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ABSTRACT

China's technology levels have grown rapidly in the first decade of the 21st century. This study examines the economic and social influences on technology utilization and availability in China's 31 administrative units. An exploratory conceptual model is established, based on prior research and including screening for spatial clustering of like-valued residuals. The empirical research goals are (1) to statistically analyze the determinants of technology usage in China at the provincial level using the most recent technology, economic, and social data, and (2) to statistically analyze the impact of spatial autocorrelation on Chinese provincial technology levels and on regression residuals. Findings indicate the most significant determinant of China's provincial technology levels is export commodities value, followed by published books, tertiary and non-state-owned employment, and to a lesser extent innovation. Spatial autocorrelation is only slightly present following the regression analysis. The implications of the study for government policies in China are examined.

Keywords: Technology utilization, technology availability, China, provinces, socio-economic influences, spatial autocorrelation, regression, government policy

INTRODUCTION

China is challenging the U.S. as the world's largest country in number of technology users, as the result of rapid growth during the 2000's first decade. In 2008, China had 641 million mobile telephone subscriptions, 298 million estimated internet subscribers, and 83.3 million broadband subscribers, which compares to respectively 270 million mobile telephone subscribers, 231 million estimated internet subscribers, and 73.1 million broadband subscribers in the United States (ITU, 2010). For the World Economic Forum's Network Readiness Index, a balanced index of technology indicators, China's world rank moved up to 37^{th} in 2009-2010 (World Economic Forum, 2010). Since China is a vast country that in physical size is nearly identical in surface area to the United States, it is also important to study the determinants of technology use in sub-national regions within China.

The present study fills in a knowledge gap on the social, economic, and infrastructure determinants of technology use in China's provinces for the rapid technological growth period of 2006-2009. In looking at the determinants it introduces a method rarely applied in digital divide research that estimates extent of spatial clustering of the observed dependent variable and of its model fit. The findings can be helpful for Chinese government policy makers at the national and provincial levels.

The paper consists of a literature review of prior related investigations, an exploratory conceptual model, research questions, methodology, findings, discussion, implications, and conclusion.

LITERATURE REVIEW AND JUSTIFICATION OF MODEL FACTORS

This section reviews prior research on spatial distribution of technology indicators within China, and discusses prior literature of determinants of technology attributes. China is recognized to have major provincial differences in its technology development (Loo, 2003; Song, 2008). Geographical differences originally stemmed from the traditional stronger economy in the eastern coastal region versus the central or western regions of China. A key turning point occurred in 1980, when the Chinese central government first established the Special Economic Zones (SEZs) in the southeast of China. The zones had greater economic independence and incentives for foreign investment than the rest of China's mainland. In the subsequent three decades the coastal region continued to develop and is now recognized as the world's manufacturing center. In the 1990s, China's government also identified ICT (information and communications technology) infrastructure as a key national economic goal (Song, 2008), which has led to rapid increase in technology industry and services (Loo, 2003; Song, 2006).

The Internet grew significantly in China starting in the mid 1990s, especially in its major cities. In 2001, the Chinese administrative units of Beijing, Guangdong, and Shanghai, each with nationally dominant cities, accounted for a third of internet use (Loo, 2003). China has 31 administrative units, consisting of 22 provinces, 5 autonomous regions, and 4 centrally administered municipalities. In this paper, all 31 will be referred to interchangeably as administrative units or provinces. In production of internet content, Beijing, Shanghai, and Guangdong are by far the leading metropolitan centers, an arrangement somewhat analogous to the dominance of San Francisco, Los Angeles, and New York as internet content providers in the U.S. (Loo, 2003). The process of developing the internet in China and other parts of Asia differs from the West in the more deliberate and active role of government, more centralized and government-dominated internet industry, reduced level of communications infrastructure, high relative cost of internet use, and language barrier for portions of the internet, since English is the dominant language for web content originating in the western advanced nations (Loo, 2003). These factors have favored greater internet and technology development in the east and southeast of China. The technology differential from high utilization in the east/southeast region to moderate in the central region to low in the west, shown be present in 2000 and 2006 (Song, 2008) is evident today.

China seems to be following, at a lag, a national economic model that was successful in Singapore, Taiwan, and South Korea, of emphasizing exports. The export economy in turn stimulates the ICT industries (Meng and Li, 2002). This approach led to regional differences as early as 1999 in GDP, as well as in ICT and the internet. For instance, in 1999, the internet penetration rate was 0.56 in the east region, 0.14 in the central region, and 0.18 in the west (Meng and Li, 2002). Challenges in transforming to a technological, export-driven economy include the fulfilling the financial needs of the high-tech sector, brain drain from domestic to multinational enterprises, insecurity in employment, persistent poverty in some localities, and periods of instability in the macro economy (Meng and Li, 2002).

Another relevant literature concerns determinants of geographical technology differences, sometimes referred to as the digital divide. These studies concern both developed and developing nations, and have been conducted with units of analysis that include countries, states or provinces, and counties. Openness to trade and liberalization of telecommunications were major enabling factors that stimulated ICT and internet access in ten countries that included

China (Gibbs et al., 2003); they were important in a regression study of developing nations (Baliamoune-Lutz, 2003), and likewise trade openness was significant for developing nations in a study of determinants of IT investment for nations (Shih et al., 2007). The trade factor is identified as a key element in the export economy that China has established over the last two decades (Meng and Li, 2002) and for Asian nations (Quibria et al., 2003). For this reason export commodities value is included as a determinant of technology utilization in the conceptual model.

Development of information infrastructure is an enabler of ICT use, and in turn stimulates the economy. During the late 1990s China's percentage telephone infrastructure growth was by far the highest among ten cases of middle-level and advanced nations (Gibbs et al., 2003). In a study of ICT diffusion in 18 Asian nations, investment in telecommunications infrastructure was a critical factor for ICT growth (Quibria et al, 2003). China's development of the internet from 1987 to 2007 was dependent on government initiatives to advance infrastructure (Raven et al., 2008), and those needs continue to be essential. In the conceptual model, infrastructure, represented by electricity output and construction enterprise expenditure, is included as a determinant.

As the Chinese economy opened up to a market economy over the past two decades, much of its technology use has occurred in the non-state-owned (i.e. market driven) sector. This specific aspect does not have precedent in prior digital divide research. We posit that provinces with higher per capita employment in the market-driven sector are associated with higher technology utilization and availability. Employment in non-state-owned units is included as an influence on technology utilization in the conceptual model.

Although professionals and knowledge workers are known to have higher levels of technology use, a variable that measures this factor has rarely been included. In a regression study of socioeconomic influences on technological sector receipts and payrolls for 164 U.S. counties, the most important correlates overall were professional/scientific/technical services workforce, followed by other services workforce (Azari and Pick, 2005). Consequently, the construct of employment in the tertiary sector is included in the model.

Cost of technology has been identified as a barrier to its adoption in studies of China (Loo, 2003; Fong, 2009). Lack of affordability as a barrier is especially present in China's rural areas

(Fong, 2009). Individual technology investments in China were shown to be more important and enterprise investments and public venues (Zhu and Wang, 2005). Hence, the determinant of individual investment in fixed assets is included in the paper's model.

Foreign direct investment (FDI) has been crucial in developing the export-driven economy of China ever since it opened up three decades ago. It was an important determinant of internet capacity in a study of 74 developed and developing nations (Robison and Crenshaw, 2002) and was most significant as a correlate of technology factors for developing nations in a study of 71 nations (Pick and Azari, 2008). FDI is included as a determinant in the present model.

Measures of innovation have been important correlates of technology levels (Quibria, 2003; Pick and Azari, 2008, Pick and Nishida, 2011) and are included in the conceptual model. Since knowledge content is essential for internet and web related dependent variables, the traditional knowledge content variable of numbers of published books is included in the conceptual model as a factor that stimulates innovation.

In most studies of determinants of technology levels, education has been significant (Robison and Crenshaw, 2002; Ono and Zavodny, 2007; Shih et al., 2007; Pick and Azari, 2008, 2011; Pick and Nishida, 2011). For instance in a comparative study of five nations including three from Asia, using microdata, education and income were the most important correlates to information technology usage, with the education categories of some college and college completion being more significant than lower levels of education (Ono and Zavodny, 2007).

Many prior investigations based on correlation and regressions have determined very high positive correlation of income and education. Multi-collinearity considerations have implied that only one can be included. Of the two, income has been largely excluded from prior models because of its weaker literature support. For example, in one of the few country-based studies that included income, weak effects of it on technology diffusion were found (Caselli and Coleman, 2001). Studies at the national level have predominantly excluded gross national product (GNP) because technology constitutes an important part of GNP. Even if gross provincial income was deemed important, which it isn't, it is not available for Chinese provinces. Since education has been more widely confirmed as important in prior studies compared to income, education in the model rather than income. Many different education measures have been utilized in previous studies (Robison and Crenshaw, 2002; Ono and Zovodny, 2007; Pick and Azari, 2008, 2011). The present study is restricted, however, to variables available from the Chinese government sources; the variable closest to those utilized previously is number of full-time employees in high education.

Since studies consistently cite the essential role of the Chinese government in stimulating technology utilization and availability (Meng and Li, 2002; Loo, 2003; Song, 2008) and since prior research has shown the crucial importance of education and R&D to technology utilization and availability (Azari and Pick, 2005; Pick and Azari, 2008), the provincial expense of government departments of education, science, public health, and culture is included as a factor in the conceptual model.

Conceptual Framework

The conceptual framework (Figure 1) includes these factors that were justified from prior research. The model may consistently overestimate or consistently underestimate outcome values for one or several geographic regions within the overall geographic area of investigation (Rosenshein, et al., 2011). In particular, some of the strength of associations present may come from geographic clustering of high or low values, rather than non-geographic social and economic forces. Hence the model screens for geographical clustering of like-valued outcome attributes.

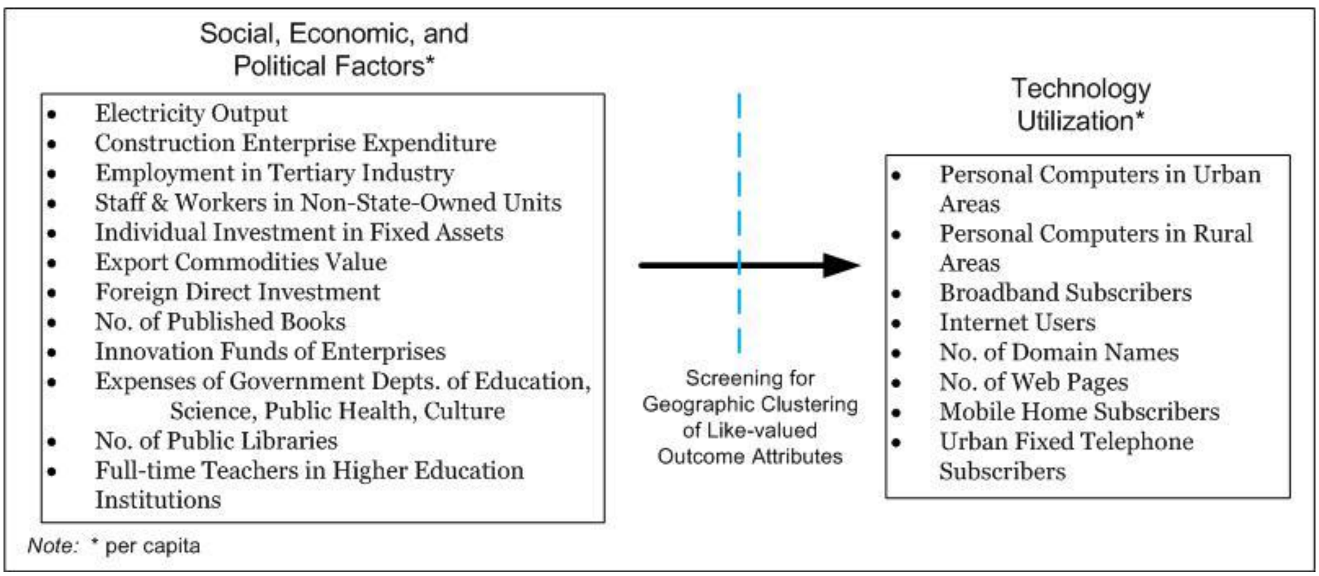

Figure 1. Conceptual Model

Research Goals and Research Questions

The research questions are the following.

1. Are the 2006 dependent variables spatially autocorrelated?
2. Are the 2009 dependent variables spatially autocorrelated?
3. What are the changes in the overall geographic pattern of clustering of the dependent variables between 2006 and 2009?
4. What are the most significant economic and social determinants of utilization of the dependent variables for China, taking into account spatial proximities, in year 2006?
5. What are the most significant economic and social determinants of utilization of the dependent variables for China, taking into account spatial proximities, in year 2009?
6. Are the 2006 and 2009 regression residuals of the ordinary least squares (OLS) regressions spatially autocorrelated?
7. What are the changes in economic determinants of technology utilization and availability between 2006 and 2009?

METHODOLOGY

Data were obtained from the China Information Almanac (2010), China Statistical Yearbook (2010), China Data Online (2010), and semi-annual surveys of China Internet Network Information Center (CNNIC, 2010). The data in all the sources were collected by the Chinese central government.

Eight dependent variables were selected, based on prior literature, to represent technological utilization and availability. They were first tested for spatial autocorrelation tests, using the Moran's I statistic (Longley, Goodchild, Maguire, and Rhind, 2011; ESRI, 2011). Moran's I is an inferential test, with the null hypothesis that the dependent variables in this case are randomly distributed spatially. Low absolute values for Moran's I indicate that the OLS regression has controlled for the spatial autocorrelation. A positive Moran's I indicates presence of spatial clusters of high values and/or low values, while a negative Moran's I indicates that a high valued data point is close spatially to low valued data points, and vice versa (Longley et al., 2011).

If, as posited in research questions 1 and 2, significant spatial autocorrelation were found to be present in for some or all of the eight dependent variables for 2006 and for 2009, then K-means cluster analysis was applied and maps created of the clusters for 2006 and 2009, which illustrate the overall patterns of the clusters of technology dependent variables in China, and also reveal the change in patterns during that time period. Further, the clusters were characterized by their total population and by the mean values of the dependent variables.

Next, multi-collinearity tests were run on the twelve independent variables and found not to have it. Their definitions and sources are given in Table 1. Ordinary least squares (OLS) stepwise regression was applied for each dependent variable for the twelve independent variables. The regression residuals were mapped and they were examined for spatial autocorrelation. Stepwise regression was chosen because this investigation is exploratory (Stebbins, 2001) since no prior similar regression studies have been done of China's provinces.

Table 1. Definitions of Variables

Variable	Dependent or Independent	Definition	Year of Data Collection	Data Source
PCs per 100 Urban Families	Dep.	personal computers per 100 urban families	2009	CI Almanac
PCs per 100 Rural Families	Dep.	personal computers per 100 rural families	2009	CI Almanac
Broadband Subscribers	Dep.	broadband subscribers per 100 population	2009	CSY
Internet Users	Dep.	internet users per 100 population	2009	CNNIC
Domain Names	Dep.	number of domain names per 100 population	2009	CNNIC
Web Pages	Dep.	number of web pages per capita	2009	CNNIC
Mobile Telephone Subscribers	Dep.	number of mobile telephone subscribers per 100 pop.	2009	CSY
urban fixed telephone subscribers	Dep.	number of urban fixed telephone subscribers per capita	2009	CDO
electricity output	Indep.	electricity output (in 100 million kilowatt hours) per capita	2009	CDO
construction enterprise output	Indep.	construction enterprise output (in 100 million yuan) per capita	2009	CDO
Employed persons in tertiary industry	Indep.	employed persons in tertiary industry per capita	2009	CDO
Staff and Workers in Non-State-Owned Units	Indep.	staff and workers in non-state-owned units (of 10,000 persons) per	2009	CDO
Individual Investment in Fixed Assets	Indep.	individual investment in fixed assets (of 100 milllion yuan) per capita	2009	CDO
Export Commodities Value	Indep.	export commodities value (in 1,000 U.S. dollars) per capita	2007	CDO
Foreign Direct Investment	Indep.	foreign direct investment (in 10,000 U.S. dollars) per capita	2008	CDO
Published Books	Indep.	number of published books (in 100 million copies) per capita	2009	CDO
Innovation Funds	Indep.	innovation funds of enterprises (in 100 million yuan) per capita	2009	CDO
Government expenses in Education, Science, Public Health, and Culture	Indep.	expenses of government departments of education, science, public health, and culture (in 100 million yuan) per capita	2009	CDO
Public Libraries	Indep.	number of public libraries per capita	2009	CDO
Full-time Teachers in Higher Education	Indep.	number of full-time teachers in higher education institutions (10,000 persons) per capita	2009	CDO

Note: all variables are numerical
CI Almanac = China Information Almanac (2010)
CSY = China Statistical Yearbook (2010)
CDO = China Data Online (2010)
CNNIC = China Internet Information Center (2010)

OLS stepwise regression was applied to test for significant factors in technology utilization and availability. The regression analysis included assessing the OLS regression diagnostic tests of

Joint Wald Statistic, Koenker (BP) Statistic for heteroscedasticity, and Jarque-Bera Statistic for skewness and kurtosis (Rosenshein et al., 2011).

Spatial autocorrelation (Moran's I) was again applied to the OLS regression residuals, in order to determine whether the errors in the estimates indicate presence or absence of spatial clustering of like valued attributes. This methodology step supports research question 6.

FINDINGS

Spatial autocorrelation tests of dependent variables, 2006 and 2009

The dependent variables in 2006 and 2009 were tested for spatial autocorrelation, measured by Moran's I. As seen in Table 2, in 2006, 7 of 8 dependent variables had significant spatial autocorrelation, the only exception being for the number of web pages. Since the administrative units of Beijing and Shanghai had very high values for most dependent variables in both 2006 and 2009, additional estimates of Moran's I were done, removing the outliers for Beijing and Shanghai. In the resultant sample for 2006, 4 of 8 dependent variables had significant spatial autocorrelation, with the exceptions of internet users, number of web pages, mobile telephone subscribers, and urban fixed telephone subscribers.

In 2009, all 8 dependent variables had significant positive spatial autocorrelation; when Beijing and Shanghai were removed, 5 of 8 dependent variables had significant spatial autocorrelation, the exceptions being internet users, mobile telephone subscribers, and urban fixed telephone subscribers. For the tests in 2006 and 2009, 68 and 81 percent respectively of dependent variables were spatially autocorrelated. This confirms that overall, high and low levels of technology utilization/availability are geographically agglomerated. The result corresponds to prior research in the late 1990s and early 2000s (Song, 2008), which demonstrated distinctive geographical regions for internet use.

Table 2. Spatial Autocorrelation of Dependent Variables, 2006 and 2009

	Dependent Variable							
	PCs per 100 Urban Families	PCs per 100 Rural Families	Broadband Subscribers per 100 Pop.	Internet Users per 100 Pop.	Number of Domain Names per 100 Pop.	Number of Web Pages per Capita	Mobile Telephone Subscribers per 100 Pop.	Urban Fixed Telephone Subscribers per Capita
2006	0.273**	0.225**	0.228**	0.281**	0.172*	0.077	0.172*	0.267*
2006, excl Beijing & Shanghai	0.264**	0.273**	0.222*	0.116	0.272**	0.121	0.038	0.151
2009	0.346***	0.206*	0.272**	0.264**	0.615***	0.086*	0.205*	0.252**
2009, excl Beijing & Shanghai	0.343***	0.239**	0.258**	0.137	0.236**	0.177*	0.061	0.143
* signif. at 0.05								
** signif. at 0.01								
*** signif at 0.001								

Cluster analysis of technology utilization and availability based on dependent variables, 2006 and 2009

Because the spatial autocorrelation analysis points strongly to clustering of high- and low-valued data points for dependent variables, K-means cluster analysis was performed for 2006 and 2009, in order to explore the overall patterning of all eight dependent variables for the nation. For six clusters in 2006, there were unique clusters for Beijing, Shanghai, and Guangdong, a mostly eastern coastal cluster (Fujian, Jiangsu, Tianjin, Zhejiang). China's central and western regions, split into the fifth and sixth clusters, the fifth consisting of 18 western, central and northeastern provinces, and the sixth of three southwestern, two central, and one eastern province. By far the highest technology utilization/availability was in the clusters of Beijing and Shanghai, with the other clusters quite low and the lowest in the fifth and sixth clusters. The ratio of the average of the Beijing and Shanghai clusters to the average of the fifth and sixth cluster varied between 3.8 for mobile subscribers to 54.2 for web pages, underscoring the very large technological differences in the regions of China in 2006.

The cluster results in 2009 for six clusters (see Figure 2), again resulted in unique clusters for Beijing and Shanghai, a third cluster eastern cluster of Tianjin and Zhejian, a fourth in the south of Fujian and Guangdong, a fifth cluster of 12 provinces in the west and south central areas plus Heilongjian in northern Manchuria, and a sixth cluster in the central east and north excluding Heilongjiang, plus Guangxi and Hainan in the south. The clusters in 2009 are meaningful geographically for the following reasons: (1) The clusters are not as different in population as they appear in land area. Excluding the unique clusters of Beijing and Shanghai, the population differences from the largest cluster (Group 5) to the smallest (Group 4) is only 8.7 to 1; (2) the division into Cluster 5 and 6 make sense because, for cluster 6, the separation of 11 geographically contiguous provinces in the west and south central regions from Heilongjiang in the northeast is justified by the latter's physical remoteness and poorer economic level. Furthermore, for cluster 5, 12 contiguous provinces in the center and northeast make sense as more intensive on the average on all six technology indicators than for cluster 6, which make stem from their closer proximity to the uniquely high technology and knowledge centers of Beijing and Shanghai, while Guangxi has proximity to the high technology province of Guangdong. Since the unique clusters are also apparent in the regression analysis, it is consistent and justified to include them. As seen in Table 2, Beijing and Shanghai have elevated values for all the dependent variables, while the clusters 3 and 4 are intermediate and clusters 5 and 6 quite low. For 2009, the ratio of averages of Beijing and Shanghai to the averages of clusters 5-6 is comparable to 2009. The growth of technology utilization and availability per capita between 2006 and 2009 is seen by the ratios of the technology utilization and availability averages of Beijing and Shanghai in 2009 to averages in 2006. Over the three years, web pages increased by 7-fold, domain names by 3.5 fold, and broadband by 1.5 fold, while only urban fixed telephone decreased by 21 percent. The latter stemmed from replacement by mobile phones. In sum, web pages and domain names thus have the greatest provincial differences between regions as well as the huge increase from 2006 to 2009. This reflects the large growth and major geographic disparities in the depth and breadth of web content.

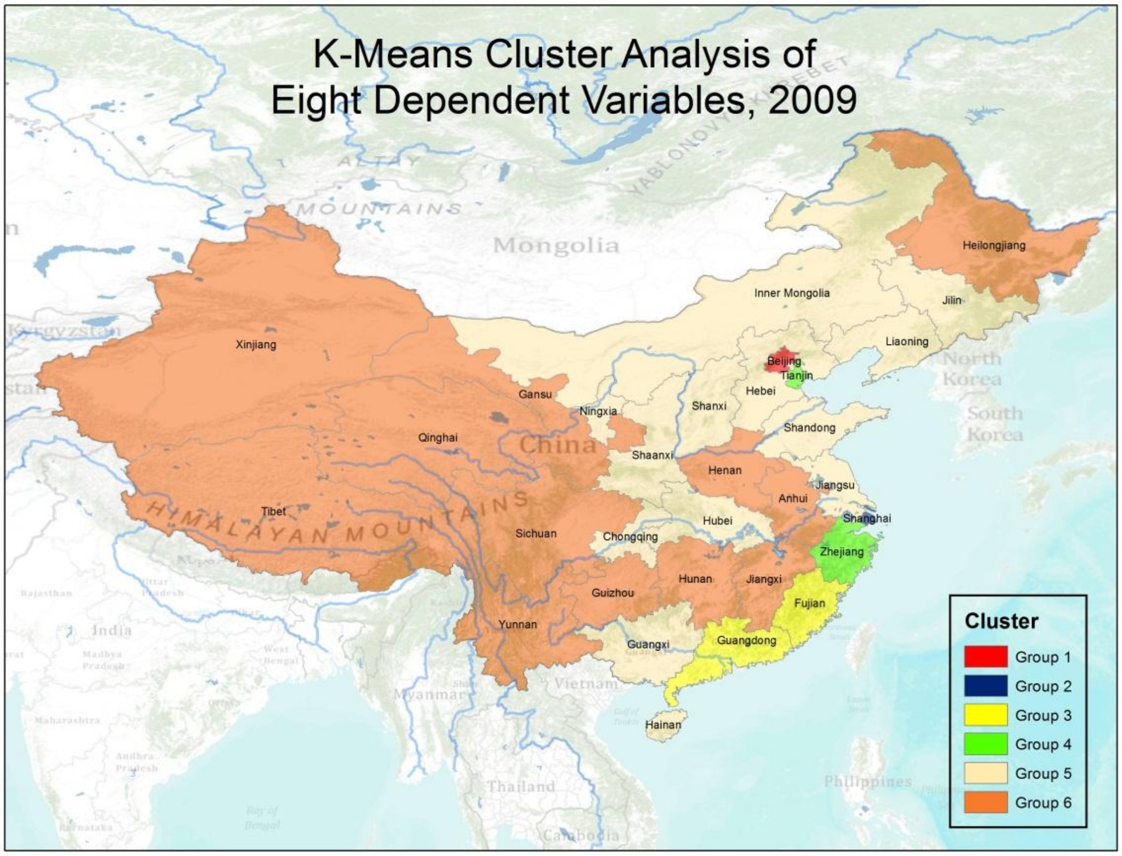

Figure 2. K-Means Cluster Analysis Based on 8 Dependent Variables, China, 2009

Table 3. Cluster Characteristics, 2009

	Clusters 2009							
Dependent Variable	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Ratio of High to Low Clusters[1]	Ratio of Averages of Clusters 1 & 2 in 2009 to 2006.
Pop. (in 1000s)	17,550	19,210	132,650	64,082	558,340	524,776		
Broadband	0.3209	0.3448	0.1662	0.1766	0.1040	0.0661	3.91	1.50
Domain Names	0.1687	0.0755	0.0213	0.0270	0.0072	0.0037	22.49	3.46
Internet User	0.6285	0.6096	0.4892	0.4706	0.2869	0.2022	2.53	2.15
Mobile Subscribers	1.0402	1.1001	0.8716	0.8503	0.5702	0.4173	2.17	1.14
Urban Fixed Telephone	0.3956	0.4807	0.2569	0.2665	0.1526	0.1131	3.30	0.79
Web Pages	549.8488	171.0206	48.7393	72.6208	10.9862	6.5049	41.21	6.77
	Beijing	Shanghai	Fujian	Tianjin	Chongqing	Anhui		
			Guangdong	Zhejiang	Guangxi	Gansu		
					Hainan	Guizhou		
					Hebei	Heilongjiang		
					Hubei	Henan		
					Inner Mongo	Hunan		
					Jiangsu	Jiangxi		
					Jilin	Qinghai		
					Liaoning	Sichuan		
					Ningxia	Tibet		
					Shaanxi	Xinjiang		
					Shandong	Yunnan		
					Shanxi			

Note 1: stands for Ratio of average of Cluster Groups 1 and 2 to average of Cluster Groups 5 and 6.

Note: Urban Pcs and Rural PCs not included in this table because the ratios cannot form a general cluster average for clusters of 2 or more provinces.

OLS regression findings

OLS stepwise regression findings for 2006 show the most important determinants to be export commodities value, significant for five regressions, and published books, significant for six (see Table 4). Published books dominates as the determinant for web pages and domain names. For urban pcs, the two dominant correlates are employees in non-state-owned units and employed persons in the tertiary sector. Other secondary correlates are construction innovation funds (for rural pcs, broadband, and web pages) and enterprise expenditure (for rural pcs and broadband). Overall, 87 percent of regressions passed the OLS regression tests (Joint Wald, Koenker (BP), and Jarque-Bera). However, Jarque-Bera failed for broadband, pcs for rural families, and web pages. Some caution is necessary when interpreting those findings, especially for the pcs for rural families. The reasons are unknown.

For 2009 OLS regressions (see Table 5), the most important correlate is export commodities value, significant for all eight dependent variables, followed by published books, significant for four. Published books is the primary determinant for web pages and for domain names. Of lesser importance are tertiary employment (for mobile telephone subscribers and urban fixed telephone subscribers) and foreign direct investment (for web pages and urban fixed telephone subscribers). In addition, construction enterprise expenditure is a significant correlate for internet user, and employees in non-state-owned units for pcs per urban families. Overall, 79 percent of regressions met the OLS regression tests (Joint Wald, Koenker, and Jarque-Bera). PCs per 100 rural families failed two tests (Koenker and Jarque-Bera). That regression is included in the results table, but needs to be treated with particular caution since the residual heteroscedasticity (variance of the sequence of random variables) and the kurtosis-skewness vary from normality. The reasons are unknown.

Table 4. Standardized Regression Results for Dependent Variables, China, 2006

		Dependent Variable							
Category	Independent Variable	PCs per 100 Urban Families	PCs per 100 Rural Families	Broadband Subscribers per 100 Pop.	Internet Users per 100 Pop.	Number of Domain Names per 100 Pop.	Number of Web Pages per Capita	Mobile Telephone Subscribers per 100 Pop.	Urban Fixed Telephone Subscribers per Capita
Industry	Electricity Ouput (100 million kwh) per capita								
Industry	Construction Enterprise Expenditure (100 million yuan) per capita		0.436***	0.465***					
Employment	Employeed Persons (10,000) in Tertiary Industry per capita	0.403***							0.444***
Employment	Staff and Workers by Non-State-Owned Units (10,000 persons) per capita	0.657***							
Individual Investment	Individual Investment in Fixed Assets (100 million yuan) per capita								
Trade	Export Commodities Value (1,000 US dollars) per capita				0.401*	0.458***	0.127***	0.717***	0.607***
Trade	Foreign Direct Investment (10,000 US dollars) per capita				0.427**				
Innovation	No. of Published Books (100 million copies) per		0.313***	0.263***	0.281***	0.730***	0.811***	0.423***	
Innovation	Innovation Funds (100 million yuan) of Enterprises per capita		0.414***	0.421***			0.283***		
Sicence, Technology, Education	Gov. Depts of Culture, Educ., Science, and Public Health Expenses (100 million yuan) of per capita								
Education	No. of Public Libraries per capita								
Education	Full-time Teachers in High Education Institutions (10,000 persons) per capita								
	Regression adjusted R square and significance level	0.786***	0.934***	0.930***	0.886***	0.939***	0.993***	0.865***	0.906***
	sample size (N)	31	31	31	31	31	31	31	31
	OLS REGRESSION TESTS								
	Joint Wald Statistic	203.3***	6771.9***	4661.1***	2339.7***	233.0***	97599.2***	96.9***	869.9***
	Koenker (BP) Statistic	0.729	2.472	0.440	2.218	1.650	3.018	4.868	0.511
	Jarque-Bera Statistic	1.477	32.329***	9.237***	1.112	165.276***	4.234	1.108	1.139
	SPATIAL AUTOCORRELATION OF RESIDUALS								
	Moran's Index	0.083	0.185*	0.196*	-0.111	-0.053	0.023	0.04	0.125

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

Controlling for Outlier values of book publishing in Beijing and Shanghai

A data analysis problem with published books is that its values are very much higher in Beijing and Shanghai for both 2006 and 2009, compared to the other provinces. The likely reason is the long-time predominance of these administrative units as cultural and intellectual capitals for book publishing. An explanation may be that the knowledge industries represented by traditional book publishing are closely associated with web pages and domain names, which reflect more recent knowledge content.

Table 5. Standardized Regression Results for Dependent Variables, 2009, China

Category	Independent Variable	PCs per 100 Urban Families	PCs per 100 Rural Families	Broadband Subscribers per 100 Pop.	Internet Users per 100 Pop.	Number of Domain Names per 100 Pop.	Number of Web Pages per Capita	Mobile Telephone Subscribers per 100 Pop.	Urban Fixed Telephone Subscribers per Capita
					Dependent Variable				
Industry	Electricity Ouput (100 million kwh) per capita								
Industry	Construction Enterprise Expenditure (100 million yuan) per capita		0.200		0.484**				
Employment	Employeed Persons (10,000) in Tertiary Industry per capita							0.401***	0.371***
Employment	Staff and Workers by Non-State-Owned Units (10,000 persons) per capita	0.433***							
Individual Investment	Individual Investment in Fixed Assets (100 million yuan) per capita								
Trade	Export Commodities Value (1,000 US dollars) per	0.596***	0.590***	0.765***	0.483***	0.239**	0.210***	0.588***	0.498***
Trade	Foreign Direct Investment (10,000 US dollars) per capita						0.073*		0.211*
Innovation	No. of Published Books (100 million copies) per		0.362***	0.411***		0.824***	0.878**		
Innovation	Innovation Funds (100 million yuan) of Enterprises per capita					0.124			
Science, Technology, Education	Gov. Depts of Culture, Educ., Science, and Public Health Expenses (100 million yuan) of per capita								
Education	No. of Public Libraries per capita								
Education	Full-time Teachers in High Education Institutions (10,000 persons) per capita								
	Regression adjusted R square and significance level	0.874***	0.911***	0.933***	0.810***	0.961***	0.987***	0.794***	0.913***
	sample size (N)	31	31	31	31	31	31	31	31
	OLS REGRESSION TESTS								
	Joint Wald Statistic	525.9***	4691.5***	117.5***	77.7***	22153.9***	35101.3***	191.4***	2317.8***
	Koenker (BP) Statistic	0.431	13.377**	2.306	11.756**	4.296	4.817	3.588	1.838
	Jarque-Bera Statistic	7.571*	7.456*	153.9***	1.940	62.306***	7.993*	0.796	0.346
	SPATIAL AUTOCORRELATION OF RESIDUALS								
	Moran's Index	-0.176	-0.125	0.122	0.187*	-0.010	0.002	0.135	0.194*

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

A test was conducted to control for the outliers by re-calculating the 2006 and 2009 regressions, excluding Beijing and Shanghai. The test results, seen in Tables 6 and 7, do reveal major change in the secondary variables, which confirms the outlier status of Beijing and Shanghai for published books.

For 2006, for most dependent variables (7 out of 8), the dominant determinant continues to be export commodities value. However, the secondary determinants have changed to construction enterprise expenditure (for rural pcs, broadband, and web pages) and employed persons in tertiary industry (for internet users and urban fixed telephone subscribers). For domain names, employment in non-state-owned units is dominant. Furthermore, staff and workers in non-state-owned units was significant for urban pcs. The OLS regression tests are quite similar to those for the whole sample in Table 4. The main difference is that the Koenker test for heteroscedasticity also fails for rural pcs; hence the domain-name results for rural pcs must be regarded cautiously.

For 2009, export commodities value remains significant for 7 out of 8 regressions. The important secondary correlates are changed to employees in non-state-owned units (for 4 regressions), employees in tertiary industry (for 3 regressions), and innovation funds of enterprises (for 2 regressions, namely web pages and urban fixed telephone subscribers). OLS regression tests are passed for 92 percent of regressions, all of which are included in this study, with caution mainly for rural pcs.

Table 6. Standardized Regression Results for Dependent Variables, 2006, China, Excluding Beijing and Shanghai

		Dependent Variable							
Category	Independent Variable	PCs per 100 Urban Families	PCs per 100 Rural Families	Broadband Subscribers per 100 Pop.	Internet Users per 100 Pop.	Number of Domain Names per 100 Pop.	Number of Web Pages per Capita	Mobile Telephone Subscribers per 100 Pop.	Urban Fixed Telephone Subscribers per Capita
Industry	Electricity Ouput (100 million kwh) per capita								
Industry	Construction Enterprise Expenditure (100 million yuan) per capita		0.457***	0.470***			0.478***		
Employment	Employeed Persons (10,000) in Tertiary Industry per capita				0.256**				0.289**
Employment	Staff and Workers by Non-State-Owned Units (10,000 persons) per capita	0.830***							
Individual Investment	Individual Investment in Fixed Assets (100 million yuan) per capita								
Trade	Export Commodities Value (1,000 US dollars) per capita		0.540***	0.509***	0.747***	0.751***	0.479***	0.849***	0.577***
Trade	Foreign Direct Investment (10,000 US dollars) per capita								
Innovation	No. of Published Books (100 million copies) per capita								
Innovation	Innovation Funds (100 million yuan) of Enterprises per capita								
Science, Technology, Education	Gov. Depts of Culture, Educ., Science, and Public Health Expenses (100 million yuan) of per capita								0.295**
Education	No. of Public Libraries per capita								
Education	Full-time Teachers in High Education Institutions (10,000 persons) per capita								
	Regression adjusted R square and significance level	0.677***	0.853***	0.819***	0.839***	0.548***	0.780***	0.710***	0.828***
	sample size (N)	29	29	29	29	29	29	29	29
	OLS REGRESSION TESTS								
	Joint Wald Statistic	122.0***	36.7***	97.6***	206.9***	28.7***	37.5***	36.0***	176.6***
	Koenker (BP) Statistic	0.564	17.382***	1.532	1.340	1.311	9.107	5.450	0.621
	Jarque-Bera Statistic	5.807	21.411***	27.253***	1.143	306.039***	7.890	0.483	2.123
	TEST OF SPATIAL AUTOCORRELATION OF RESIDUALS								
	Moran's Index	0.080	0.161	0.059	-0.042	0.048	0.039	0.064	-0.027

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

Table 7. Standardized Regression Results for Dependent Variables, 2009, China, Excluding Beijing and Shanghai

		Dependent Variable							
Category	Independent Variable	PCs per 100 Urban Families	PCs per 100 Rural Families	Broadband Subscribers per 100 Pop.	Internet Users per 100 Pop.	Number of Domain Names per 100 Pop.	Number of Web Pages per Capita	Mobile Telephone Subscribers per 100 Pop.	Fixed Telephone Subscribers per Capita
Industry	Electricity Ouput (100 million kwh) per capita							0.293**	
Industry	Construction Enterprise Expenditure (100 million yuan) per capita								
Employment	Employed Persons (10,000) in Tertiary Industry per capita				0.264**			0.251*	0.327***
Employment	Staff and Workers by Non-State-Owned Units (10,000 persons) per capita	0.385***	0.479**		0.273*	0.718***			
Individual Investment	Individual Investment in Fixed Assets (100 million yuan) per capita			0.254*					
Trade	Export Commodities Value (1,000 US dollars) per capita	0.571***	0.416*	0.761***	0.555***		0.682***	0.684***	0.559***
Trade	Foreign Direct Investment (10,000 US dollars) per capita								
Innovation	No. of Published Books (100 million copies) per capita								
Innovation	Innovation Funds (100 million yuan) of Enterprises per capita						0.346***		0.225*
Science, Technology, Education	Gov. Depts of Culture, Educ., Science, and Public Health Expenses (100 million yuan) of per capita								
Education	No. of Public Libraries per capita								
Education	Full-time Teachers in High Education Institutions (10,000 persons) per capita								
	Regression adjusted R square and significance level	0.783	0.674***	0.790***	0.811***	0.498***	0.783***	0.783***	0.787***
	sample size (N)	29	29	29	29	29	29	29	29
	OLS REGRESSION TESTS								
	Joint Wald Statistic	195.5***	19.7***	128.5***	226.7***	11.9***	67.8***	180.2***	314.5***
	Koenker (BP) Statistic	0.582	9.229	0.989	0.666	2.911	9.103	0.317	5.536
	Jarque-Bera Statistic	8.340	23.470***	0.274	0.529	8.522*	0.195	0.969	0.594
	TEST OF SPATIAL AUTOCORRELATION OF RESIDUALS								
	Moran's Index	-0.163	-0.092	0.057	0.152	-0.028	0.075	0.089	0.136

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

Spatial Autocorrelation of Residuals

Overall findings reveal for the regression residuals only slight spatial autocorrelation, as measured by significant values for Moran's I. For the OLS regression residuals given in Tables 4-7, 94 percent were not spatially autocorrelated, while those with spatial autocorrelation were at the 0.05 level (rural pcs for the whole sample in 2009 and internet users for the sample excluding Beijing and Shanghai in 2009). The decrease from 75 percent of dependent variables autocorrelated to 6 percent of regression residuals autocorrelated supports that the OLS regressions have been highly effective in controlling for the major spatial clustering of high values and low values for dependent variables for both years.

DISCUSSION

Technology growth in China at the provincial level, 2006-2009

An explosion in technology utilization/availability occurred in China from 2006 to 2009. Annual growth rates for 2006 to 2009, calculated on provincial per capita averages, were as follows: pcs urban (17.7%), pcs rural (49.0%), broadband subscribers (32.1%), internet users (36.7%), domain names (73.0%), web pages (84.7%), mobile telephone subscribers (17.9%), and urban fixed telephone subscribers (-5.0%). This growth stemmed from robust economic expansion, in spite of a recession towards the end of the period, that favored business and personal purchase of pcs, mobile phones, internet, and web services; and government relaxation of some constraints on internet and web favoring broadband subscriptions, internet users, domain names, and web pages. Although on March 30, 2010, Google elected, due to censorship, to redirect Google China traffic to Google Hong Kong, by June 30, 2010, it moderated this to only an optional link to Google Hong Kong. Overall, China's massive trend has been towards rapid growth in internet and web use. Also, there was improvement in infrastructure throughout China, including expansion in broadband networking, cell phone towers, and web servers, that favored rapid technology utilization growth. Furthermore, China's growth benefitted by the worldwide shift of the rapid growth of global technology use from the economically advanced countries favored in the 1990s to middle-level nations in the 2000s, sometimes referred to as the global internet's "second wave."

Interpretation of OLS Regression Findings

The major finding of this investigation is that export commodities value is the dominant determinant of technology utilization and availability at the provincial level. Export commodities value has not previously been cited as a factor in digital divide research. The reason could be that heavily export-based economies have not been studied from the standpoint of their internal regions and states/provinces. China increased its exports vastly in the period of 1990-2003, during which it exported goods valued at $380 billion (Hale and Hale, 2003). Since 2003, China's exports continued at a high level through 2007, although the proportion of domestic consumption in the nation's economy declined slightly (Klein and Cukier, 2009). As the Great Recession of 2007-2009 ended, China returned to its prior level of huge exports (Klein and Cukier, 2009). The related aspects of China's huge economic boom have been growing world exports, liberalization of the economy, national-government-initiated investment particularly in infrastructure, and focus on high tech (Hale and Hale, 2003; Klein and Cukier, 2009).

Another relevant trend has been growing foreign direct investment, which by 2003 was $450 billion annually, fifth in the world (Hale and Hale, 2003) and is even higher today. Although some problems loom for this export-driven economy including wage inflation, devaluation of the Chinese renminbi, greater domestic consumption, and some non-productive infrastructure (Wong, 2010), it is likely this model will continue for some time in the future. Consequently, in China's provinces, the strong association of export commodities value and technological utilization and availability is due to export-related foreign and domestic investments which have focused on technology (Hale and Hale, 2003). The export economy and FDI have also been highly geographically weighted towards China's eastern region, which corresponds to the much higher technology levels in the east mentioned earlier. However, exports have been better associated than FDI with technology at the provincial level. FDI is a significant correlate in only one out of 32 regressions in this study (internet users in 2006).

An important secondary finding is that published books is quite prevalent as a significant determinant in 2006 and 2009. We interpret this influence as being due to the outlier status of Beijing and Shanghai in published books that is similar to their leadership status in technology utilization and availability. Those two centrally administered municipalities are the intellectual capitals of mainland China and the traditional location of both origin of book products and, more recently, the origin of development of web content production, internet communications, and the technologies to support these and for consumers in the centrally administered municipalities to consume the content. The consumption of published books and of web and internet content is more evenly balanced throughout China, but provincial data on consumption for these two variables are not available. Prior studies have not identified published books as important, perhaps due to other nations' provincial and state data being more keyed to consumption of knowledge products and services than its production, and also because knowledge content has not been emphasized in the literature.

Two other secondary factors of tertiary employment and employment in non-state-owned enterprises were present mainly for the samples excluding Beijing and Shanghai. Three coefficients of these two employment factors were significant for the samples in 2006 and seven coefficients of the two employment factors were significant for the 2009 samples. Each factor is about equal in importance overall. Tertiary workers have been rarely included in digital divide literature; an exception is that "professional/scientific/technical services" workforce, which is tertiary, was significantly associated with dependent variables IS-data processing payroll per capita and IS-data processing receipts per capita in a study of U.S counties (Azari and Pick, 2005). A workforce with secondary and higher education, appropriate for the tertiary sector, has been noted as essential to developing technology use in Asia (Quibria, 2003). In China's case, the export-oriented factories need engineers, IT specialists, and business specialists to manage and raise the manufacturing to world class standards. Hence, tertiary workforce is essential. Likewise, the secondary factor of workforce in non-state-owned units can be justified since a workforce with higher technology skill level is necessary for those units to be competitive in worldwide markets. It follows that these units are also more likely to utilize IT and have it available.

Lastly, a secondary factor that is important in 2006 for the full sample and the sample excluding Beijing and Shanghai is construction enterprise expenditure. Its importance in 2006 relates to a portion of the investment in infrastructure including IT infrastructure that China implemented in the 1990s and 2000s as it opened up its economy. It is an important part of the domestic and foreign investment that has been essential to its economic growth (Hale and Hale, 2003). By 2009, some of the IT infrastructure, especially in the East, had reached a mature level, so construction enterprise expenditure became less crucial. In the West, however, construction especially in ICT continues to be crucial for technology availability and utilization, so it should be considered for future studies that emphasize the western provinces.

Example of Internet Users in 2009

Figure 3 shows a map of the spatial distribution of the regression residuals for internet users in 2009. Even though these residuals did not show significant spatial autocorrelation, as measured by Moran's I (see Table 7), there are four agglomerations, numbered 1-4 that can be interpreted as an example.

1. **"Policy-oriented model."** Shanxi, Hebei, Beijing, Tianjin, Liaoning have high positively spatial autocorrelation. In China, these provinces are called "Jing-Jin-Tang Old Industrial Base."

These provinces have similar industry structures (mainly state-owned large and medium enterprises, heavy industry), and Beijing is the core municipality. In these provinces, the IT utilization development model is "policy-oriented", that is, central government in Beijing makes the policy on state-owned industries development in near provinces. And these state-owned companies may invest on hardware, e.g., internet.

2. **"Low-end industry transfer model."** Shanghai, Jiangsu, Anhui, Zhejiang, Jiangxi in clusters 3, 4, and 6 are called "Yangtze River Delta Economic Zone (Hu-Ning-Hang Light Industrial Base)" which focus on the free economic market. Shanghai is the core in these provinces. In these provinces, the IT utilization development model may be "low-end industry transfer model," although less so for Jiangsu Province, which is partly a foreign export hub for electronics manufacturing. With development of Shanghai, it may transfer some low-end industries to nearby provinces, such as Anhui. These industries are most private light industry which may not invest in the Internet. Thus, with the development of Shanghai, the IT utilization of surrounding provinces may be lower.

3. **"Overseas Model."** Guangdong and Fujian have high positive spatial autocorrelation, the provinces are called "Pearl River Delta Economic Zone." They do not have a core. In many respects, the core of industry development is overseas, e.g. in Taiwan, Hong Kong, or Korea. These provinces share a common economic development model, that is, take industry transferred from overseas. These provinces have not upgraded their own industry and transferred low-end industry to other provinces. Thus, other near provinces do not have spatial correlations with them.

4. **"Highland Model."** Tibet has negative spatial correlation with other western provinces. The possible reason is that Tibet is highland, and the internet cannot be developed as easily as other near provinces. That means, in China's western provinces, there is not a clearly interpretable agglomeration in terms of IT utilization.

Limitations

The limitations of this research study involve constraints of data, sample size, and variables. The sample size is limited to 31, so methodological techniques that can be applied are limited, and exclude structural equation modeling, subsample regressions, geographically weighted regressions, and other techniques. The three-year change could be alternatively be studied by including provincial technology growth rates as dependent variables and accounting for

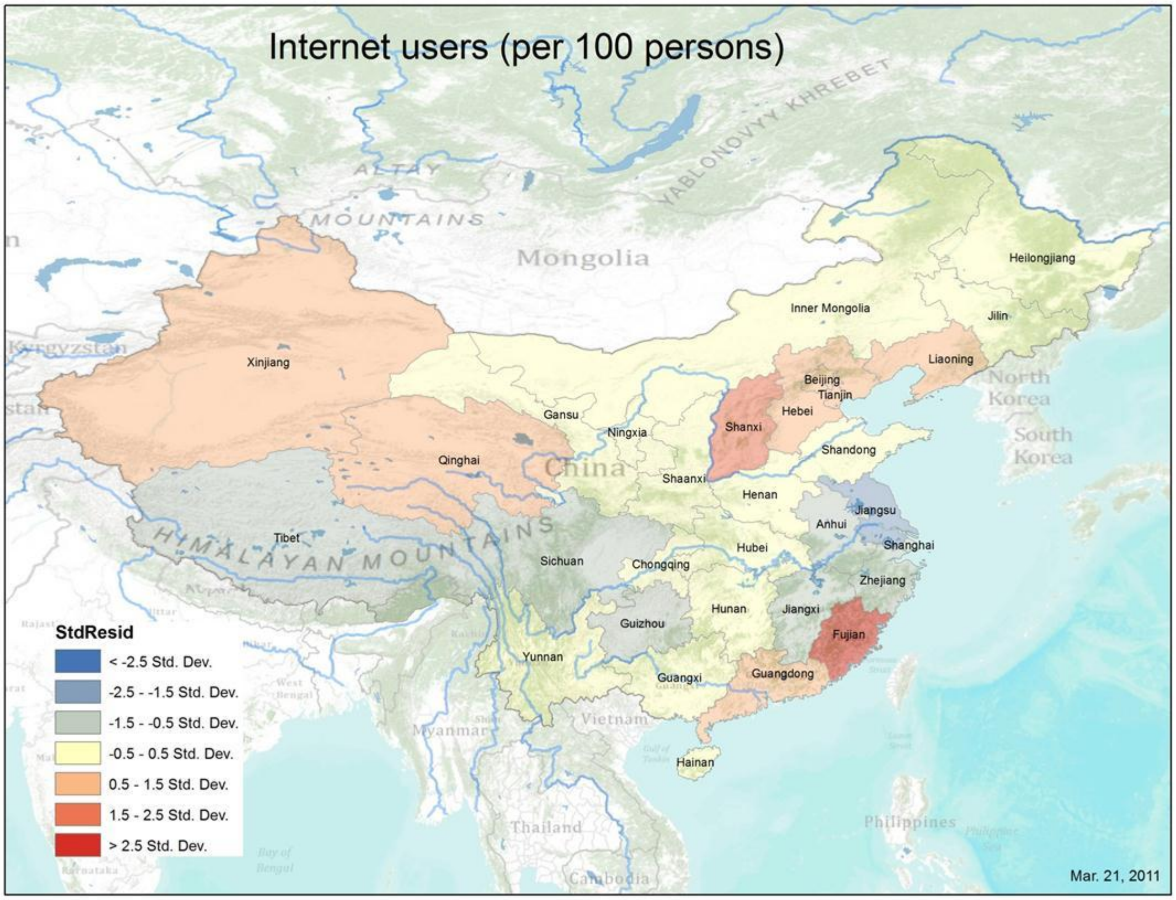

Figure 3. Regression Residuals for Internet Users per Capita, China, 2009

provincial change with either provincial socioeconomic change or average socioeconomic values for the period. Although we did a preliminary analysis along these lines, we did not feel it yield as rich interpretation as cross-sectional regressions for the start and end years. Another limitation is that variables are constrained by the extent of China's statistical agencies' provincial data. Some variables appearing in the Chinese literature are not available in government sources for all provinces. Future large-scale field studies could collect these data. Attributes have not so far been collected by the agencies on societal openness, judicial independence, and technological investment, ones found to be significant in prior studies. Further, information at the provincial level on R&D and innovation is limited. A further literature limitation is that case studies of provinces are scarce, which would help on qualitative understanding of particular provinces.

Results for research questions

1. *Are the 2006 dependent variables spatially autocorrelated?*

7/8 are spatially autocorrelated. Excluding Beijing and Shanghai, 4/8 are spatially autocorrelated

2. *Are the 2009 dependent variables spatially autocorrelated?*

All are spatially autocorrelated. Excluding Beijing and Shanghai, 5/8 are spatially autocorrelated.

3. *What are the changes in the overall geographic pattern of clustering of the dependent variables between 2006 and 2009?*

Although the Beijing unique cluster and SE and E clusters are fairly consistent, the fragmented SW and central N cluster is consolidated to become a large W and central S cluster.

4. *What are the most significant economic and social determinants of utilization of the dependent variables for China, taking into account spatial proximities, in year 2006?*

The most significant determinants are export commodities value and no. of published books. When Beijing and Shanghai are excluded, they become export commodities value, tertiary employment, employment in non-state-owned units, and construction enterprise expenditure.

5. *What are the most significant economic and social determinants of utilization of the dependent variables for China, taking into account spatial proximities, in year 2009?*

The most significant determinants are export commodities value and no. of published books. When Beijing and Shanghai are excluded, they become export commodities value and the employment factors of employment in non-state-owned units and tertiary employees.

6. *Are the 2006 and 2009 regression residuals following ordinary least squares (OLS) regression spatially autocorrelated?*

For both years, only two residuals are spatially autocorrelated, internet users in 2009 and urban fixed telephone subscribers in 2009. When Beijing and Shanghai are excluded, no residuals are autocorrelated.

7. *What are the changes in economic determinants of technology utilization and availability between 2006 and 2009?*

The changes between 2006 and 2009 relate to the secondary determinants outside of Beijing and Shanghai, which change from industry and transportation determinants related to construction and highways in 2006 to employment in the tertiary and business sectors in 2009.

POLICY IMPLICATIONS

Among the policy implications are the following:

1. Technology utilization for expanding web content has been associated with the publishing centers of Beijing and Shanghai. Other centers for development of web content might be supported in other provinces with publishing and higher education concentrations such as Guangdong, Jiangsu and Zhenjiang. The web content of some provinces in Western and Middle Region, such as Hunan, Anhui and Chongqing, which have good foundations on higher education, could be stimulated by policies more easily.

2. Since technology utilization is so closely related to export commodities value, other provinces could be supported for export industries and export of commodities. There would likely be the effect that those provinces would be stimulated in technology utilization. Currently, the Chinese government encourages "low-down industry transfer," i.e. in particular, several export industries will be transferred from developed provinces (e.g., Beijing and Shanghai) to Middle and Western Regions in the period of "twelfth 5-year plan" (2011-2015). It is expected that other provinces will be stimulated similarly in technology utilization within 5 years.

3. The signs in 2009 that innovation funds of enterprises are associated with technology utilization for web pages and urban fixed telephone subscribers could be more fully supported by encouragement of innovation and R&D in more enterprises in China. In the Chinese government's "twelfth 5-year plan," innovation funds will be improved, and more enterprises in China will be encouraged to establish an Engineering Research Center, Innovation Center, and other R&D centers. However, there is a tendency that developed provinces have advantages to establish R&D centers (e.g., the advantages of lifestyle environment and higher education resources). Also, they may enhance their advantages by providing high salaries and innovation funds to attract very qualified talents (e.g., those with PhDs). Thus, to reduce the digital divide of

technology utilization in China, Middle and Western provinces need to be provided with more innovation funds or otherwise supported by the central government to keep and attract their own talented individuals to develop R&D in enterprises of these provinces.

4. The Western region which has by far the lowest technology utilization can be stimulated by policies building on the results of the study, which include more export oriented enterprises, higher proportion of non-state-owned enterprises, innovation and R&D in enterprises, and more publication-related activities. This applies also to a lesser extent to provinces in the Middle Region of China. In the context of "low-down industry transfer," more export oriented and non-state-owned enterprises will be encouraged to transfer to the Western and Middle Regions. For those provinces, some policies such as tax cuts and/or cheaper land for industry may be provided for these enterprises, and it is expected that the policies will neutralize or reverse a downward trend in the level of technology utilization within the next 5 years.

CONCLUSION

China's provincial technology levels grew extremely rapidly 2006-2009. This is in concert with a second global shift in rapid technology growth during this period in mid-level economies.

An exploratory conceptual model was established, based on prior literature, and including screening for spatial clustering of like-valued outcome attributes.

Findings indicate China's provinces are spatially agglomerated in high or low levels of technology variables, and the agglomeration pattern has not changed much from 2006-2009, with the main change in the West Region. The most dominant determinant of China's technology levels both years is export commodities value. The interpretation is that provinces that have major export have modern manufacturing industries and support sectors that need technologies of varied types. Secondary determinants on technology utilization and availability are published books, tertiary and business sector employment, and construction enterprise expenditure for 2006. They relate to the knowledge generation concentrations especially in Beijing and Shanghai; to the role of need engineers, IT specialists, and business specialists to manage and raise the export-oriented manufacturing to world class standards; and to a shift from technology associated with infrastructure (secondary production) in 2006 to technology more associated with knowledge and business services (tertiary production) in 2009.

The research checked validity of findings by conventional OLS regression diagnostics and also by screening of the dependent variables and the OLS regression residuals for spatial autocorrelation. The empirical findings not only justified that the dependent variables were highly spatially agglomerated with significant spatial autocorrelation further elaborated by cluster analysis, but also that the OLS regression model controlled largely for spatial autocorrelation in regression residuals.

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