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Digital-divide Across Asian Countries: Is the Convergence Robust?*

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This paper uses conventional and contemporary approaches to test for the decline in digital-divide across 40 Asian nations over 10 year period from 2000 to 2009. GINI coefficient, HH index show that countries are becoming more equitable in relative terms with regard to information and communication technologies (ICTs) use. The relative convergence (the size of beta, β) shows that the convergence rate is about 9%. In contrast, contemporary approaches that test for panel non-stationarity with and without cross-sectional dependency show little evidence of convergence among countries. Even though the ICT use is growing at higher rate in the lower level countries, the absolute size of gaps between countries has not shrunk. Thus, we need to focus how to reduce the absolute gap as well as the equity of ICT use. The convergence rate seems not to be enough for the poorly accessed countries to catch up in absolute level.

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1. INTRODUCTION

This paper attempts to make a contribution to the literature on the convergence of more backward countries, as defined in terms of their information and communication technologies (ICTs) use, towards the leading countries. The renewed concern has emerged because it is believed that the considerable benefits of ICTs might accrue to only certain groups which are already advanced in society, which may lead to other groups relatively more disadvantaged.

In most developing and transition economies, there is an apprehension that the lack of access and use of ICTs may further deepen the existing social and economic inequities by depriving those which are already marginalized to participate in the global economy. This implies that instead of narrowing the gap between them and advantaged groups, the gap is likely to increase. What implication does it have at macro-level? At macro-level, as long as the value addition with the use of ICT is more by the advantaged group, it will result in increased per-capita income. Thus, even if the gap widens within the country, at aggregate level it will masquerade as by showing increased catch-up by the country.

This paper deals with the issue of digital divide among Asian countries, as defined in terms of their ICT access. The widespread use of ICTs began primarily from early 1990s onwards. According to some researchers, there are a number of reasons why use of ICT should have diffused faster in backward countries. For example S-shaped diffusion curve might lead the narrowing the gap between the advanced and the other. There are however, counter-arguments, which suggest that the diffusion of ICT would not follow the traditional S-shaped logistic diffusion curve.

The purpose of this article is to examine the convergence of Asian nations as regard to digital use. In particular, this paper uses conventional and contemporary approaches to test for the decline in digital-divide across 40 Asian countries over 10 year period from 2000 to 2009.

This research is different from earlier studies on two points: (a) it uses more recent data until 2009; and (b) the study employs latest econometrics techniques to see the convergence. The study has important policy implications. If it finds that digital-divide is on the rise, the existing inequalities across nations with respect to economic well-being and social divisions may accentuate. A pro-active policy addressing the diffusion factors from the laggards would be needed. On the other hand, a declining digital-divide would imply attenuation of digital use disparities across nations and the world may see more equity in near future. This suggests that the nations may need to continue with the same policies.

Section 2 talks about theoretical background and different contexts in which digital divide is measured. The section then gives a brief literature review on the convergence of digital-divide. This is followed by the methodology to be employed in section 3 along with the data used for the analysis. Section 4 gives the results and the inferences and the paper concludes with section 5.

2. DEFINITION, THEORY, AND LITERATURE

2.1. Definition

A number of definitions exist for "digital-divide". One of the most comprehensive definition is by OECD (2001), which defines the term as "… the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both to their opportunities to access information and communication technologies (ICTs) and to their use of the internet for a wide variety of activities". In the context of ICT, the digital-divide is talked with respect to three key components: (a) internet; (b) personal computer; and (c) landline and mobile phones. There are major regional differences with respect to ICT access and use among various countries.

Keniston (2004) talked about the four different levels of digital divide.

Two of which are within a geographical boundary, one is across the nations and one cuts across geographical boundaries and is cultural and linguistic in nature. Out of them, the third digital-divide is across nations i.e., between rich and poor countries. This paper primarily investigates the digital divide across the countries.

Similarly, Fink and Kenny (2003) summarize four different interpretation of digital divide that has appeared in the literature: (a) gap in access to use of ICTs — proxied by the number and spread of telephones or web-enabled computers etc.; (b) gap in the ability to use ICTs — quantified by the skills base and the presence of numerous complimentary assets; (c) gap in actual use — the hours/minutes of telecommunications for various purposes; the number of internet hosts and the level of electronic commerce; and lastly (d) the gap in the impact of use. The existence of the first three types of gaps, however leads to a differential impact on the financial and economic returns in the economy. Recently, the digital divide is known to be increasingly related to differences in the speed and quality of access to ICT (ITU, 2007).

The discussion thus suggests that digital-divide is a multifaceted problem, which requires policy interventions at multi-levels to bridge it. Some of the problems highlighted in the literature include: a dearth of physical infrastructure and telecommunication investment (in most backward countries), difficult topography of inaccessible regions (e.g., in Nepal, Bhutan etc.), low population densities (in hilly regions and desert areas), a lack of both general and ICT-specific human skills (in Sub-Saharan Africa, South Asia etc.), regulatory uncertainty (in most developing countries), and a lack of efficient market structures, institutions and competition (OECD, 2004). As a consequence, merely access to new technologies, both in terms of technical infrastructure and basic IT skills — will not be sufficient to prevent the widening of a digital-gap, though they are necessary prerequisites (Husing and Selhofer, 2004).

Hence, because of its complex nature, the aspects of the divide need to be evaluated and corresponding policy suggestions are to be made. The focus of the present paper is however to see the digital-divide across nations.

2.2. Theory

The research question attempting to see the ICT diffusion or digital access though seems new, in reality, it is an off-shoot of earlier “knowledge-gap” hypothesis which was focus in the 1970s. According to the “knowledge gap” hypothesis given by Tichenor *et al*. (1970), “segments of the population with higher socio-economic status tend to acquire information at a faster rate than the lower status segments so that the gap in knowledge between these segments tends to increase rather than decrease”. With the emergence of digital media such as computer, internet etc., the hypothesis has re-christened under the term “digital-divide”. Furthermore, many researchers (see for example, Soete, 1985; Kagami and Tsuji, 2001) suggest the reason why the gap among the countries tends to be reduced. They said that ICT should have diffused faster in backward countries. The most importantly, being a highly competitive seller market for ICT products in conjunction with a rapid rate of technological obsolescence has resulted in price cutting, which leads to rapid diffusion. Furthermore, the late comers also have two key advantages such as: the “fast-follower” advantage; and the “leap-frogging advantage” (Wong, 2002). The late comers may be able to learn from the experience of the advanced countries without having to pay the cost of initial learning and experimentation (Mody and Dahlman, 1992), thereby can avoid legacy problem of having too much asset-specific investment sunk into earlier generations of old technologies and can leap-frog easily (Wong, 2002).[1)]

These arguments could be implied in S-shaped diffusion curve whose three stages are initial adoption, rapid growth and maturity. According to S-shape curve, it is probable that the countries tend to converge each other. For example, Romero *et al*. (2011) shows by using logistic function that how the groups converge each other under S-shape curve hypothesis.[2)]

[1)] The more disruptive the new technological advances, the greater the new “attacker’s advantage” in exploiting new technologies versus the incumbents (Foster, 1986). The increasing use of mobile for multi-media applications in emerging economies is one such example.

[2)] Yeom (2003) and Norris (2001) shows the two figures of convergence and non convergence

There are however, counter-arguments, which suggest that the diffusion of ICT would not follow the traditional S-shaped logistic diffusion curve. Some studies argue that only those countries who have requisite level of education and skills would be able to converge (Wong, 2002; Mody and Dahlman, 1992). In this, the presence of threshold level of education and skills have important implication for overall convergence. The laggards lacking absorptive capacity may fall further behind, whereas the industrializing countries having threshold absorptive capacity may be able to converge. According to Wong (2002), the efficient adoption of ICT requires both kinds of business infrastructure; "hard" physical capital like computers, network infrastructures etc. and "soft" social capital that includes relatively efficient factor and product markets, well functioning financial and regulatory institutions etc. While it will be easier for few technologically active firms to leapfrog, but nation as a whole may find it extremely difficult unless both infrastructures are available.[3)] According to Mody and Dahlman (1992) and Rogers (2001) among other factors, wider diffusion of ICT requires incentive to adopt new technologies and existence of national infrastructure to support adoption.

2.3. Literature at the Empirical Study Side

Earlier studies looked into the determinants of digital-divide and the studies have also looked into the role of institutions and kind of infrastructure needed that facilitates reduction in digital-divide (see for example, Billon *et al.*, 2010; Chinn and Fairlie, 2007 and the literature cited therein). Regarding studies looking into digital divide, Wong (2002) examines the ICT diffusion/adoption performance of eleven Asian countries' vis-à-vis 32

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cases by using two concepts; normalization model and stratification model.

[3)] A study by Norris (2000), however, concludes that the prime reason for global digital-divide is economic development rather than disparities in human capital such as education and literacy. Moreover, not all ICTs require substantial levels of education. For instance, use of telephone and internet may require little education, whereas computers may require higher level of human skills.

non-Asian countries for the year 1998 with respect to eight indicators.[4)] He indicates that Asian countries lag behind the overall mean for non-Asian countries and there exists a clear digital-divide between the more advanced and less developed country groups within Asian region. The digital-divide between the two groups over five year period from 1994 to 1998 was not shown to be narrowed. Chen and Wellman (2004) indicate that the divide is occurring along four diverse lines — socio-economic status, gender, age and region. A recent study (ASEANONE, 2005) for 10 ASEAN countries shows that the differences in performance are declining, thereby indicating that the digital-divide gap is falling. Sciadas *et al*. (2005) constructs a digital divide index using 21 indicators for 139 countries for the period 1995-2003 and finds that the magnitude of digital-divide remains huge and is widening among the countries. In addition, Kim (2004) and Vicente *et al*. (2006) are good materials to see the cases of Korea and European countries.

The literature indicates that different studies have used different indicators such as internet use per capita, mobile phone use per capita, number of computers per 100 persons, number of internet hosts per 100 persons etc. to quantify digital-divide. Refer Hilbert (2011) for a discussion on different indicators used. The present study computes an index of ICTization using three indicators: internet subscriptions per 100 inhabitants, mobile users per 100 persons and fixed telephone lines per 100 inhabitants.

3. METHOD, DATA AND VARIABLES

Two approaches have been used in order to test whether digital divide is declining or not- conventional and contemporary. For conventional approach, we first borrowed some basic measures form other area of economics; GINI coefficient and Hirschman-Herfindahl Index, borrowed

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[4)] The countries include five more advanced – Japan and the four NIEs — South Korea, Taiwan, Singapore and Hong Kong; and six less developed — China and India and ASEAN4 — Malaysia, Thailand, Philippines and Indonesia.

from the "income inequality" literature and "market share" literature. Next, we use the concept of "β convergence" which we borrowed from "economic growth" literature. For the contemporary approach, we use quite newly developed method in time series analysis of econometrics.

3.1. Conventional Approaches

3.1.1. GINI coefficient and Hirschman-Herfindahl Index

Elsewhere literature has developed indices to test for inequality, especially in income and market share. We have borrowed these indices to see the prevalence of digital-divide. The checking of inequality in income distribution uses GINI coefficient. The measure, which lies between zero and one, shows how serious the income inequality condition is in an economy. A large value of the coefficient means that the income is distributed more against the poor. By analogy, a higher value of GINI coefficient would imply a greater digital-divide among the countries. The coefficient is computed by arranging the countries in order of increasing digital access value and then taking the cumulative access value on the vertical axis and the proportion of countries on the horizontal axis so as to plot the two frequencies. The Gini coefficient is defined graphically as a ratio of two surfaces involving the summation of all vertical deviations between the Lorenz curve (a graphical representation of the proportionality of a distribution to the cumulative percentage of the values) and the perfect equality line (A) divided by the difference between the perfect equality and perfect inequality lines (A+B), where B is the area between the Lorenz curve and the horizontal axis.

Similarly, borrowing from income (or market share) distribution area, Hirschman-Herfindahl (hereafter HH) Index is measured as the summation of the squares of the individual countries' shares in the world. ($HH = \Sigma S_i^2$, $0 < HH \leq 1$). Again a higher value of HH index implies greater digital divide and vice-versa.

3.1.2. *β*-convergence

In the "economic growth" research the convergence of income level was one of the key issues and many researchers including Baumol (1986) Barro and Sala-i-Martin (1991, 1992, 1995) explored the relation between growth rate of a country and its initial condition. If digital rankings tend to converge together, then the growth rates would be higher for the lower level countries. Thus we need to check if the relation between the two variables is negative. A negative relation could imply the narrowing of digital divide. But, if there is no such relation, then there would be no tendency to converge among the countries. Consider the equation following Barro and Sala-i-Martin (1995), where y_{it} is the digital access index.

$$(1/T)\log(y_{it} / y_{i0}) = \alpha - [(1 - e^{\beta T}) / T]\log(y_{io}) + u_{i0,\,T}. \qquad (1)$$

If $\beta > 0$, this would imply that the levels of digital access are growing faster in low level countries and the digital-divide is shrinking. If $\beta < 0$, the digital-divide is worsening.

3.2. Contemporary Approach

The β as obtained from above equation though conveys a great deal about convergence, the equation as such does not use most of the information. The technique uses information of only two years — initial and the terminal period. It is possible that these two years are aberrations in terms of ICT use. β obtained would be biased upward or downward depending upon if the ICT use in the first and the last period differs greatly from the trend due to some external shock. We try to make use of the intermediate period information also and borrow a concept which is used in "economic growth" area in recent years. However, when we use intermediate information in the panel framework, two key problems — stationarity and cross- dependence needs to be looked into.

3.2.1. Panel Unit Root test

In growth literature, Evans (1997, 1998), Evans and Karras (1996, 1997), Quah (1996), Kim (2011), among others, deal with the convergence problem using panel non-stationarity approach. The approach formulates the hypothesis that economies have parallel balanced growth paths, also called the convergence hypothesis. From digital-divide point of view, let y_{it} be the logarithm of digital access level in economy *i* during period *t*, and assuming that it is non-stationary for every economy under consideration. Under the assumption, the digital access level of these economies will have parallel growth paths, i.e., y_{it} converge around a common trend, if and only if $y_{it} - y_{jt}$ is stationary for every pair of economies *i* and *j* in the collection. But if digital access of some of the countries are poorly integrated with that of the rest, $y_{it} - y_{jt}$ will be difference-stationary for only some pairs of economies *i* and *j*, thereby implying that there will be no tendency to converge among the countries.

We can test these two hypotheses by using panel unit root tests. Consider the following equation:

$$\Delta Z_{it} = \gamma_i + \rho_i Z_{i,\,t-1} + \sum_{k=1}^{p} (\Phi_{ik} \Delta Z_{it-1}) + u_i, \;\; t = 1,\ 2,\ \ldots,\ T, \qquad (2)$$

where $Z_{it} = y_{it} - (1/N)\sum y_{it}$ and ρ_i, φ_i are parameters. p is a sufficiently large integer, and the *u*'s are i.i.d. error terms. If any of the pair-wise differences $y_{it} - y_{jt}$ is difference-stationary, so will z_{it}, barring cointegration of the pair-wise differences with each other. Furthermore, if all of the pair-wise differences are mean-stationary, so will z_{it}. Hence, all of the quantities $\{z_{it}\}$ are either difference-stationary or mean-stationary. Essentially, we are testing for unit root for z_{it} in panel framework.

Consider the following two specific hypotheses:

$$H_0: \rho_i = 0 \textit{ for all } i,$$

$$H_1: \rho_i < 0 \textit{ for all } i.$$

In principle, the null hypothesis H_0 can be tested against the alternative hypothesis H_1 using panel unit-root methods. If the null hypothesis is not rejected z_{it} could be non stationary and some countries' digital access values are not converging. If the null hypothesis is rejected, then all z_{it} are stationary and it means their ICT access converge around a common trend. Thereby, suggesting that digital-divide is on the decline.

There are several methods for this panel unit root test ― Levin-Lin-Chu test, Harris-Tzavalis test, Breitung test, Im-Pesaran-Shin test etc. (see Breitung and Pesaran (2005) for the survey). We use Im, Pesaran, and Shin (2003, hereafter IPS) method, because it relaxes the assumption of common autoregressive parameter for each panel, as is necessary for our sample, which consists of countries with varying income and also ICT access. Besides, the method does not require the panel to be strongly balanced (STATA 2010).

3.2.2. Cross sectional dependency

One of the limitations of the panel unit-root test methods like IPS is the assumption of cross-sectional independence. This presupposes that the shocks that affect any given country relative to its international common trend should not affect any other economy. This assumption is highly restrictive and is unlikely to happen in the real world. For example, many of the shocks that affect the relative per capita output of the U.S. are also likely to affect the relative per capita output of Canada since the two economies are closely integrated.[5] Papell and Theodoridis (2001) and Maddala and Wu (1999) have shown that the cross-sectional dependence can greatly affect inference. This cross-sectional dependency has been dealt extensively in non-stationary panel data econometrics literature. Chang (2002), Harris *et al*. (2005), and Phillips and Sul (2007) are some of the papers dealing with this problem. See Breitung and Pesaran (2005) for a

[5] The recent financial crises in the U.S. and its spread to other countries and the 1997 East Asian crises affecting large number of countries are two such examples indicating that countries are well integrated.

survey of this literature.

The issue of cross-section dependence is important in ICT area too. This is because the technologies are fairly standard and their spread across frontiers is very rapid. Any new ICT innovation in the U.S. will immediately spread to the Canada and the European Union and to countries like India and Newly Industrialized economies (NIEs). Similarly, given the dependency on only few operating systems, any policy shock to them will influence the uptake of ICT use in many other countries.

In the present paper, we analyze the convergence of digital-divide using two recently developed methods that deal with the cross-sectional dependency problem permits every economy to have its own dynamics, and in addition to exhibiting cross-sectional dependence, the technique has an advantage of yielding unbiased estimates of dynamics. This implies that one can obtain an accurate estimate of the rate at which any given economy's info-state converges around the trend. After the initial work of Chang (2002), the econometrics literature in this area has grown a lot. See for example, Harris *et al*. (2005), Phillips and Sul (2007) among others.

Another method is from Harris *et al*. (2005, hereafter HLM). It suggests two tests to deal with cross sectional dependence problem: raw test and factor test. The method has several distinct features the hypotheses direction is opposite to that of Chang's. The method hypothesizes convergence as the null and divergence as the alternative.

3.3. Data

There is no common perspective to conceptualize and measure the digital divide (Vehovar *et al*., 2006), partly because the digital divide can differ with the type of technologies in focus, since different technologies exhibit different pattern of diffusion (Billon *et al*., 2010). The existing studies have used different indicators to quantify digital-divide, including internet use per capita, mobile phone use per capita, number of computers per 100 persons, number of internet hosts per 100 persons etc. Of course, these measures are partial in nature, therefore the present study combines three distinct indicators of ICT diffusion to construct an index of ICTization: internet subscriptions per 100 inhabitants, mobile users per 100 persons and fixed telephone lines per 100 inhabitants.[6)]

$$ICTindex_{ijt} = {}_{i=1,3}\sum(w_i ICTindicator_{ijt}),$$

where w_i is the weight for each of the ICT indicator. We assume equal weights for each of the three ICT indicators (that is, $w_i = 0.33$).

For the index, we have used data for 40 Asian countries from International Telecommunication Union (ITU) (2010) data. The ITU data gives information on telephone, personal computer, internet and other telecommunication and electronics use, apart from the data on telephone costs. These Asian countries group includes various levels of per capita incomes; from rich countries like Japan and Saudi Arabia to Bangladesh and Myanmar. Furthermore, in terms of IT levels, this group has quite various countries, too; for example, UAE is the number one country in the world but Myanmar is shown as the lowest level country out of 159 countries. Some countries are very big like China and Japan, but some others are very small. We might refer this feature in the appendix table.[7)]

[6)] As a robustness check, we also use a more comprehensive index given by G. Sciadas *et al*. (2005). The results however, remain same. The only limitation of the index is that it is until 2005.

[7)] Actually, it would rather desirable that the analysis have more time series data. But, because of data finding problem, the authors selected only 10 years data. In particular many Asian countries do not have long span of "digital" side data.

4. EMPIRICAL RESULTS

4.1. Conventional Approach

4.1.1. GINI coefficient and HH Index

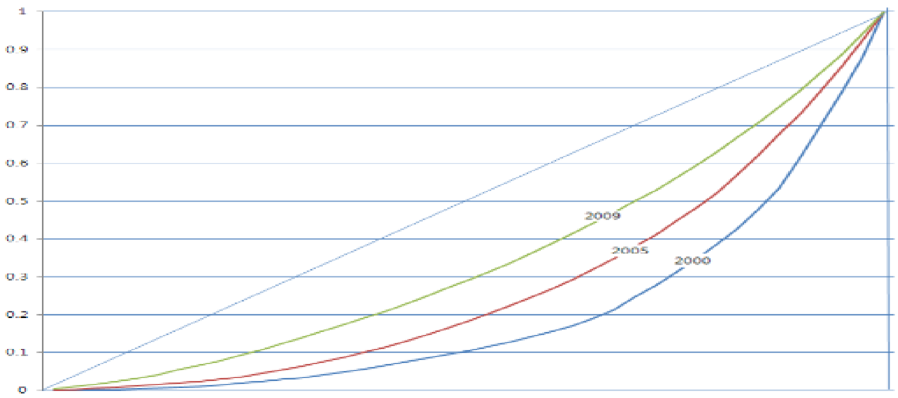
Table 1 reports the GINI coefficients (row 1) and the HH index (row 3). For both the measures, the numbers are reducing. This suggests a converging tendency. Since countries differ in terms of their populations, estimates of GINI Coefficient would be biased if these population differences are not accounted for. When we recalculate GINI coefficients using the populations as the weights of the individual countries, we still find the same trend of decreasing value of coefficients (row 2).[8] Based on these measures, it could be said that the digital inequality during the period has been shrinking. Figure 1 that gives the shift in the Lorenz curve also suggests a declining digital divide across the nations over 10 year period.

Table 1 Gini Coefficients and H-H Index

Measure	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gini Coef.	0.283	0.275	0.264	0.252	0.237	0.217	0.191	0.176	0.156	0.146
WGC*	0.364	0.354	0.342	0.307	0.285	0.287	0.279	0.270	0.271	0.260
HH	0.060	0.057	0.053	0.050	0.046	0.041	0.037	0.035	0.033	0.032

Note: * WGC: Weighted Gini Coefficient with population used as weights.

Figure 1 Shifts of Lorenz Curves over 10 Years Period



4.1.2. *β*-convergence

Table 2 reports the results for the equation 1 using least square method. We obtained a positive value of β, indicating negative relationship between the initial value and growth rate. It seems that the countries starting with lower level of ICT index are getting digital access faster than initially high level countries.[9)]

It looks reasonable to conclude that digital-divide has been declining. The average convergence rate (β) of 0.091 implies that the degree of digital-divide is shrinking at the rate of 9.15% per year.[10)] This rate seems quite high compared to the usual 2% as found for income convergence in the growth literature. In particular, the shrinking rate is higher in more recent years; 4.8% in the first half of the decade (column 2) and 11.8% in the second half decade (column 3). From the two values of β, it is clear that the converging behavior has been accelerated of late. The two possible reasons are the widespread use of mobile phones especially in poor countries who seem to have bypassed the requirement of fixed telephony infrastructure and second, the increased adoption of broad-band in internet communication.

Table 2 *β*-convergence in Asia

	Period-2000-2009	Period-2000-2004	Period-2005-2009	World (2000-2009)
$\hat{\alpha}$	0.307* (15.482)	0.266* (9.042)	0.458* (7.772)	0.311* (41.181)
$\hat{\beta}$	0.091* (4.315)	0.048* (3.255)	0.118* (3.692)	0.101* (13.997)
$\bar{R}^2$	0.732	0.358	0.564	0.869
D.W.	2.154	2.002	2.237	1.812
No. of Obs.	40	40	40	159

Note: * significance at 1% level and numbers in the parenthesis are *t*-statistic.

9) As a matter of facts, we need to concern the heterogeneity problem here because these Asian countries are showing very different features in a wide sense. Income level, IT levels, and country sizes are spread very widely over the countries. But this paper itself is testing if there has been the narrowing of gaps among the countries. Thus we did not care a lot about this problem at the first step of the research. Authors thank the anonymous referee pointing out this problem.

10) Note that the convergence rate is quite close to that of when we take the Whole world (column 4).

Table 3 Contemporary Approaches Results

Method	Statistic	Results
IPS	1.426	Not reject "no convergence"[a]
Chang	0.961	Not reject "no convergence"[a]
HLM[b] (Raw Test)	1.802 (p=0.035)	Reject "H_0=convergence"
HLM[b] (Factor Test)	−0.9689 (p=0.795)	Not reject "H_0=convergence"

Notes: a) the statistics of IPS and Chang's tests have standard normal distribution in asymptotic. b) null hypothesis of HLM is stationarity.

Based on the results of conventional approaches, we can conclude that the digital-divide is declining. The countries which are starting at lower info-state levels are accessing and employing ICT faster than the leaders.

4.2. Contemporary Approaches and the Results[11)]

Table 3 reports the results for the contemporary approaches without (IPS method) and with consideration of cross-section dependency (Chang and HLM method). From the table, we can see that the contemporary approaches yield different results than the one we have obtained using conventional approaches. In most cases, convergence is either rejected or not accepted; only one case (factor test of HLM) is the exception. It seems that digital-divide still exists and the ICT index is not converging. The digital-divide thus, has not been shrinking at the global level.

4.3. Discussion

Using conventional approaches to test for decline in digital-divide across Asian nations over 10 year period, we show that countries are becoming more

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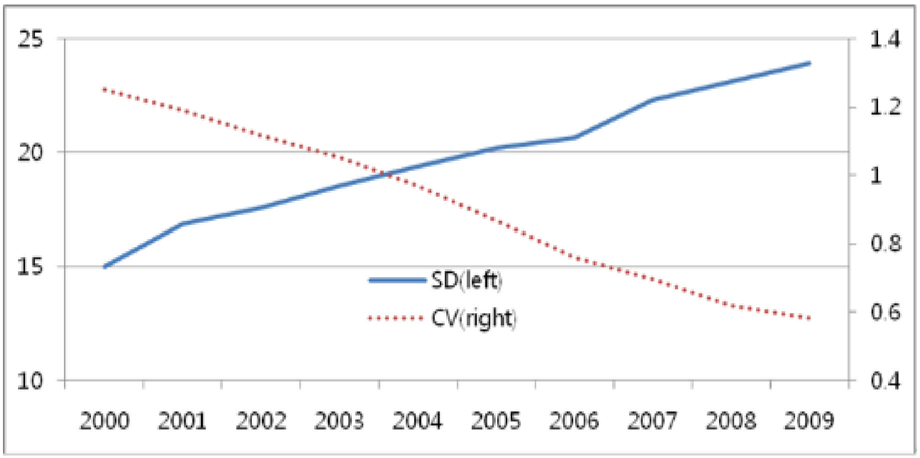
[11)] The authors would like to thank Professors Yoosoon Chang and David Harris for providing the GAUSS code for the estimation.

Figure 2 Absolute Divide vs. Relative Divide



Note: SD (standard deviation) decreases but CV (coefficient of variation) decreases.

equitable in relative terms with regard to ICT use. This has resulted in the digital access spreading over to the poorly accessed (at lower and middle level accessed) countries. The conventional approaches gives us that there is converging tendency of digital indicators, however the modern approaches do not show the same results. Actually, it is not easy to explain what makes this difference. The thing is, we cannot not be sure that the gap of ICT among the Asian countries has been narrowed. Of course, we cannot say that even the newer methods are always better and older ones are inferior to the new one. Thus we tried to explain the difference shown in the results.[12)]

Note that the conventional approaches are referring "relative" convergence: inequalities of distribution, negative relationship between the initial level and the growth rates. It seems that, even though the digital situation in the Asian countries has been getting faster growth in the low ICT accessed countries, there still exist long way to go for enjoying similar level with leading countries. This is easily illustrated in figure 2, where we report the standard deviation and coefficient of variation of ICT access over the 10

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12) A reviewer pointed that no convergence of digital divide using the time series techniques might result from power problem of short time span.

year period. Standard deviation of the ICD access index has rather been growing instead of declining, which suggests that the digital divide in Asian countries has been getting worsened in the absolute terms. Of course, we might say that the digital divide has been lessened in relative terms from the fact that the CV (standard deviation divided by average) has been falling due to the increasing trend of average level of digital access. As the result, it is not very reliable to use the conventional way to see the convergence of digital access, but we need to keep in mind the absolute size of digital divide. In order to improve the welfare of the people in countries having low ICT access, the issue is how to narrow the gap between them and the countries already endowed with high ICT access.

5. CONCLUDING REMARKS

This paper uses conventional and contemporary approaches to test for the decline in digital-divide as measured by digital infra levels using ITU data across 40 Asian nations over 10 year period from 2000 to 2009. The conventional methods like GINI coefficient, HH index measures show that countries are becoming more equitable in relative terms with regard to ICT use. This has resulted in the digital access spreading over to the lower and middle level countries. Furthermore, the size of beta (β) shows that the convergence rate is about 9% which seems quite big number compared with 2% in the growth literature. In contrast, using contemporary approaches we find little evidence of convergence among countries once we account for cross-sectional dependency by using panel unit root approach.

Given the fact that ICT status are growing faster in low level countries, it apparently seems that the ICT status could converge to the level of that in the leading countries in the long run. On the other hand, if we see the absolute gap between the countries, the standard deviation has increased. We would better conclude that the modern approach of panel unit root tests found this point.

Several explanations exist why widespread diffusion of ICT has not taken place: several countries in Asian (and Latin American) region are specializing in manufacturing — this hampers the diffusion and adoption of ICT in many service sectors. Further, according to Dedrick and Kraemer (1998),[13] inadequate diffusion and adoption of advanced ICT in much of the non-manufacturing services sectors has resulted in these countries trapped in low-margin electronics manufacturing and thus lack the ability to high margin service sectors such as software development, innovative design and IT services. Lastly, ICT being a non-neutral, capital and skilled labour intensive technology for most countries, it exhibits significant bias effects when applied outside of the place where it is first introduced and implemented (Antonelli, 2003).

Since our results do not find the robust evidence of convergence, we need to look into what factors augment or reduce digital divide. If these factors can be nailed in the laggard countries, we may find convergence in due course of time. The literature has found a number of factors militating against ICT diffusion. Some of the important ones are low per-capita income, non-availability of communication infrastructure (as measured by telephone mainline density), access to electricity, regulatory and intellectual property rights institutional environment (Mody and Dahlman, 1992; Wong, 1992; Dasgupta *et al*., 2001; Chinn and Fairlie, 2007).

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[13] As referred in Wong (2002).

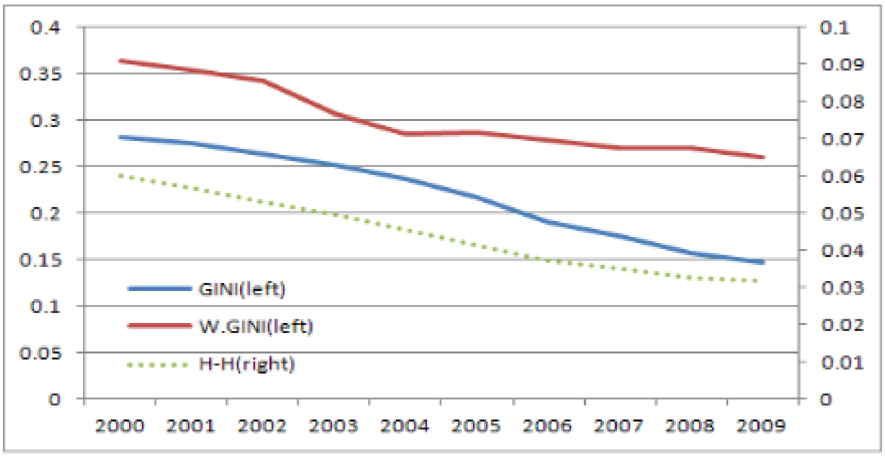
APPENDIX

Table A1 Countries and IDI Classification

Country	IDI	2009	Big	Rank	Country	IDI	2009	Big	Rank
Azerbaijan	3	36.52	0	86	Maldives	3	56.76	0	43
Bahrain	1	82.53	0	6	Mongolia	3	31.04	0	97
Bangladesh	4	10.72	1	139	Myanmar	4	0.85	0	159
Brunei	2	50.62	0	53	Nepal	4	9.707	0	143
Cambodia	4	12.76	0	133	Oman	3	50.95	0	52
China	3	32.38	1	92	Pakistan	4	20.54	1	115
Hong Kong	1	92.27	0	2	Philippines	3	29.76	0	101
India	4	16.07	1	127	Qatar	2	68.5	0	16
Indonesia	3	28.19	1	104	Saudi Arab	2	65.99	0	22
Iran	3	36.69	0	85	Singapore	1	67.81	0	19
Japan	1	57.85	1	41	Sri Lanka	3	29.29	0	102
Jordan	3	35.67	0	87	Syria	3	21.84	0	112
Kazakhstan	3	43.83	0	67	Tajikistan	3	24.89	0	109
Korea	1	57.64	0	42	Thailand	3	44.63	0	64
Kuwait	2	43.95	0	66	Turkey	2	38.19	0	78
Kyrgyzstan	3	30.6	0	99	Turkmenistan	3	12.92	0	131
Lao P.D.R.	4	17.79	0	123	U.A.Emirates	1	98.88	0	1
Lebanon	3	20.47	0	116	Uzbekistan	3	25.48	0	108
Macao, China	1	82.77	0	5	Viet Nam	3	48.04	0	57
Malaysia	2	48.88	0	56	Yemen	4	7.652	0	148

Notes: * Big: population is larger than 100 million and rank is 2009 ranking out of 159 countries. ** IDI : ICT Development Index.

Figure A1 Trend of GINI Coefficients and H-H Index



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