0.370*	-0.887***		-0.552***
Foreign Direct Investment (per 1000 pop.)	0.604*		-0.419**		
Regression adjusted R square	0.357**	0.165*	0.529***	0.194**	0.488***
sample size (N)	29	29	29	29	29

South America

	PCs per 100 Pop.	PCs per 100 Pop. (Excl. Cap for Innov.)	Broadband Internet Subscribers per 100 Pop.	Internet Users per 100 Pop.	Secure Internet Servers per 100 Pop.	Secure Internet Servers per 100 Pop. (Excl. Jud. Ind.)	Mobile Telephone Subscribers per 100 Pop.
Tertiary education enrollment rate			0.573**				N.S.
Availability of Scientists and Engineers		0.587**	0.418*				N.S.
Capacity for Innovation	0.602**						N.S.
Burden of Government Regulation				-0.518**			N.S.
Freedom of the Press							N.S.
Judicial Independence				0.697***	0.611**		N.S.
Government Prioritization of Information Technology							N.S.
Percent of Females in the Labor Force							N.S.
Foreign Direct Investment (per 1000 pop.)						0.671**	N.S.
Regression adjusted R square	0.322**	0.303**	0.608***	0.620***	0.336**	0.417**	N.S.
sample size (N)	17	17	18	18	18	18	

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

N.S. = not significant

Table 5. Standardized Regression Results for Dependent Variables, 2008-2009, for nations in Africa separately and in South America separately