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ICT production and diffusion in Asia
Digital dividends or digital divide?

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Abstract

This paper examines the empirical evidence to determine whether Asian countries, despite having captured a disproportionately high share of global production of ICT goods, have as a group been laggard in the adoption of ICT in comparison to non-Asian countries. Using regression analysis, it is shown that as a group Asian countries have indeed had generally lower rates of ICT adoption relative to their levels of potential as predicted on the basis of their current level of development (GDP/capita) and competitiveness (world competitiveness index). In addition, disparities in ICT diffusion are found to be significantly higher among Asian countries than among non-Asian countries. In particular, a significant 'digital divide' is found to exist between the five more advanced countries of the region (Japan and the four Asian NIEs) and the other seven developing Asian countries. Policy implications of the findings for the Asian countries are highlighted. © 2002 Elsevier Science B.V. All rights reserved.

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JEL Classification: O1; O3; O57

1. Introduction

The explosive growth of information and communications technologies (ICT) in recent years, particularly the rise of internet and its related applications, has created unprecedented opportunities, but also threats for late-industrializing countries. In terms of opportunity, the rapid growth of global market demand for

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exportable ICT goods and services presents these countries with the possibility for rapid economic growth through leveraging their low-cost manufacturing advantage to capture a significant share of global ICT *production*. Indeed, competitive manufacturing of electronics goods has been a major contributor to the rapid economic growth of many East Asian developing countries in the past, particularly the region's four NIEs (see e.g. Ernst and O'Connor, 1992; Dedrick and Kraemer, 1998, and Wong, 2001).

Rapid advances in ICT also present the late-industrializing nations opportunities for rapidly catching-up with the more advanced nations through rapid *diffusion* in the use of new ICT (Kagami and Tsuji, 2001). Late-comers may be able to exploit new ICT more efficiently than the advanced countries for two reasons: first, they may be able to learn from the experience of the advanced countries without having to pay the cost of initial learning and experimentation (the 'fast follower' advantage); second, they may be able to 'leapfrog' into the latest generation of technologies, thus avoiding the 'legacy' problems of having too much asset-specific investments sunk into earlier generations of obsolete technologies (the 'leapfrogging' advantage). The more 'disruptive' the new technological advances, the greater the new 'attacker's advantage' can be in exploiting new technologies versus the incumbents (Foster, 1986).

Such opportunities for growth and catching-up, however, may be outweighed by considerable threats arising from their late-comer position. First, technological learning may require a long cumulative process of human capital development through incremental learning by doing. Consequently, new technologies cannot be diffused at a faster pace in the late-industrializing countries than in the advanced countries because of the human capital bottleneck. Second, efficient adoption of new ICT may pre-suppose the existence of business infrastructure not only in the form of 'hard' physical capital (computers, network infrastructures, etc.), but also 'soft' social capital (relatively efficient factor and product markets, well-functioning financial and regulatory institutions, etc.). Thus, while it is possible for new individual firms to overtake established industry leaders by being faster and more nimble in exploiting new, disruptive technological innovation, it is more difficult for an entire nation to leapfrog other nations technologically. Third, the late-comer countries may lack the financial resources to invest in new technologies as aggressively as the advanced nations, with the result that the latter will reap greater productivity and innovation benefits from new technology than the former (Jalava and Pohjola, 2002).

Given that advanced countries are able to adopt and apply new ICT faster than the late-industrializing nations, they may be able to overcome their factor cost disadvantage compared to the late-industrializing countries, thus giving them the ability to re-capture much of the ICT manufacturing activities that have migrated to the developing countries over the last 20 years.

The question of whether existing inequalities in economic well-being across nations may be accentuated or attenuated by the ICT revolution ultimately rests on how these opportunities and threats are actually realized in practice. Will the rapid market growth and technological disruption opportunities created by the ICT revolution generate sufficient ‘digital dividends’ to the late-industrializing countries? Or will the weight of cumulative advantages enable the more advanced countries to better exploit the new technologies, leading to an increasing ‘digital divide’ between the more advanced and late-comer nations?

This issue of ‘digital dividends’ versus ‘digital divide’ is particularly pertinent in the current debate on the economic development prospects of East Asia. From the late 1960s to the mid-1990s, East Asia has generally benefited from being the manufacturing workhorse for the rapidly expanding global electronics industry, the precursor of the recent ICT revolution. It may be argued that the high presence of ICT goods manufacturing is likely to spill over into a high rate of diffusion and adoption of ICT in the rest of the economy.[1] However, the recent Asian financial crisis in 1997–99 has instead highlighted the possibility of an opposite effect: excessive focus on manufacturing may lead to neglect and subsequent underdevelopment of the services industries, especially financial services and other knowledge-based services which are ICT intensive. Accordingly, many Asian governments, through excessive domestic regulations in general and possible policy bias in favour of manufacturing in particular, may have deterred (or at least not encouraged) the widespread diffusion and adoption of ICT applications in many service sectors of the economy. As a result, Asia will become increasingly unable to compete in the new global ‘knowledge-based economy’ (KBE) where the sources of competitive advantage are high knowledge-intensity and fast adoption of new technological innovation, not low-cost manufacturing and other factor cost advantage (Jalava and Pohjola, 2002; OECD, 2000; Bosworth and Triplett, 2001). For example, Dedrick and Kraemer (1998) have argued that East Asian countries—because of inadequate diffusion and adoption of advanced ICT in much of the non-manufacturing services sectors—have become trapped in low-margin electronics manufacturing, and lack the ability to move into high-margin service sectors such as software development, innovative design and IT services. Rather than being complementary, ICT production may divert resources away from ICT diffusion activities.

This paper attempts to throw light on the impact of the ICT revolution on Asian economic development by providing empirical evidence on three inter-related questions: (i) to what extent have Asian countries as a group been laggard in the adoption of ICT when compared to non-Asian countries, despite having captured a disproportionately high share of global production of ICT goods? (ii) To the extent that there is a gap between Asia and the advanced OECD countries in ICT diffusion, has it widened over time? (iii) Within Asia, has the gap in ICT adoption between the more advanced countries—Japan and the four Asian NIEs—and other developing countries of the continent widened? Based on the empirical evidence

[1] See, for example, Wong (1998) for argument along this line in the case of Singapore.

presented, I hope to provide some new insights on the policy implications of the ICT revolution for Asian countries.

The paper is organized as follows. In the next section, I briefly review the empirical evidence indicating that Asia has, indeed, captured a disproportionate share of manufacturing for the global ICT goods market, one of the opportunities provided by the ICT revolution. In the third section, I examine the empirical evidence on the pace of adoption of various ICT goods and services in Asia versus other countries elsewhere. Using a regression analysis, after controlling for a number of indicators of the level of economic development, I show that Asia as a whole lags behind a representative basket of countries in the world. The regression results also indicate a significant and growing gap over time between the more advanced versus the less developed countries within Asia. Finally, I discuss possible policy implications from the empirical findings in Section 4.

2. Asia's growing share of global ICT production and market

Various earlier studies have highlighted the growing importance of East Asia as a major production platform for the global electronics industry up to the mid-1990s.[2] Nevertheless, it is useful to provide a statistical overview of how Asia has continued to dominate global production of ICT goods up to the late 1990s. A useful data source in this regard is the *Annual Yearbook on World Electronics Data* by Elsevier, which provides time-series data on electronics production by major producing countries from 1985 onwards (Elsevier, 2000 and earlier years). Table 1 summarizes the available data from 1985 to 98 on annual electronics output by eleven Asian countries comprising Japan the four Asian NIEs (Singapore, Korea, Taiwan and Hong Kong), the ASEAN4 (Malaysia, Thailand, Philippines and Indonesia), China and India. Table 2 provides information on Asia's share of global production for selected electronics sub-sectors.

Overall, the total share of Asia in global production rose from about 25% in 1985 to nearly 40% in 1990 and as much as 46% in 1995, before declining slightly to 45% in 1997 and dropping further to 39% in 1998. The sharp drop in 1998 was due mainly to Japan, but the turmoil caused by the onset of the financial crisis, including sharp depreciation of most Asian currencies, may have contributed to the declines in electronics production in most other Asian countries in that year as well.

A 'flying geese' pattern of shifting electronics production share within Asia from Japan to the Asian NIEs and later to the ASEAN4 and China can be clearly discerned over the period 1985–98. Japan's share of global production rose strongly from 18.4% to a peak of 28.1% in 1991. It has since experienced gradual

[2] See, for example, Ernst and O'Connor (1992); Dedrick and Kraemer (1998), and Borrus et al., 2000).

Table 1
Asian share of global electronics production in 1985–98 (US$ million)

	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
Japan	89 390	184 490	207 402	196 047	212 044	234 129	267 461	244 953	234 660	196 179
Hong Kong	3680	8066	8340	8505	8948	9157	9596	8746	8706	8217
Singapore	4458	14 992	16 709	20 245	23 556	31 599	39 783	43 597	43 554	37 850
South Korea	6501	23 031	25 446	26 143	28 803	36 141	49 276	48 136	49 406	39 275
Taiwan	5922	14 682	15 779	17 851	21 116	23 338	29 311	32 123	36 265	33 575
Indonesia	580	1269	1653	2169	2782	3971	4861	6006	6073	5213
Malaysia	1851	7363	9089	12 506	16 129	21 035	27 727	29 575	30 023	27 420
Philippines	1063	2049	2139	2333	2983	4069	4225	5527	7310	7280
Thailand	626	4033	5403	6185	7349	9675	12 521	14 399	14 655	14 576
China	5581	12 039	13 663	15 954	17 797	23 456	28 290	33 370	39 543	46 859
India	2012	5149	4166	4258	4252	5044	5781	6276	5813	6345
Asia	121 664	277 163	309 789	312 196	345 759	401 614	478 832	472 708	476 008	422 789
World	481 708	699 098	738 791	748 186	778 570	877 863	1 039 293	1 059 496	1 055 401	1 087 783
Percentage of world total										
Asian NIEs	4.27	8.69	8.97	9.72	10.59	11.42	12.31	12.52	13.07	10.93
Japan	18.56	26.39	28.07	26.20	27.24	26.67	25.73	23.12	22.23	18.03
Other Asia	2.43	4.56	4.89	5.80	6.59	7.66	8.03	8.98	9.80	9.90
All Asia	25.26	39.65	41.93	41.73	44.41	45.75	46.07	44.62	45.10	38.87

India and world figures for 1997 and 1998 are forecasts at 1996 constant values and exchange rates; China and world figures for 1985 are estimated by extrapolation from their average growth rates over 1987–90; China figures for 1997 and 1998 are estimated by extrapolation from average growth rate over 1990–96. Source: Elsevier (1988–1998 and 2000).

Table 2
Asian share of global production, selected subsectors

	1987		1990		1996	
	US$ mil	%	US$ mil	%	US$ mil	%
EDP	49 230	35.14	73 680	41.14	144 904	47.97
Office equipment	6329	38.77	7608	43.93	9357	50.74
Control and instrument electronics	6328	12.68	8200	13.08	12 660	15.51
Medical and industrial electronics	4672	25.40	5874	24.81	9242	25.61
Radio communications (incl. mobiles) and radar	10 279	13.67	13 252	15.01	31 022	25.47
Telecommunications	15 400	26.99	20 930	29.24	32 987	31.91
Consumer electronics	45 380	67.30	55 085	66.62	60 994	62.90
Components production	68 157	50.61	92 534	53.30	171 542	57.30

Source: Elsevier (various years).

decline to 18% in 1998 in proportionate market share; in absolute terms, its production peaked in 1995. The share of the four Asian NIEs rose from 4.3% in 1985 to 8.7% in 1990, 12.3% in 1995, and peaked at 13% in 1997; their share has declined to 11% in 1998. The share of the ASEAN4 rose from 0.8% in 1985 to 2.1% in 1990, 4.8% in 1995, and 5.0% in 1998. Like the ASEAN4, China's share also increased steadily over the years, whereas India's has been more or less stable around 0.6%. Unlike all the other East Asian countries, India's participation in the global ICT industry has been through software production, not hardware production (Arora and Athreye, 2002). Unfortunately, reliable statistics on software production are not available for most Asian countries.

In terms of specific electronics sub-sectors, Asia achieved the highest share in consumer electronics (67% in 1987 with a slight decline to 63% in 1996), electronics components (51% in 1987, increasing to 57% in 1996) and computer-related products (35% in 1987, increasing to 48% in 1996). Although more recent statistics by detailed sub-sectors are not available after 1996 for Asia as a whole, data for the Asian NIEs alone indicate a continuing expansion of their production shares in the computer and peripheral subsectors after 1996.

Table 3 shows the estimated revealed comparative advantage (RCA) ratios for electronics production in 1998 for the 11 Asian countries versus the mean RCA values for a sample of 34 of the more advanced non-Asian countries. It is interesting to note that eight of the 11 countries in Asia have electronics RCA values that are greater than 1 (the exceptions are India, Indonesia and Hong Kong); the average for all Asian countries is 1.32. In contrast, only three of the non-Asian countries (USA, Israel and Brazil) have mean RCA values for electronics exports greater than 1; the mean for all non-Asian countries is 0.42.

To examine whether electronics RCA is related to the level of economic

Table 3
Revealed comparative advantage (RCA) in electronics production, 1998

Country	RCA in electronics production[a]
Indonesia	0.535
Malaysia	1.874
Philippines	1.237
Thailand	1.341
China	1.279
India	0.699
Japan	2.534
Hong Kong	0.236
Korea	1.487
Singapore	1.726
Taiwan	1.522
Means	
Asia	1.315
Non-Asian countries	0.421
All countries	0.640

Ideally, share of electronics export, rather than production, should be used in the denominator. Unfortunately, data for world electronics export for 1998 are not yet available from Elsevier, and published data from WTO (2000) on electronics exports are available for a much smaller subset of countries only. As there is a high correlation between electronics production and export, the bias in using the above proxy measure is not expected to be significant. If anything, it tends to underestimate the difference between Asia and non-Asia, as the latter (especially the OECD countries) have lower electronics export/production ratios. Source: Elsevier (2000) for electronics production; WTO (2000) for world merchandise exports.

[a] Share of world electronics production/share of world merchandise exports 1998.

development and competitiveness in general, regression analysis of electronics RCA was carried out against two different measures, one for the level of economic development, and one for competitiveness. As a proxy for the economic development level, we chose GDP per capita, measured in constant US dollars on PPP basis. For competitiveness, we chose the world competitiveness index (CI) as compiled by IMD for its annual *World Competitiveness Yearbook* (IMD, 1999). The regression, using the log–log model specification, was run for a sample of about 50 countries for which data are available for 1998. To test for whether the subsample of Asian countries exhibits different behaviour compared to non-Asian countries, we introduced a dummy variable (Asia = 1, non-Asia = 0) for both the intercept and slope terms, respectively. Table 4 summarizes the results.

As expected, electronics RCA is found to be significantly correlated with both GDP/capita and competitiveness index, with the elasticity coefficients being bigger than one for both cases: a 1% increase in GDP per capita (competitiveness index) is associated with a 1.14% (4.3%) increase in electronics RCA, respective-

Table 4
Regression results of electronics RCA against GDP/capita and competitiveness index (CI)

Explanatory variables	α_0	α_1	β_1	β_2	Adjusted R^2
GDP/capita, no Asian dummy	−12.392**	1.147**			0.165[a]
GDP/capita, with Asian dummy	−25.430**	2.444**	23.792**	−2.254**	0.580
CI, no Asian dummy	−19.229**	4.297**			0.200[a]
CI, with Asian dummy	−25.834**	5.793**	24.750*	−5.479†	0.413

Equation used (without Asian dummy variable): $\ln(Y) = \alpha_0 + \alpha_1 \log(X)$; equation used (with Asian dummy variable): $\ln(Y) = \alpha_0 + \alpha_1 \log(X) + \beta_1(\text{Asia}) + \beta_2 \log(X) \cdot (\text{Asia})$. ** Significant at 0.01 level. * Significant at 0.05 level. † Significant at 0.1 level.

[a] R^2.

ly. Interestingly, the Asian dummy for intercept and slope are both significant, with the former positive and the latter negative, i.e. the electronics RCA varies less among Asian countries, although they are generally at a higher mean level than in most non-Asian countries.

Table 5, using estimates from the same data source (Elsevier, 2000), contrasts the changing share of Asia in the global consumption of ICT goods versus production over 1987–97. As can be seen, Asia's share of global consumption of ICT goods, while gradually increasing over time (from less than 29% in 1988 to about 32.5% in 1997), was consistently lower than its share in global production. The consumption–production gap was particularly pronounced in the case of the computer-related, consumer electronics and components sub-sectors.

Table 5
Asia's share of global electronics consumption, 1988–97

	1988		1993		1997	
	US$ mil	% of world total	US$ mil	% of world total	US$ mil	% of world total
Japan	126 156	20.30	136 605	18.23	199 248	18.40
Hong Kong	4565	0.73	6596	0.88	8516	0.79
Singapore	5300	0.85	12 156	1.62	21 102	1.95
South Korea	11 054	1.78	17 570	2.34	33 003	3.05
Taiwan	7130	1.15	11 912	1.59	16 858	1.56
Indonesia	1427	0.23	3376	0.45	5707	0.53
Malaysia	1874	0.30	7356	0.98	13 521	1.25
Philippines	599	0.10	1735	0.23	3963	0.37
Thailand	1717	0.28	5508	0.74	9607	0.89
China	12 220	1.97	19 368	2.58	33 838	3.12
India	4831	0.78	4206	0.56	6324	0.58
Asia	176 873	28.46	226 388	30.22	351 687	32.48
World	621 404		749 254		1 082 908	

The year 1997 is forecast at 1996 constant values and exchange rates. Source: Elsevier (1990–1998).

Table 6
ICT diffusion in Asia

Country	Computers per 1000	MIPS[a] per 1000	Internet hosts per 1000	Telephone (main) lines in use per 1000	Cellular mobile telephone per 1000 subscribers	Secure servers/million Jan. 2001	Electronics market per capita (US$)	ICT per capita (US$)
Indonesia	11	1435	0.11	26.7	5.2	60	18.60	8.86
Malaysia	78	12 107	1.93	204.7	101.5	146	488.38	214.69
Philippines	16	2203	0.21	31.9	19.0	68	53.02	26.75
Thailand	33	5139	0.03	82.2	39.6	116	122.71	52.11
China	7	1084	0.02	73.6	20.1	184	29.80	31.40
India	4	513	0.01	20.3	1.2	122	6.08	13.17
Japan	272	47 331	11.03	493.9	315.7	5153	1135.14	2485.69
Hong Kong	310	53 981	20.09	583.6	430.8	538	1210.90	1820.13
Korea	150	26 096	4.22	467.0	304.2	345	379.94	431.95
Singapore	344	59 864	13.45	464.6	280.7	525	4173.85	2348.20
Taiwan	178	31 053	16.71	542.7	194.7	372	848.49	610.86
Mean								
Asia	127.55	21 891.45	6.16	271.93	155.70	636.25	769.72	731.256
OECD[b]	270.48	46 790.44	26.18	496.40	230.64	4377.88	671.43	1396.77
Non-Asia	221.48	38 083.79	20.55	424.71	182.61	2613.51	607.06	1022.39

All data are for 1998 unless otherwise stated. Source: IMD (1999 and 2000); WEF (1998); Elsevier (various years); WTO (2000); World Telecommunication Indicators (International Telecommunication Union); www.netcraft.com; WITSA (2000).

[a] Millions of instructions per second.

[b] Includes: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Korea and Japan excluded.

3. ICT diffusion: are Asian countries laggards?

While the continent has performed as a group disproportionately well in ICT production (with the possible exception of India, Indonesia and Hong Kong), a rather mixed picture emerges when we examine Asian countries' performance in terms of diffusion or adoption of various ICT goods and services relative to non-Asian countries. For the purpose of this analysis, comparable data are compiled for the following eight indicators of ICT diffusion: (i) number of computers per 1000 people; (ii) computing power in millions of instruction per second (MIPS) per 1000; (iii) number of internet hosts per 1000; (iv) number of secure e-commerce hosts per 1000; (v) number of fixed telephone lines per 1000; (vi) number of cellular phone subscribers per 1000, (vii) estimated electronics goods consumption per capita; and (viii) estimated ICT expenditure per capita. Table 6 summarizes the available data for these ICT diffusion indicators for each of the eleven individual Asian countries for the year 1998 (or nearest year when data for the relevant years were not available). Table 7 summarizes the growth trends of these ICT diffusion indicators over 1994–98 for Asia as a whole. Similar data are compiled for 32 non-Asian countries for which data are available; these include all the (non-Asian) OECD countries and most of the newly industrializing countries from the Middle East, Latin America and former Eastern European countries. Although the sample coverage of countries is considerably smaller than that in Norris (2000), it has the advantage of providing a broad range of ICT diffusion indicators instead of just internet hosts.

Overall, it is observed that as a group the Asian countries appear to have significantly lower mean ICT adoption intensities in comparison to the OECD countries in 1998. The gap appears to be biggest for internet hosts per 1000 and secure e-commerce hosts per 1000, and smallest for cellular phone subscriptions per 1000. Even if we use the broader basket of non-Asian countries as the reference, Asian countries still appear to lag behind the overall mean values for non-Asian countries.[3]

While Table 7 shows that Asia as a group has made rapid improvement in all the ICT diffusion indicators over the period 1994–97, the gap between Asia and the OECD countries appears to have narrowed only moderately, OECD countries also registered significant improvement on all indicators. In the case of secure e-commerce servers, the gap has actually increased.[4] The picture appears to be slightly better if we compare Asia with all non-Asian countries as the reference group. Between 1997 and 98, the gap between Asia and non-Asia stopped

[3] The only exception is electronics consumption per capita which, however, may be misleading since it includes not just final consumption, but also intermediate goods used in electronics production; the more narrowly defined indicator of ICT expenditure does show an Asian deficit.

[4] It should be noted that our findings appear to be contrary to the findings of Kraemer and Dedrick (2000), who found an increasing gap between Asia and the OECD countries for about the same period.

Table 7
ICT diffusion: Asian versus non-Asian countries, 1994–98

	1994	1995	1996	1997	1998
Computers per 1000					
Asia	54.10	78.40	84.91	109.00	127.55
Non-Asia	107.21	131.33	156.85	188.67	221.48
OECD[a]	133.40	161.64	192.52	230.56	270.48
Asia/Non-Asia	0.50	0.60	0.54	0.58	0.58
Asia/OECD[a]	0.41	0.49	0.44	0.47	0.47
MIPS per 1000					
Asia	608.70	2026.27	4922.82	11 233.55	21 891.45
Non-Asia	1318.06	3858.76	9058.55	19 536.03	38 083.79
OECD[a]	1601.00	4773.80	11 175.12	24 007.16	46 790.44
Asia/Non-Asia	0.46	0.53	0.54	0.58	0.57
Asia/OECD[a]	0.38	0.42	0.44	0.47	0.47
Internet hosts per 1000					
Asia			1.45	3.24	6.16
Non-Asia			7.21	12.17	20.55
OECD[a]			9.19	15.58	26.18
Asia/Non-Asia			0.20	0.27	0.30
Asia/OECD [a]			0.16	0.21	0.24
Telephone (main) lines per 1000					
Asia	215.62	227.70	258.99	270.51	271.93
Non-Asia	333.60	368.39	391.62	405.97	424.71
OECD[a]	428.55	437.24	462.51	475.84	496.40
Asia/Non-Asia	0.65	0.62	0.66	0.67	0.64
Asia/OECD[a]	0.50	0.52	0.56	0.57	0.55
Cellular mobile phone subscribers per 1000					
Asia	21.38	31.63	69.88	105.99	155.70
Non-Asia	26.62	39.93	88.85	123.54	182.61
OECD[a]	33.28	49.76	108.75	155.57	230.64
Asia/Non-Asia	0.80	0.79	0.79	0.86	0.85
Asia/OECD[a]	0.64	0.64	0.64	0.68	0.68
Secure servers per million				Nov. 1996	Jan. 2001
Asia				0.62	24.68
Non-Asia				1.42	47.26
OECD[a]				1.69	75.78
Asia/Non-Asia				0.44	0.52
Asia/OECD[a]				0.37	0.33
ICT per capita (US$, current exchange rates)					
Asia	543.68	622.98	705.74	755.87	731.26
Non-Asia	754.91	870.61	915.54	925.18	1022.39
OECD[a]	1037.18	1199.78	1260.91	1263.50	1396.77
Asia/Non-Asia	0.72	0.72	0.77	0.82	0.72
Asia/OECD[a]	0.52	0.52	0.56	0.60	0.52

[a] Includes: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Korea and Japan excluded.

narrowing or even increased, due no doubt to the adverse impact of the financial crisis that gripped much of Asia from mid-1997.

Such an aggregate comparison of the mean diffusion rates of Asia versus non-Asia may, however, be potentially misleading, given that the Asian countries as a group may systematically be at lower levels of economic development than the sample of non-Asian countries, which includes all the advanced OECD countries. The intensity of ICT adoption is likely to vary with the general level of economic development of the countries concerned. Consequently, without controlling for possible differences in the average level of economic development between the Asian and non-Asian groups, a comparison of the means of the two groups may be unfairly biased against Asia if the countries in the Asian sample have generally lower levels of economic development compared to the non-Asian sample.

To control for such possible biases, we first run regression of the various diffusion indicators against two different control variables separately: (i) GDP/capita (at constant PPP US$), as a proxy measure to control for the level of economic development of the countries; and (ii) the world competitiveness index (CI) from IMD (1999), as a proxy measure to control for the overall level of competitiveness of the countries. By regressing the ICT indicators against these two indicators for the sample of all countries (11 Asian and 32 non-Asian countries), we can use the resulting regression lines to estimate the predicted level of ICT diffusion for any given level of economic development or competitiveness. We can thus estimate the extent to which the Asian countries, given their level of development or competitiveness, fall below their predicted norms. In addition, we can also test whether the Asian countries as a subsample exhibited different regression behaviour from the non-Asian subsample.

We choose to use two different control variables, one as a proxy measure for past economic performance (GDP/capita), and one as a proxy measure for expected future economic performance (competitiveness). Although the competitiveness index is found to be statistically highly correlated with GDP/capita (Pearson correlation: 0.852), we find it useful to retain both, as they yield somewhat different results. Methodologically, the CI measure is constructed independently from GDP/capita, based on the notion of potential capacity for future economic performance (competitiveness) rather than the outcome of past economic performance (GDP/capita) (IMD, 2000). While other studies[5] on the determinants of internet diffusion have used GDP/capita as explanatory variables, none have used the competitiveness index variable.

A log–log model specification is used for both sets of regression, as it not only provides much better statistical fit than the linear specification model, but it also has the advantage of providing a constant estimate of the average elasticity of the

[5] See, for example, Kiiski and Pohjola (2002) and Norris (2000).

Table 8
ICT diffusion versus GDP/capita and competitiveness index: regression results (without Asian dummy variable)

ICT indicator	α_0	α_1	R^2
GDP/capita			
Computers/1000	−11.282**	1.692**	0.916
MIPS/1000	−7.441**	1.822**	0.927
Internet hosts/1000	−25.253**	2.820**	0.798
Telephone (main lines)/1000	−5.794**	1.209**	0.856
Cellular phone subscribers/1000	−11.853**	1.729**	0.732
Secure servers/million	−21.752**	2.592**	0.874
Electronics market per capita	−12.084**	1.879**	0.898
ICT per capita	−13.914**	2.121**	0.946
Competitive index			
Computers/1000	−15.061**	4.763**	0.554
MIPS/1000	−11.690**	5.173**	0.569
Internet hosts/1000	−31.351**	7.891**	0.476
Telephone (main lines)/1000	−7.031**	3.053**	0.416
Cellular phone subscribers/1000	−15.246**	4.755**	0.422
Secure servers/million	−28.407**	7.502**	0.557
Electronics market per capita	−19.335**	6.020**	0.671

Equation used: $\ln(Y) = \alpha_0 + \alpha_1 \log(X)$. ** Significant at 0.01 level.

dependent variables on the control variables. Table 8 summarizes the regression results.[6]

Overall, it is found that the simple log–log regression model fits all of ICT diffusion variables well, i.e. each of the intensity of ICT adoption is found to be significantly dependent on the level of economic development and competitiveness of the nations. More importantly, it is shown that the elasticity of adoption as a function of either GDP/capita or competitiveness index is bigger than one for all of the indicator variables. What this means is that the disparity in ICT adoption intensity is higher than the disparity of GDP per capita or competitiveness index. A 1% increase in GDP/capita, for example, would lead to a 1.7% increase in the number of computers per 1000 people. Interestingly, the magnitude of this GDP/capita-elasticity appears to be higher for the more recent ICT, particularly cellular phones (1.73), internet hosts (2.82) and secure e-commerce hosts (2.59). In contrast, the elasticity is the lowest for fixed telephone line intensity (1.21).

The regression fit is found to be uniformly better for GDP/capita than for competitiveness index (CI). However, in every instance, the estimated elasticity coefficients against CI are higher than for GDP/capita: for example, the elasticity

[6] As an alternative to GDP/capita, GNP/capita was also tried. Similarly, an alternative measure of competitiveness provided by the *Global Competitiveness Report* (WEF 1999) was also tried. However, both yielded very similar results, and hence their estimates are not reported.

for internet host intensity was 7.9 with respect to the competitiveness index versus 2.8 for GDP/capita. Despite the uniformly higher elasticity estimate for CI versus GDP/capita, the pattern of variation in the estimated magnitude of the elasticity coefficients across the seven ICT diffusion indicators was very similar: the correlation of the two sets of elasticity estimates is 0.981.

To examine possible differences between the subgroup of Asian countries compared to non-Asian, we re-run the regression after introducing a dummy variable for membership in Asia (Asia = 1, non-Asia = 0), which enters in both the additive as well as multiplicative term in the model specification, to test for possible significant differences in intercept and slope for the two subgroups. Table 9 summarizes the regression findings.

If we first look at the regression results for the competitiveness index as the control variable, it is interesting to observe that the coefficients for the Asian dummy for intercept are uniformly negative for all ICT indicators; they are significant at 0.05 level for five of the indicators and at 0.10 level for two of them. At the same time, the coefficients for the Asian slope (elasticity) dummy are uniformly positive for all ICT variables; they are significant at the 0.05 level for four of the indicators and at the 0.11–0.15 level for three of them. What this means is that the Asian subsample exhibits a higher rate of variability in all the ICT indicators compared to the non-Asian subsample over the same range of

Table 9
ICT diffusion versus GDP/capita and competitiveness index: regression results (with Asian dummy variable)

ICT indicator	α_0	α_1	β_1	β_2	Adjusted R^2
GDP/capita					
Computers/1000	−10.798**	1.645**	−0.390	0.024	0.913
MIPS/1000	−7.251**	1.805**	0.047	−0.018	0.923
Internet hosts/1000	−21.041**	2.404**	−5.012	0.435	0.821
Telephone (main lines)/1000	−3.244**	0.951**	−3.967**	0.393**	0.886
Cellular phone subscribers/1000	−11.258**	1.660**	−2.159	0.262	0.724
Secure servers/million	−20.964**	2.519**	−0.794	0.032	0.875
Electronics market per capita	−12.217**	1.881**	−1.472	0.209	0.914
ICT per capita	−12.832**	2.015**	−1.565	0.134	0.950
Competitiveness index					
Computers/1000	−12.980**	4.327**	$-9.242^{\dagger}$	1.961	0.693
MIPS/1000	−9.551**	4.726**	−9.501	2.015	0.697
Internet hosts/1000	−26.506**	6.871**	−21.501*	4.591*	0.706
Telephone (main lines)/1000	−4.211*	2.431**	−12.452**	2.768**	0.646
Cellular phone subscribers/1000	−12.114**	4.044**	$-13.779^{\dagger}$	3.143	0.462
Secure servers/million	−24.218**	6.609**	−17.070*	$3.622^{\dagger}$	0.756
Electronics market per capita	−15.212**	5.071**	−16.158**	3.730*	0.736
ICT per capita	−14.799**	5.133**	−17.841**	3.933**	0.765

Equation used: $\ln(Y) = \alpha_0 + \alpha_1 \log(X) + \beta_1(\text{Asia}) + \beta_2(\log(X) \cdot \text{Asia})$. ** Significant at 0.01 level. * Significant at 0.05 level. † Significant at 0.1 level.

competitiveness index variation. For example, the elasticity coefficient for internet hosts per 1000 is 6.9 for the non-Asian subsample, but 11.5 ($6.9 + 4.6$) for the Asian subsample.

Turning to the regression results for GDP/capita as the control variable, a similar pattern is observed (negative Asian dummy for intercept, positive Asian elasticity dummy); however, all except one of the coefficients are statistically significant at the 0.10 level. Notwithstanding the lack of statistical significance, the results none the less closely mirror the findings in the case of competitiveness index; the correlation between the two sets of elasticity estimates for the Asian subsample is extremely high (0.992).

We can now answer the question of whether Asian countries as a group are laggards in ICT adoption by estimating the extent to which ICT diffusion rates in this country group are below the norm established by the regression lines for GDP/capita and CI, respectively. To do this, we first calculate the 'predicted' value for each of the ICT adoption indicators for each of the Asian countries using the estimated regression models for the various ICT adoption indicators as a function of GDP/capita and competitiveness index, respectively. We then calculate the ratio of the actual observed value to the predicted values, and then finally compute the mean of these ratios for all Asian countries. A mean ratio of less than one would indicate that the Asian countries as a group had an ICT adoption rate that is *below* their potential as predicted from the regression model. A related indicator would be the proportion of Asian countries that fall below the regression line: a significantly higher proportion than half would indicate that Asian countries tend to under-perform compared to the average trend line. Table 10 summarizes the results.

The most obvious observation from Table 10 is that the Asian countries as a group indeed exhibit *lower* levels of ICT penetration than can be predicted from their level of economic development (as measured by GDP per capita) or their level of competitiveness (as measured by their world competitiveness index). The only exceptions are mobile phone penetration and electronics consumption/capita, where the actual Asian averages outperform their predicted values. The under-performance of Asian countries appears to be more severe relative to their competitiveness level. Eight or nine of the 11 Asian countries fall below the regression line for competitiveness index in all ICT adoption intensity indicators except mobile phones. The mean ratio of actual versus predicted intensities range from 0.48 for secure e-commerce servers and 0.64 for internet hosts to 0.76 for fixed telephone lines and 1.31 for mobile phones. The extent of under-performance appears to be much less when GDP/capita is used as the control, but the pattern is very similar to that for competitiveness index. In particular, Asia's under-performance is the severest for internet and e-commerce host diffusion.

The above findings suggest that given their level of economic development and competitiveness, the Asian countries as a group do lag behind the average norm. However, in view of our earlier observations that the Asian countries jointly

Table 10
Ratio of actual versus predicted intensity of ICT adoption for Asian countries

	All Asia	Asian NIEs and Japan	Other Asian countries
World competitiveness index			
Computers per 1000	0.73	1.26	0.30
MIPS per 1000	0.77	1.35	0.29
Internet hosts per 1000	0.64	1.30	0.09
Telephone (main) lines per 1000	0.76	1.31	0.29
Cellular phone subscribers per 1000	1.31	2.38	0.42
Secure servers/million	0.48	0.96	0.15
Electronic markets/capita	1.09	1.80	0.50
ICT per capita	0.70	1.36	0.15
GDP per capita			
Computers per 1000	0.92	0.92	0.93
MIPS per 1000	0.95	0.94	0.96
Internet hosts per 1000	0.78	0.81	0.74
Telephone (main) lines per 1000	0.87	1.02	0.74
Cellular phone subscribers per 1000	1.38	1.54	1.25
Secure servers per million	0.80	0.83	0.75
Electronic markets per capita	1.49	1.63	1.38
ICT per capita	0.87	0.94	0.82

Equation used: $\ln(Y) = \alpha_0 + \alpha_1 \log(X)$. All data are for 1998, except for secure servers/million, which are for January 2001.

exhibit higher disparities in ICT diffusion intensities, this observation of low mean adoption rates for the group as a whole suggests that they may be caused by the existence of a subgroup of Asian countries that *significantly* under-perform, while some group members may actually perform above the norm for their level of development and competitiveness. This is borne out by the subgroup analysis presented in Table 11, which breaks down the continent into two groups: Japan and the four Asian NIEs, and the other six countries (ASEAN4, China and India). The first group represents the more advanced countries, with mean GDP/capita 4.4 times that of the second group. In terms of competitiveness index, economies in the first group all rank higher than those in the second group, with their mean CI more than three times that of the second group.

A clear digital divide can be discerned between the more advanced and less developed country groups from Table 11. The average levels of ICT adoption for the six less developed countries are only about one-tenth of the levels achieved by the advanced group of five countries in 1998. For internet hosts and secure e-commerce hosts, the ratio is much worse (3 and 2%, respectively). Despite some improvement from 1994 to 1998 for nearly all ICT diffusion indicators, the digital divide between the advanced Asian countries and their less advanced neighbours remains very high indeed.

The contrast becomes even stronger when we examine the ratio of actual versus

Table 11
Gap in ICT diffusion over 1994–98: Japan and Asian NIEs versus other Asian countries

	1994	1995	1996	1997	1998
Computers per 1000					
Asia NIEs + Japan	103.60	138.20	167.40	215.20	250.80
Other Asia	4.60	18.60	16.17	20.50	24.83
All Asia	54.10	78.40	84.91	109.00	127.55
Other Asia/(Japan + Asian NIEs)	0.04	0.13	0.10	0.10	0.10
MIPS per 1000					
Asia NIEs + Japan	1167.80	4101.60	9741.20	22 484.80	43 665.00
Other Asia	49.60	296.83	907.50	1857.50	3746.83
All Asia	608.70	2026.27	4922.82	11 233.55	21 891.45
Other Asia/(Japan + Asian NIEs)	0.04	0.07	0.09	0.08	0.09
Internet hosts per 1000					
Asia NIEs + Japan			3.12	6.81	13.10
Other Asia			0.06	0.27	0.39
All Asia			1.45	3.24	6.16
Other Asia/(Japan + Asian NIEs)			0.02	0.04	0.03
Telephone (main) lines per 1000					
Asia NIEs + Japan	431.80	449.48	494.38	511.36	510.36
Other Asia	35.47	42.88	62.83	69.80	73.23
All Asia	215.62	227.70	258.99	270.51	271.93
Other Asia/(Japan + Asia NIEs)	0.08	0.10	0.13	0.14	0.14
Cellular phone subscribers per 1000					
Asia NIEs + Japan	33.14	48.00	126.16	198.98	305.22
Other Asia	6.68	11.18	22.98	28.50	31.10
All Asia	21.38	31.63	69.88	105.99	155.70
Other Asia/(Japan + Asia NIEs)	0.20	0.23	0.18	0.14	0.10
Secure servers per million				Nov 1996	Jan 2001
Asia NIEs + Japan				1.02	65.43
Other Asia				0.10	1.40
All Asia				0.62	24.68
Other Asia/(Japan + Asia NIEs)				0.10	0.02
ICT per capita					
Asia NIEs + Japan	1135.29	1296.43	1467.34	1581.17	1539.37
Other Asia	50.67	61.78	71.08	68.11	57.83
All Asia	543.68	622.98	705.74	755.87	731.26
Other Asia/(Japan + Asia NIEs)	0.04	0.05	0.05	0.04	0.04

predicted performance in ICT diffusion against competitiveness for the two groups. While the group of five advanced Asian nations uniformly performs above the norm of competitiveness for all indicators of ICT diffusion except secure e-commerce hosts, the group of six less developed countries uniformly under-performs relative to the norm. The under-performance is particularly severe for internet hosts and secure e-commerce hosts (0.09 and 0.15, respectively).

Furthermore, it is the significant under-performance of the less developed group that drags the average performance of all Asian countries, as a group, below their predicted levels for six of the eight diffusion indicators, despite the above-norm performance of the group of advanced Asian countries. The contrast is much less marked when GDP/capita is used as the control.

Having examined the pattern of ICT diffusion in Asia in detail, we can now return to the question posed earlier regarding the possible spillover effects of ICT manufacturing activities on ICT diffusion and use in the overall economy of the countries concerned. Table 12 summarizes the results of regressing the various ICT diffusion indicators on electronics RCA as a proxy measure of the country's competitiveness in ICT manufacturing activities in the same sample of Asian and non-Asian countries. The possible difference in behaviour of the Asian subsample is investigated in the same way, using an Asian dummy. The results clearly show that there is no statistically significant correlation between competitiveness in electronics production and all the ICT diffusion indicators except secure e-commerce servers, electronics consumption/capita and ICT expenditure/capita in the sample of all countries. The picture improves somewhat when the Asian dummy variable is introduced, although none of the Asian dummy variables for slope are significant. If we examine the direct Pearson correlation coefficients between electronics RCA and the ICT diffusion indicators for both the all-country

Table 12
Regression results for ICT diffusion versus electronics RCA

ICT indicator	α_0	α_1	β_1	β_2	R^2	Adjusted R^2
Equation used: $\ln(Y) = \alpha_0 + \alpha_1 \log(X)$						
Computers/1000	5.059**	0.112	–	–	0.032	–
MIPS/1000	10.177**	0.137	–	–	0.041	–
Internet hosts/1000	1.842**	0.078	–	–	0.005	–
Telephone (main lines)/1000	5.783**	0.027	–	–	0.003	–
Cellular phone subscribers/1000	4.903**	0.153	–	–	0.044	–
Secure servers/million	3.327**	0.345*	–	–	0.138	–
Electronics market per capita	6.251**	0.311**	–	–	0.178	–
ICT/capita	6.507**	0.279*	–	–	0.131	–
Equation used: $\ln(Y) = \alpha_0 + \alpha_1 \log(X) + \beta_1(\text{Asia}) + \beta_2(\log(X) \cdot \text{Asia})$						
Computers/1000	5.594**	2.47*	−1.469**	0.297	–	0.218
MIPS/1000	10.752**	0.282*	−1.579**	0.315	–	0.225
Internet hosts/1000	2.908**	0.352†	−2.872**	0.322	–	0.238
Telephone (main lines)/1000	6.208**	0.131	−1.191*	0.352	–	0.214
Cellular phone subscribers/1000	5.344**	0.258*	−1.269*	0.518	–	0.123
Secure servers/million	4.291**	0.567**	−2.770**	0.016	–	0.349
Electronics market per capita	6.711**	0.421**	−1.319**	0.511	–	0.275
ICT/capita	7.437**	0.493**	−2.390**	0.206	–	0.389

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level. † Correlation is significant at the 0.1 level.

sample and the Asian-country only subsample, the only significant one is the electronics consumption/capita variable which, as explained earlier, includes intermediate goods for electronics production. This empirical observation is thus consistent with the argument that high involvement in ICT production has little or no positive spillover effects on ICT diffusion.

4. Discussion of policy implications

Confirming the widespread popular impression of the existence of a digital divide between more advanced and less advanced countries, our findings above show that the disparity in the intensity of ICT adoption among countries is, indeed, wider than the disparities in their GDP per capita. Moreover, the disparity is higher for the two internet-related indicators (internet hosts/1000 and secure e-commerce hosts/1000). Interestingly, we also find the disparity to be uniformly higher relative to the competitiveness index of these countries. To the extent that the competitiveness index is a valid measure for *future* economic performance potential, our findings therefore suggest that the digital divide is likely to become even more severe in the future.

In comparing the subsample of Asian versus non-Asian countries, we find that the Asian countries as a group exhibit a *higher* disparity in ICT diffusion than the non-Asian ones, after controlling for their level of economic development or competitiveness. In particular, the more advanced countries of the region (Japan and the four Asian NIEs) have achieved, as a group, above-norm ICT diffusion intensities, while the six less developed Asian nations significantly under-perform relative to their level of economic development and competitiveness. Thus, the digital divide within Asia appears to be more severe than that existing across all countries in the sample. Although the average gaps in ICT diffusion intensity between the Asian and non-Asian countries as well as among Asian countries have slightly narrowed over 1994–98, the gap remains wide, particularly in the internet-related areas.

Last but not least, we find that the correlation between competitiveness in electronics production and ICT diffusion intensity to be significantly weaker than the correlation between GDP/capita or competitiveness index with ICT diffusion. This is true for all countries in the sample, and even more so for the Asian subsample. This empirical observation is thus consistent with the argument that high involvement in ICT production has little or no positive spillover effects on ICT diffusion.

Two major policy implications can be highlighted from the above empirical findings. First, while East Asia as a whole has benefited substantially from the ICT revolution over the last 30 years as a *manufacturer* of ICT goods, through various public policies targeted at increasing manufacturing investments and improving manufacturing export competitiveness, the same does not appear to be true when it comes to being a *user* of ICT. Only the more advanced countries (Japan and the four Asian NIEs) appear to have performed well in exploiting the use of ICT. In imitating the industrial success of Japan and the four Asian NIEs, the less advanced Asian countries may thus have over-emphasized industrial policy to favour of electronics manufacturing at the expense of promoting ICT diffusion in the services sectors. Hence, for these countries, the key policy challenge of the future is not how to promote further ICT production, however important this may have been in the past, but how to promote a faster pace of adoption of ICT in the economy as a whole, particularly the services sectors. An important pre-condition for faster ICT diffusion is greater deregulation of these sectors, including in particular greater liberalization and openness to competition, both local and foreign. In this regard, the entry of China into WTO is to be welcomed, while the slow progress of trade and services liberalization in ASEAN and India is a concern.

Secondly, the economics of the production of ICT goods has generally in the past been favourable to Asia by providing a significant regional spillover effect, resulting in the 'flying geese' pattern of diffusion of production from the more advanced countries to their less advanced regional neighbours, as discussed in Section 2 earlier (see also Borrus et al., 2000 and Ohki, 2001). This regional complementation effect has occurred more or less naturally and was not the result of conscious public policy to promote regional cooperation.[7] Indeed, despite much public rhetoric, specific regional economic cooperation programmes in Asia have been few and these have had little impact. As we turn to the diffusion of ICT applications in general and to the development of e-commerce and advanced internet-enabled services in particular, it is, however, not clear that the same favourable regional spillover benefits will accrue naturally through market forces. Indeed, the opposite may well be true: the economics of internet and e-commerce suggests the importance of *cyberspace* proximity (network connectivity, trust, etc.) rather than *geographic* proximity, for facilitating use and transactions. Furthermore, the fragmentation of Asia into a large number of relatively small markets divided by language, culture, technical standards, lack of legal institutions and trust for e-commerce transactions and other barriers is likely to discourage widespread diffusion of new ICT and internet-based applications. These natural market heterogeneity and fragmentation factors need to be mitigated by conscious public policy actions to promote regional harmonization and cross-border transactions. It is thus important that public policymakers in the countries in Asia realize this, and begin to work together to promote regional cooperation in ICT market development in general and cross-border internet-based e-commerce activities in particular. In the absence of such policy intervention, ICT diffusion in Asia risks

[7] See, for example, McKendrick et al. (2000) for a detailed analysis in the case of the data storage industry in Asia.

being balkanized into a number of ICT hubs with high connectivity with other advanced countries outside Asia, but little intra-Asian transactions.

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