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Abstract

The paper presents some empirical results of Information & Communication Technology diffusion within China and across countries in Asia. The paper finds that China and most developing countries in Asia are bypassing fixed-line telephone infrastructure by adopting wireless technology. The results also show that the market potentials of mobile phones are greater than fixed-line telephones in these developing countries.

Keywords: Internet, diffusion, China, bass diffusion model

Introduction

Over the past decade, a rapid development has taken place in the field of information and communication technologies[1] (ICTs). Recent technological advances in the Internet and the World Wide Web (WWW) have opened up a new digital world. Similar to the past diffusion pattern of other information technologies, the Internet is first developed and advanced in countries with sufficient economic and technological resources. Less developed countries are now following the developed world at distance and at variable paces (Petrazzini and Kibati, 1999; Peha, 1999).

Some observers are highly optimistic about the distributive impact of the Internet. For example, Nicholas Negroponte of MIT Media Labs (**http://www.wired.com/wired/6.01/negroponte.html**) argues that the Internet is different from past technologies and the leapfrogging story could be right this time. However, empirical evidence indicates that new ICTs can be highly beneficial to certain communities and countries and may lead to divergence, rather than convergence, between developed and developing countries (Rodriguez and Wilson, 2000). The term Digital Divide has been used to refer to the overall gap and disparity between developed and developing countries in ICT utilization and the Internet access (Lu, 2001).

While there has been voluminous and diverse literature investigating diffusion of innovations in developed countries, the studies regarding to the same issue in developing countries are still rather scarce and anecdotal. Therefore, the current paper addresses two important issues: *(1) How ICT diffusion pattern varies from developing countries to developed countries; (2) Whether ICT diffusion narrows or widens digital divide, both across countries and across different regions within a country.*

To examine these issues, we draw on the past conceptual and empirical work in innovation diffusion to empirically compare the diffusion of ICTs and the Internet in China with a number of other economies in world. We choose China as the focus of the current study because China is one of the fastest growing markets (and the biggest one) in the world and has drawn a great deal of attentions in recent years.

As in most countries, there had been only one government owned telecom service provider in China since 1949 – the central and local Postal and Telecommunication Administration (PTA). Realizing that telecommunications industry is a crucial infrastructure for sustaining China's economic development, the Central Government of China started to open its telecom markets in late 1990s.

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[1]The World Bank defines information and communication technologies (ICTs) as a set of electronic means that facilitate the production, transmission, processing, and display of information.

In 1998, the Ministry of Information Industry (MII) was formed to oversee the telecom sector. Ever since then, in an effort to move away from national monopolies to competitive environment, the telecom sector of China has been experiencing continual regulation and deregulation, consolidation and deconsolidation (Tan et al., 1999). During this period of time, the investment in Chinese telecom industry has been growing at a much faster speed compared to other developing countries. For instance, in 1999, Chinese telecom investment was about eight times that of India (Euromonitor, 2001). From 1995 to 1999, China has achieved the annual growth rate of about 29% -of fixed-line telephones, the highest among the countries in the East Asia and Pacific region. By October 2002, China had more than 200 million fixed-line subscribers – the second largest in the world after the US and over 195 million cellular users – the largest in the world (Dahlman and Aubert, 2001; MII, 2002). The number of Internet users in China reached 59.1 million by December 2002 (CNNIC, 2003). Therefore, it is valuable to compare the diffusion patterns of ICTs and the Internet in China with other countries and economies.

Although the number of ICTs and Internet users in China is large in terms of raw numbers, it represents only a small proportion of China's total 1.3 billion population (twenty percent and six percent, respectively). With about seventy percent of its people engaged in agriculture, China remains an agricultural society with only eastern provinces industrialized. While per capita GDP of the developed provinces and large cities have achieved the level close to that of upper-middle income countries, the overall per capita GDP of China is only $877 (WDI, 2001). We could conjecture that the digital divide across different provinces within China may be as large as that between China and developed countries. Therefore, a study of the ICTs and the Internet diffusion within China is also important.

The structure of the paper is as follows. First, we briefly review the relevant literature. The research methodology and data-collection processes are then discussed. We empirically examine and compare ICT and the Internet diffusion patterns and digital divide within China as well as across countries in the discussion section. We conclude by discussing the limitations of the study and the implications of the findings for practitioners and academics.

Research Framework

To study innovation diffusion across regions, two important issues need to be addressed. The first is to determine and compare the speed of innovation diffusion and the second issue is to find diffusion patterns that may (partly) explain the differences in speed of innovation diffusion across regions. Various forms of diffusion patterns have been proposed in the literature. The Bass Diffusion Model (BDM) (Bass, 1969), which assumes a slower logistic (S-shaped) diffusion pattern, has been widely applied to a variety of innovation diffusion processes in marketing research. The discrete time version of the BDM is written as:

$$y(i,t) - y(i,t-1) = [\,p(i) + q(i)/m(i) * y(i,t-1)][m(i) - y(i,t-1)] + u(i,t) \tag{1}$$

Where,

y(i,t)	=	cumulative penetration (per-capita use) of an innovation in country i at time t
m(i)	=	market penetration potential in country i
p(i)	=	coefficient of innovativeness (external influence) in country i
q(i)	=	coefficient of imitativeness (internal influence) in country i
u(i,t)	=	disturbance term in country i at time t

The underlying behavioral rationale of the BDM is that the probability for the population adopting an innovation at time T given that it has not yet been adopted depends on two forces, the tendency of the population to innovate and the tendency of the population to imitate. The difference between innovators and imitators is that innovators are not affected by the number of existing adopters in the timing of their initial adoption while the number of existing adopters influences imitators. Correspondently, the tendency of the population to innovate, acting mainly based on external forces of the social system and independent of the existing number of adopters, is captured by the parameter p. The other force, the tendency of the population to imitate, is captured by the parameter q, which represents the internal social influence of existing number of adopters within the system on potential adopters. The parameter m indicates the market penetration potential of a region.

A number of studies have applied the BDM to investigate innovation diffusion process in the international settings. Heeler and Hustad (1980) tested the BDM with more than ten innovations across a large number of countries in various regions (both developed and developing countries). They found that the performance of the model degrades largely when applied to international settings, especially in developing countries. One possible explanation for the estimation difficulties is that the structure of the BDM might not be flexible enough to represent multiple diffusion processes that occur in different cultural and environmental contexts. Gatignon et al. (1989) examined the penetration of six innovations in fourteen developed countries in Europe and the impact of the country characteristics on the penetration. Their basic findings generally confirm the applicability of the BDM in a particular setting, i.e., within a certain geographical area with relatively homogeneous country characteristics. Talukdar et al. (2002) applied the BDM to examine innovation and diffuse of six products across many countries (both developing and developed countries). Instead of estimating p_i, q_i and m_i of each country individually, by pooling the data across countries and products, they focused on investigating the relationships between country characteristics and parameter p, q and m in general.

The products used in the previous Bass model-related studies are mostly consumer durables like sewing machine, calculator, and CD player, etc. In most studies, the products have been chosen with very little justification and the possible inter-relationships between diffusions of different products are rarely considered. The primary focus of this study is to compare the diffusion patterns of the Internet and Internet-related technologies across regions. The information technologies examined in this study, therefore, are chosen based on their impact on the Internet accessibility for the population of a country or a region. This study is also concerned about the possible interaction effects of multiple technologies used for similar purpose. It employs the BDM to estimate the coefficients of innovation (p_i), imitation ($q_{i)}$ and market potential (m_i) of each region (country or province) for each innovation.

The literature on innovation adoption in developed countries is primarily concerned about consumers' perception of the innovation and their willingness to adopt (Rogers, 1983). However, in the case of developing countries, customers' ability to pay is much more important. While studies have shown that the level of technological advances of a region is positively associated with its per capita income (Barro, 1997), the current study goes beyond examining the relationship between economic growth and technological progress, it is focused on investigating whether the differences in ICT advances between different countries and regions have become wider or narrower over time.

Research Methodology

Measures of Penetration

Since this study is focused on diffusion of Internet and Internet-related technologies, the main consideration for choosing variables to measure the penetration is that they should either directly reflect the penetration of the Internet or represent the penetration of Internet-related information technologies. . A variety of measures have been proposed to measure Internet diffusion, ranging from single variables such as the number of domain names, WWW pages, and hosts etc. to more complex multi-dimensional measures (Wolcott et al., 2001). This study chooses two commonly adopted measures, the number of Internet users and WWW websites, as direct Internet penetration indicators. Besides, it is clear that telephone mainlines, mobile telephones, cable TV and personal computers are basic devices to access the Internet. Thus, penetration of telephone mainlines, mobile telephones, personal computers and cable TV, is also included in the study. We use Purchasing Power Parity (PPP) adjusted average income per capita and GDP per capita to measure per capita income across countries and across provinces within China, respectively.

Other than China, a number of countries and population groups such as some countries in East Asia and South Asia (they are geographically or economically close to China), the US (the leading economy in world) and several aggregated population groups (the lower-middle income, the middle income, the upper-middle income group, the high-income) are included in the study to help develop a framework for comparison.

Data

Country-level and income data for various population groups were obtained from the databases of the World Bank (WDI online, 2001) and the International Telecommunications Union (ITU) of the United Nation (UN). To correct for the influence of widely varying populations on the model estimation, per capita penetration data is chosen or computed if not directly available in data sources. The data of the number of WWW websites are not available at country level therefore were not included in the across-country study. Province-level data within China were assembled from various reports of the Ministry of Information Industry (MII), the Statistics Bureau, the Statistics Information Center, and the China Internet Network Information Center. Since the data on ICT diffusion are extremely sparse in most developing countries and many provinces within China, the study has to limit its scope to examine diffusion patterns and possible digital divide based on the available data. To achieve stability in estimating the model parameters, the analysis time period was limited to only those intervals for which sufficient data are available.

Model Estimation

The discrete BDM in equation (1) may be rewritten as:

$$y(i,t) - y(i,t-1) = p(i)m(i) + [q(i) - p(i)] * y(i,t-1) - [q(i)/m(i)]y^2(i,t-1) \quad (2)$$

Substituting a_i, b_i, c_i for the coefficients in equation (1),

$$y(i,t) - y(i,t-1) = a(i) + b(i) * y(i,t-1) - c(i)y^2(i,t-1) \quad (3)$$

Where, y(i,t)-y(i,t-1) represents a single period of penetration accumulation at time t for a country i, and y(i, t-1) refers to cumulative penetration up through period t-1 for a country i. Following Bass's estimation method, multiple regression with Ordinary Least Square estimates is used to estimate the coefficients a_i, b_i, and c_i in equation (3). The model parameters p_i, q_i, and m_i are then uniquely identified by a_i, b_i, c_i in the form of:

$$p(i) = a(i)/m(i)$$
$$q(i) = -m(i)c(i)$$
$$m(i) = [-b(i) \pm \sqrt{b^2(i) - 4c(i)a(i)}]/[2c(i)]$$

Since a number of different indicators - telephone mainlines, mobile telephones, personal computers, cable TV subscribers and Internet users – are used in the study, they may capture different aspects of technological progress as well as other idiosyncratic characteristics of a particular country or province. For example, a large number of mobile phones per capita may reflect a possible lack of fixed-line infrastructure in a particular region instead of technological advances. A composed index, which combines penetration information of all these technologies, is needed to determine the overall technological advance of a region and make comparison across regions. To capture the common source of variations in the levels of technological progress, principal component analysis is used. The composed component score, a linear combination of the progress of different technologies, measures to what extent the variances in its components is due to a single common factor that differs across regions. This component score, therefore, may be used as an indicator of the overall technological advances in different regions. For the purpose of comparison, the study uses technological penetration data of year 1996 and year 2000 to construct the component scores and calculate the progress of Internet-related technologies both across countries and across provinces within China. Since Chinese provincial data before 1996 are sparse and insufficient to construct component scores, the study is forced to use year 1996 as base. Contrasting the diffusion patterns within China and across different countries over the same period of time could prevent heterogeneity in the model from other sources.

Results and Discussions

Diffusion Patterns across Countries

The diffusion parameters estimated using Ordinary Least Square for each country and income group for each technology are shown in Table 1-1 and Table 1-2. The empty cells represent the cases that do not have sufficient data for parameter estimation. The cells labeled 'N/A' represent the cases for which the signs of estimated coefficients make the computation of the basic diffusion parameters (p, q, and m) impossible (e.g. negative value of the coefficient a and negative argument of square root in computing m). Failure to obtain parameters with the correct signs is a common problem in the studies using the BDM. The results of this study are acceptable compared to the studies of Gatignon et al. (1989) and Heeler and Hustad (1980), where the parameters could not be estimated in about one third of the cases due to the wrong signs at the first stage.

The results reflect some important diffusion patterns across regions. Talukdar et al. (2002) found that market potential (m) is positively related to consumers' ability to pay (measured by per capita income PPP) in a nation and their willingness to pay. The data in Table 1-1 and 1-2 show that market potential of each technology in each country or region is largely correlated to the income level of the country or region. The estimated market potential parameter (m) of China is relatively lower than most other countries for each technology. However, as per capita penetration data is used in the model estimation, the total market potential of a country is given by tm(i) = m(i)N(i), where N(i) is the population of the country i. Therefore, for a country where the per capita market potential m is low, the total market for a technology in raw numbers can be quite large due to the size of the population of the country (e.g. China).

Table 1-1. Estimated Diffusion Parameters from the Bass Model by Country/Region

Technology / Country	Income Classification*	Mainline Telephones			Mobile Phones			PCs			Cable TV Subscribers			Internet Users		
		m	p	q	m	p	q	m	p	q	m	p	q	m	p	q
China	Lower Middle	46.087	0.002	0.333	113.561	0.002	0.704	22.184	0.005	0.689	N/A	N/A	N/A	11.872	0.004	3.781
Hong Kong, China	High	N/A	N/A	N/A	1053.705	0.002	0.658	N/A	N/A	N/A	69.287	0.139	1.028	378.658	0.040	1.683
India	Low	43.530	0.002	0.138	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12.886	0.002	0.968
Indonesia	Low	39.487	0.014	0.407	296.334	0.000	0.653	10.533	0.012	0.447				N/A	N/A	N/A
Japan	High	1163.529	0.062	0.317	532.935	0.007	0.769	531.345	0.001	0.289	177.925	0.101	0.491	324.135	0.020	0.428
Korea, Rep.	High	482.844	0.006	0.222	559.664	0.007	1.425	144.567	0.088	0.147	N/A	N/A	N/A	331.582	0.025	2.676
Malaysia	Upper Middle	235.049	0.001	0.210	N/A	N/A	N/A	N/A	N/A	N/A				164.348	0.016	1.248
Pakistan	Low	25.399	0.011	0.250	2.612	0.005	0.913									
Philippines	Lower Middle	123.287	0.002	0.157	N/A	N/A	N/A	N/A	N/A	N/A				19.698	0.078	6.751
Singapore	High	N/A	N/A	N/A	212.347	0.040	0.212	699.454	0.014	0.292	N/A	N/A	N/A	330.868	0.020	0.732
Thailand	Lower Middle	103.192	0.013	0.347	43.081	0.005	0.818	28.015	0.037	0.269						
Vietnam	Low	39.950	0.002	0.486	N/A	N/A	N/A									
East Asia & Pacific		28.887	0.013	0.325	N/A	N/A	N/A	34.612	0.001	0.402	59.784	0.087	0.271	16.495	0.006	2.416
South Asia		N/A	N/A	N/A	1.946	0.032	0.355	N/A	N/A	N/A				10.436	0.002	0.961
United States	High	1210.119	0.216	1.246	723.258	0.002	0.293	391.235	0.056	0.115	257.180	0.016	0.178	531.097	0.014	0.463

*The classification follows the World Bank's income classification code at **http://www.worldbank.org/data/countryclass/classgroups.htm**.

Table 1-2. Estimated Diffusion Parameters from the Bass Model by Income Group*

Technology / Country	Mainline Telephones				Mobile Phones			PCs			Cable TV Subscribers			Internet Users	
	m	p	q	m	p	q	m	p	q	m	P	q	m	p	q
Lower middle income	N/A	N/A	N/A	72.693	0.003	0.627	41.055	0.005	0.366	N/A	N/A	N/A	25.912	0.006	1.649
Middle income	N/A	N/A	N/A	675.17	0	0.749	89.908	0.006	0.254	N/A	N/A	N/A	74.658	0	1.066
Upper middle income	205.055	0.096	0.494	294.692	0.001	0.928	170.557	0.012	0.117	84.454	0.28	0.649	435.83	0.001	0.691
High income	N/A	N/A	N/A	821.17	0	0.497	445.19	0.152	0.739	225.859	0.023	0.08	635.047	0.003	0.627

*The classification follows the World Bank's income classification code at **http://www.worldbank.org/data/countryclass/classgroups.htm**.

Note: Some of the estimates for the 'q' parameters vary considerably (i.e., greater than 1.0 in a number of cells) due probably to a lack of sufficient number of data points.

In general, the market potential parameter (m) of different technologies in a country is positively correlated because the income level of the country implicitly determines all of them. The telephone mainlines and mobile phones, however, are somehow substitutes of each other, which means that consumers may be more willing to adopt a mobile phone if fixed-line telephones are not available. The data for telephone mainlines and mobile phones in Table 1-1 and 1-2 support this conjecture. The market potential parameters (m) of mobile phones are greater than those of telephone mainlines in most developing countries listed in Table 1-1, indicating a possible lack of fixed-line infrastructure in those countries. This may also indicate that many developing countries in Asia are bypassing fixed-line telephone infrastructure by adopting wireless technology, which does not necessarily depend on traditional telephone infrastructure. For example, the number of mobile phones in China has increased thirteen times from 1996 to 2000, compared to only three times increase in the number of fixed-line telephones. By 2002, the number of mobile phones in China has increased to 195 million, tripling the number of 2000.

Some factors that may influence the coefficients of innovativeness and imitativeness of a nation, such as cosmopolitanism, mobility, sex roles, consumers' inclination and ability to process non-word-of-mouth information, population homogeneity, and persuasiveness of existing adopters, have been identified by a number of studies (Gatignon et al., 1989; Talukdar et al., 2002). However, a lack of sufficient number of data points or time series data has prevented us from examining these factors and drawing general conclusions on the coefficients of innovativeness and imitativeness across countries.

Digital Divide across Countries and Different Provinces in China

A single sample principal component computed from the principal component analysis accounts for over 95% and 93% of the total sample variances across countries and across provinces within China respectively. The results confirm our assumption that there may be a single common source of ICT progress that differs across regions. Table 2-1 and Table 2-2 show the ICT component scores and the corresponding relative indices – the ICT component scores divided by the score of the US – by region and income group respectively. Table 3 shows the ICT component scores and the relative indices – divided by the score of Beijing – by province.

The across-country data in Table 2-1 shows that the US is at the top and Pakistan is at the bottom in 1996. Hong Kong moves to the top in year 2000, due largely to the fast diffusion of mobile phones in Hong Kong – the penetration has increased from 13.1 per 100 people in 1996 to 80.9 per 100 people in 2000. Surprisingly, the ICT diffusion in many countries of East Asia was not hindered by Asian economic crisis of 1997. Instead, the ICT adoption in Hong Kong, Korea, Singapore and Japan were higher than that of US and average high-income countries. China is the fastest growing country in terms of the growth rate of the composed ICT score (about 200 percent within 5 years). The raw ICT component score of China has increased by about 90 (points). The increase is comparable to that of middle-income countries, although her GDP per capita is only about three fifth of average middle-income countries.

What are the factors that lead to the fast technological progress in China? Economic growth, investment in R&D, government efficiency, regulatory policy, and IT base infrastructure, etc. are some factors that have been identified in the literature (Barro, 1997). Since the fast technological progress in China has taken place during the same period of time when the Central Government of China started to open its telecom markets and deconsolidate the telecom industry, we conjecture that the efforts of Chinese government to introduce competition into its telecom sector (even though they are all state-designed competitors) may be a contributor to the fast growth of ICTs. Further, Chinese economy has been growing much faster than the world average during this period of time. The Purchasing Power Parity (PPP) adjusted GDP per capita of China has increased from $630 in 1996 to $877 in 2001, representing an annual growth rate of about eight percent. Meanwhile, the costs of telecommunications and computing have been decreasing largely. For instance, in China, the average cost of local call (US$ per three minutes), a telecom cost indicator used by the World Bank, has decreased from $.08 in 1996 to $.03 in 2001. At the same time, the costs of the Internet access devices, such as mobile phones and PCs, have been going down as well. Therefore, fast economic growth and lower telecom costs could be two other important influential factors.

The provincial data within China in Table 3 shows that a number of large municipalities (Beijing, Shanghai and Tianjin) have the top ICT component scores in the list while several western provinces, such as Guizhou, Gansu, and Qinhai, are the areas with the lowest ICT penetration scores. The results are consistent with geographical and economic conditions in China that the western part of the country has long been falling behind the eastern and coastal areas. The digital disparity between the most advanced area (Beijing) and the least advanced area (Tibet) is as large as the gap between China and the US.

The correlations between the per capita income and the ICT component scores as well as the corresponding ICT growth rates across different regions are listed in Table 4. There is no surprise that the per capita GDP is positively correlated to the ICT component scores both across countries and across provinces within China, which means significant digital divide does exist between poor countries/regions and their rich counterparts. Considering the dynamic aspects of technological progress, Table 4 shows that the growth of the ICT component scores in absolute value over time is positively correlated to the per capita income. It follows from the intuition that rich regions have a larger base of resources to start with and hence the increase in absolute value is always bigger than that of poor regions, which have a smaller initial base value of resources. However, this does not necessarily mean that digital divide between poor and rich regions is increasing over time.

To test whether digital divide between different regions have increased or decreased over time, we need to examine the correlation between the growth rate of the ICT component scores and the per capita income. If the growth rate of ICTs is higher for poor countries or provinces, they would probably catch up with rich countries sooner or later (only when poor countries/provinces can keep staying at the higher growth rate over a sufficiently long period of time). Table 4 shows that the correlation between growth rate of ICTs from 1996 to 2000 and per capita income is significantly negative both across countries and across provinces within China. It implies that digital divide between Asia/China and other high-income countries as well as among different provinces in China have not increased over this period of time (1996-2000). The findings of the study are partially consistent with Rodriguez and Wilson's study (2000), in which they found significant divergence between developing and developed countries around the world from 1994 to 1996, with the exception of East Asia.

Table 2-1. ICT Component Scores over Time (by Country/Region)

Country	GDP Per Capita, PPP ($) (1995)	1996		2000		Growth	Growth Rate
		Component Scores	Index	Component Scores	Index		
China	2691.812	39.90172	0.054361	131.174	0.124577	91.27227	2.287427
Hong Kong, China	22430.61	596.5865	0.81277	1080.378	1.02604	483.791	0.810932
India	1867.974	14.3558	0.019558	32.93208	0.031276	18.57628	1.293991
Indonesia	2928.351	18.88657	0.02573	36.94961	0.035091	18.06305	0.956397
Japan	24199.31	562.404	0.766201	929.8332	0.883068	367.4292	0.653319
Korea, Rep.	13813.69	412.9378	0.562573	852.0558	0.809202	439.1179	1.0634
Malaysia	7515.403	182.9819	0.249289	334.9005	0.318057	151.9186	0.830238
Mongolia	1481.394	28.7967	0.039232	71.94885	0.06833	43.15215	1.49851
Pakistan	1779.981	14.19092	0.019333	17.79258	0.016898	3.601655	0.2538
Philippines	3645.912	30.34032	0.041335	88.50866	0.084057	58.16835	1.917196
Singapore	19431.68	501.6292	0.683403	972.2815	0.923381	470.6522	0.938247
Thailand	6289.481	74.48572	0.101477	109.8145	0.104291	35.32879	0.474303
East Asia & Pacific	2839.991	38.57238	0.05255	110.771	0.1052	72.19863	1.87177
South Asia	1796.574	13.06257	0.017796	29.20016	0.027732	16.1376	1.235408
United States	28283.89	734.0163	1	1052.958	1	318.9417	0.434516

Table 2-2. ICT Component Scores over Time (by Income Group)

Country	GDP Per Capita, PPP ($) (1995)	1996		2000		Growth	Growth Rate
		Component Scores	Index	Component Scores	Index		
Lower middle income	3768.98	58.7007	0.079972	138.7219	0.131745	80.02115	1.363206
Middle income	4474.988	69.96565	0.095319	161.1064	0.153004	91.1407	1.302649
Upper middle income	7601.912	118.8043	0.161855	256.6833	0.243774	137.879	1.160556
High income	22851.34	573.6071	0.781464	952.3784	0.904479	378.7712	0.660332

Table 3. ICT Component Scores over Time in China (by Province)

Provinces	GDP Per Capita (RMB) (1998)	1996		2001		Growth	Growth Rate
		Component Scores	Index	Component Scores	Index		
Anhui	4576	4.202327	0.154681	13.16037	0.221149	8.95804	2.131686
Beijing	18482	27.16771	1	59.50913	1	32.34142	1.190436
Chongqing	4684	4.294806	0.158085	14.52996	0.244164	10.23516	2.383148
Fujian	10369	12.56703	0.462572	29.06703	0.488447	16.5	1.31296
Gansu	3456	3.774	0.138915	11.93592	0.200573	8.161923	2.162672
Guangdong	11143	19.41593	0.714669	35.29134	0.593041	15.87542	0.817649
Guangxi	4076	3.496	0.128682	13.21304	0.222034	9.717041	2.779474
Guizhou	2342	1.457409	0.053645	8.062227	0.135479	6.604818	4.531891
Hainan	6022	8.764623	0.322612	19.85769	0.333691	11.09306	1.265663
Hebei	6525	3.653985	0.134497	15.86569	0.266609	12.21171	3.342024
Heilongjiang	7544	10.52508	0.387411	21.58315	0.362686	11.05807	1.05064
Henan	4712	3.797023	0.139762	12.44979	0.209208	8.652763	2.278828
Hubei	6300	6.877388	0.253146	13.74969	0.231052	6.872305	0.999261
Hunan	4953	6.381171	0.234881	13.40866	0.225321	7.027488	1.101285
Jiangsu	10021	8.353508	0.307479	24.19849	0.406635	15.84498	1.896806
Jiangxi	4484	3.632305	0.133699	13.95883	0.234566	10.32653	2.842968
Jilin	5916	9.04784	0.333037	20.98702	0.352669	11.93918	1.319561
Liaoning	9333	10.56781	0.388984	26.52686	0.445761	15.95904	1.510156
Neimenggu	5068	3.454461	0.127153	15.75526	0.264754	12.3008	3.560845
Ningxia	4270	4.783705	0.176081	15.97542	0.268453	11.19171	2.339549
Qinhai	4367	3.853096	0.141826	13.77588	0.231492	9.922785	2.575276
Shandong	8120	7.307774	0.268987	18.82437	0.316327	11.5166	1.575938
Shanghai	28253	23.09444	0.85007	55.8019	0.937703	32.70745	1.416248
Shanxi	5040	3.315488	0.122038	15.59238	0.262017	12.2769	3.702893
Shanxi(xian)	3834	4.51198	0.166079	16.64265	0.279665	12.13066	2.688546
Sichuan	4339	4.129478	0.151999	12.86607	0.216203	8.736593	2.115665
Tianjin	14808	18.43863	0.678697	35.97921	0.6046	17.54058	0.951295
Tibet	3716	.	.	6.751742	0.113457	6.751742	.
Xinjiang	6229	.	.	15.15261	0.254627	15.15261	.
Yunnan	4355	4.001861	0.147302	13.42688	0.225627	9.425023	2.35516
Zhejiang	11247	12.30889	0.453071	35.02567	0.588576	22.71678	1.845558

Table 4. Correlations between Per Capita GDP and ICT Progress

Correlations		ICT Scores	P-Value	Growth of ICTs	P-Value	Growth Rate of ICTs	P-Value
GDP Per Capita	Across Countries	0.96728	<0.0001	0.88918	<0.0001	-0.52574	0.0173
	Across Provinces in China	0.93889	<0.0001	0.92168	<0.0001	-0.48924	0.0071

Conclusions

This study investigates the diffusion patterns across regions and whether digital divide has been widened or narrowed over time. The diffusion patterns of ICTs across a group of countries and different areas within China identified in the study have some management as well as policy implications. Specifically, through a composed technological index measuring information progress of regions, the study has shown that less-developed countries and less-developed provinces in China have lagged far behind their rich counterparts in ICT diffusion. The study has also shown that China and other countries in East Asia have been aggressively catching up with developed countries since 1996. However, the impressive growth rate of ICTs in China cannot hide a wide penetration disparity between China and developed countries as well as others in the East Asia and Pacific region. Maintenance of such a high growth rate is critical for sustaining progress in information technologies.

The estimated parameters of the diffusion model disclose some interesting patterns of ICT diffusion across countries. First, because of a possible lack of fixed-line infrastructure in most developing countries in Asia, these countries are now bypassing fixed-line telephone infrastructure by adopting wireless technology. It shows that new technologies may provide developing countries opportunities to catch up with their rich counterparts. The substitutive effect between mobile technology and traditional fix-line technology shows that some technologies do have distributive impact on technological progress across regions. Secondly, the market potentials of mobile phones are conjectured to be greater than those of telephone mainlines in most developing countries in Asia. In China, the number of mobile phones will surpass fixed-line telephones anytime now. The official projected figure released by the MII (2002) is 258 million and 247 million for mobile phones and fixed-line telephones by the end of 2003, reflecting similar trend as found in this study.

There are several limitations of this study, which provides an agenda for future research. First, due to the limited availability of the secondary data, the study has been forced to exclude some countries or provinces in the model estimation, which may cause upward bias since most countries or provinces excluded in the study are the poorest within a certain region. Second, the two-step parameter estimation used in the study does not take possible common error structure into account, which may lead to less accurate parameter estimates. Future studies may refine the diffusion model by including more complex correlation structure between fix-lined infrastructure, mobile phones and the Internet access, etc.

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