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Digital inequality: A five country comparison using microdata ☆

Hiroshi Ono [a,*], Madeline Zavodny [b]

[a] *Stockholm School of Economics, P.O. Box 6501, S-113 83 Stockholm, Sweden*
[b] *Department of Economics, Agnes Scott College, 141 E. College Ave., Decatur, GA 30030, USA*

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Abstract

This study examines patterns and determinants of information technology (IT) usage in five countries: the U.S., Sweden, Japan, South Korea and Singapore. We focus on cross-country differences in IT access and use across sex, age, education and income groups. We examine how any such differences have evolved over time. Our results indicate that there are differences in IT usage in all five countries, but gaps tend to be more prevalent in the three Asian nations than in the U.S. and Sweden. Our findings generally suggest that differences in IT usage along demographic and socioeconomic dimensions reflect the extent of differences in other areas of the economy and society.

Keywords: Information technology; Computers; Internet; Digital divide; Digital inequality

1. Introduction

Information technologies (IT) such as computers and the Internet have become increasingly important means for individuals to gain access to information and have changed how

☆ Paper presented at the American Sociological Association meeting, Philadelphia, August 2005. Direct all correspondence to Hiroshi Ono, Stockholm School of Economics, P.O. Box 6501, 113 83 Stockholm, Sweden <email: Hiroshi.Ono@hhs.se>. Ono gratefully acknowledges financial support from the Swedish Council for Working Life and Social Research (*Forskningsrädet för Arbetsliv och Socialvetenskap* [FAS]). We thank Juro Toda and Kaga Yanagisawa for assistance and support with the Nomura Research Institute data and Erik Bihagen and Yutaka Honkawa for assistance with the aggregate-level data.
* Corresponding author. Fax: +46 8 31 30 17.
E-mail addresses: Hiroshi.Ono@hhs.se (H. Ono), mzavodny@agnesscott.edu (M. Zavodny).

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we process information. In spite of the tremendous increase in IT use in recent years, a pattern of "digital inequality," or differences in IT access and usage, persists both across countries and across certain socioeconomic and demographic groups within countries.[1] In 2000, the 29 OECD member states contained 90% of all Internet users in the world, and there were more Internet users in Sweden than in the entire continent of Africa (Norris, 2000). In 2004, the rate of Internet penetration was 31% for Europe as a whole versus 8% for Asia and less than 3% for Africa (ITU, 2006). Within most countries, nonusers tend to be disproportionately women, minorities, less-educated and the poor (OECD, 2001).[2] And even among IT users there are often systematic differences across such groups in intensity and types of use (e.g., DiMaggio et al., 2004).

Unequal access to and use of IT is linked with social and economic inequality because of both its causes and its potential consequences. It is important to assess the extent of differences in IT usage and their underlying causes because access to computers and the Internet improves opportunities for education, employment and civil engagement. At the international level, various organizations such as the United Nations, OECD, World Bank and the World Economic Forum have expressed grave concerns that "the explosion of the Internet may leave many nations far behind, producing growing disparities between advanced industrialized and developing societies" (Norris, 2000, p. 2). At the individual level, "differential spread of the Internet (may) lead to increasing inequalities, benefiting those who are already in advantageous positions and denying access to better resources for the underprivileged" (Hargittai, 2003, pp. 826–827). Further, differences in IT access and use may reflect, or even be caused by, broader patterns of inequality, such as differences in education and employment across racial and ethnic groups or between the sexes.

This paper assesses the magnitude of digital inequality within and across countries and over time in the United States, Sweden, and three East Asian countries—Japan, South Korea and Singapore. We focus on these five countries because they represent developed economies in three different geographic regions with salient differences in their economic and social institutional base. After briefly reviewing the available data regarding differences in IT access and usage in the five countries, we examine the determinants of digital inequality within these countries. Our general hypothesis is that digital inequality reflects inequality in other facets of the economy and society. We therefore examine the extent to which inequality in such areas as education, income and gender carries over to IT access and use. Our empirical analysis is made possible through comparable individual-level microdata on IT usage for five countries.

This study adds to the literature empirical evidence on patterns of IT usage in countries other than the U.S., which has been the focus of most earlier research. Relatively little is known about the extent, causes and consequences of digital inequality in developed countries outside of the U.S. Because social and economic institutions and patterns of inequality—e.g., English literacy, gender inequality, income inequality and education—differ in a

[1] We use the phrase "digital inequality" because it (along with "digital divide") is the convention in this literature. In addition, we hypothesize that general patterns of differences in IT access and use are related to broader social and economic inequality. However, we note concerns that digital inequality is not necessarily a value neutral phrase. Our study is focused on exploring the extent of digital disparities, not on whether or how societies should reduce such gaps.

[2] For updated estimates of IT ownership and use in the U.S., see U.S. Census Bureau publications available at: http://www.census.gov/population/www/socdemo/computer.html.

variety of ways between the U.S., Western Europe and East Asia, the determinants of IT diffusion are not necessarily consistent or comparable across these regions.

This study looks beyond access to examine patterns of IT use in different locations. Recent empirical studies point to the importance of distinguishing access from use. As exemplified by the expression "universal access," policy measures in many areas have emphasized the need to provide equal access to computers and the Internet. However, equal access may not lead to equal use. Despite improvements in access rates, there exists a sizeable gap in actual usage even among industrialized nations, as discussed below. Merely creating access to computers does not guarantee that individuals have the necessary skills or desire to use them. DiMaggio et al. (2004) advocate examining access separately from use to avoid conflating the distinction between opportunity and choice. Use presumes access, but not vice versa.

Our focus on comparing digital inequality *within* countries complements previous research that has examined such gaps *across* countries. Several empirical studies have assessed IT diffusion in an international context (e.g., Caselli and Coleman, 2001; Chinn and Fairlie, 2004, 2006; Guillen and Suarez, 2001, 2005; Hargittai, 1999; Quibria et al., 2003; Wong, 2002). These studies examine digital inequality as a function of macrolevel indicators such as per capita gross domestic product (GDP), human capital and industrial competitiveness. Few studies have systematically investigated patterns of individual IT usage in a multinational context.[3]

2. Background

Table 1 reports two commonly used indicators of IT diffusion: computer ownership at home and the number of Internet users per 100 inhabitants during the period 1997–2002. This is the peak period of IT growth in most industrialized nations (Castells, 2001), which is reflected in the tremendous increase in IT use in the five countries. In all of these countries, the majority of households owned a computer and the majority of individuals used the Internet by the year 2002. However, there are differences across the countries in growth rates, or the speed of diffusion. For example, in 1997 Sweden already had relatively high levels of computer ownership and Internet use, and it maintained its leading position in 2002. South Korea experienced the largest gain in digital access, starting from relatively low computer ownership and Internet use and catching up with or even surpassing several other countries by 2002.

What factors underlie differences in IT diffusion across countries? Average income and education levels are important variables, but significant variation remains even after controlling for these and other economic indicators. A consistent finding in the literature is that Internet penetration in South Korea is considerably higher than expected based on average income and other macroeconomic variables (Kim et al., 2003). Internet penetration

[3] Related research includes the UCLA World Internet Project <www.digitalcenter.org>, which reports differences in Internet use by gender, age, education and income (highest and lowest quartiles) for a number of countries. Chen and Wellman (2003, 2004) also discuss differences in Internet usage within several countries. Although we examine fewer countries than those studies, we do so in a multivariate regression context and examine computer ownership and use in addition to Internet use. Ono (2006) analyzes IT usage in three Asian nations. Haisken-DeNew and D'Ambrosio (2003) estimate the relationship between IT use and wages in five countries (Great Britain, Italy, Germany, Norway and Israel) but do not examine differences in who uses IT within those countries.

Table 1
Computer ownership and Internet use

	U.S.		Sweden		Japan		South Korea		Singapore	
	Computer ownership	Internet use	Computer ownership	Internet use	Computer ownership	Internet use	Computer ownership	Internet use	Computer ownership	Internet use
1997	36.6	22.1	37.5	23.7	22.1	9.2	29.0	3.6	41.0	13.2
1998	42.1	30.8	57.3	33.4	25.2	13.4	—	6.8	—	19.1
1999	—	36.7	—	41.4	29.5	21.4	—	23.8	58.9	24.0
2000	51.0	44.1	66.3	45.6	38.6	29.9	—	40.4	61.0	32.4
2001	56.5	50.1	—	51.6	50.1	38.4	53.8	51.5	63.9	41.2
2002	—	55.2	73.4	57.3	57.2	44.9	60.1	55.1	68.4	50.4

Note. Computer ownership is percentage of households that own a computer. Internet use is the percentage of individuals that use the Internet (from any location).
Source: Internet use data for all countries from International Telecommunication Union (ITU). Computer ownership data source is National Telecommunications and Information Administration (NTIA) in the U.S., Statistics Sweden (SCB) in Sweden, Economic and Social Research Institute (ESRI) in Japan, National Statistical Office (NSO) in South Korea, and Infocomm Development Authority (IDA) in Singapore.

in Japan tends to be lower than predicted, in contrast, whereas Singapore has usage rates close to predictions (Aizu, 2002; Quibria et al., 2003).

One of the key determinants of Internet penetration is the timing of migration from dial-up access to broadband (or high-speed Internet access).[4] South Korea's rapid increase in Internet usage is often attributed to its successful launch of broadband after many other wealthier countries had already pushed dial-up access (Kim et al., 2003). In 2002, South Korea had the highest broadband access rate in the world, which at 19.1 per 100 inhabitants was nearly double the access rate of second-ranked Canada with 10.2 per 100 inhabitants (OECD, 2003). Broadband not only provides easier access to the Internet, but it also generates positive spillovers by encouraging providers to supply richer content which further enhances Internet use.

English ability may be another factor that influences IT usage rates. Over 90% of online content is in English (OECD, 2001), which may create a barrier to access for nonEnglish speakers. The ITU (2001) credits Singapore's high rate of Internet access in part to widespread use of English in the educational, health, government and corporate sectors. Guillen and Suarez (2001) note that a high percentage of the population speaks English as a second language in Scandinavian countries, including Sweden, and this contributes to relatively high rates of Internet use in those countries. Ono and Zavodny (2005) suggest that poor English skills among the Japanese population may have contributed to Japan's low rates of computer and Internet use relative to the U.S. during the 1990s.[5]

Surprisingly little has been reported in support of the role of government policy in Internet diffusion, especially among industrialized nations. For example, Kim et al. (2003) find

[4] Internet access prices are another likely factor. However, empirical research involving international comparisons rarely includes price considerations due to the complications involved in standardizing prices across countries and over time.

[5] For example, Japanese high school students scored lower on standardized test of English and they felt less confident about using English than did South Korean students (Yoshida, 2004). According to the Educational Testing Service (ETS, 2004), the mean score of the Test of English as a Foreign Language (TOEFL) was 190 in Japan, 213 in South Korea and 252 in Singapore. It should be noted, however, that these are the mean scores among test takers only and do not represent the mean score of the population.

that policy measures and competitiveness had no effect on broadband penetration among the OECD countries. Guillen and Suarez's (2001) study of 141 countries finds little evidence that competition and privatization of telecommunication services are positively associated with Internet penetration rates. In a comparative study of broadband penetration in Japan, South Korea and Singapore, Aizu (2002) suggests that Japan had many policy initiatives with few results.[6] In the case of South Korea, Aizu gives some credit to the government's role in pushing the Korea Information Infrastructure plan but explains that the country's success had more to do with the cultural context of South Korea, such as the grass-roots, bottom-up culture of the Internet community there. In further support of the role of culture, Kim (2002) notes that the Confucian orientation of South Korea led parents there to view the Internet not as a form of entertainment but as a medium of education. In contrast, the top-down, authoritarian approach taken by Singapore may have kickstarted that country's information infrastructure, but the government's tight control and censorship most likely inhibited its potential growth by restricting content (Aizu, 2002; Guillen and Suarez, 2001).[7]

3. Determinants of digital inequality within countries

A key concern arising from digital inequality within countries is whether all individuals are able to realize the potential benefits from IT. To this end, a major challenge for public policy is to ensure that developments in the information and communications industry do not exacerbate existing class cleavages (Melody, 1987), and that benefits are distributed equally, "as a source of opportunity rather than as a reinforcement of privilege" (DiMaggio and Hargittai, 2001, p. 3). In countries where evidence is available, there are considerable differences in access and use across various demographic groups.[8] Nonusers are disproportionately female, older, less educated and poor. While the age effect may be a cohort effect (not a period effect) such that age differences will diminish with the succession of cohorts, convergence over time across gender, education and income groups may be less certain.

The extent and determinants of digital inequality may not be the same across countries if such gaps are rooted in inequality in other aspects of society. As DiMaggio et al. (2004, p. 359) explain:

> Technologies adapt to ongoing social practices and concerns rather than "influencing" society as an external force (Fischer, 1992). Rather than exploit all the possibilities inherent in new technologies, people use them to do what they are already doing more effectively. Technology may contribute to change by influencing actors' opportunities, constraints and incentives; but its relationship to the social world is co-evolutionary, not causal.

Comparing digital inequality across countries thus requires examining country-specific factors. In the U.S., research indicates that racial and ethnic socioeconomic inequality carries over to IT access and use (Fairlie, 2003, 2004; Ono and Zavodny, 2003b). In Japan, where gender inequality is greater than in most other industrialized nations, a sizeable

[6] Frieden (2005) notes that the "e-Japan" strategy involved some 220 projects in the first year alone as the country targeted infrastructure, human resources, e-commerce, e-government and network security all at once.

[7] According to the World Economic Forum (2003), Singapore ranked number 3 out of 82 countries with regard to government enforcement and restrictions on Internet content.

[8] See DiMaggio et al. (2004) for review of literature in the U.S. and elsewhere.

Table 2
Selected indicators of economic and social inequality

	U.S.	Sweden	Japan	South Korea	Singapore
GDP per capita (PPP USD)	35,750	26,050	26,940	16,950	24,040
Gini index of inequality	40.8	25.0	24.9	31.6	42.5
Ratio of income of top 10% to bottom 10%	16.0	5.9	4.5	7.8	17.7
Completed high school (%)	68.1	66.0	36.0	67.7	19.9
Completed college (%)	22.5	10.5	11.7	12.1	3.7
Gender empowerment measure (GEM)	0.76	0.83	0.52	0.36	0.59
Gender empowerment measure (GEM) rank	10	3	44	63	26
Ratio of women's average earnings to men's	0.62	0.68	0.45	0.46	0.50

Source: digital access index from ITU (2003). Percentages completed high school and college are from Barro and Lee (2000) and are for the population age 15 and older. All other data from UNDP (2003).

gender gap in IT access and use persists. Gender gaps in IT access and use are no longer observed in the U.S., in contrast (Ono and Zavodny, 2005).

Table 2 presents several indicators of income, education and gender inequality. GDP per capita (adjusted for purchasing power parity, PPP) is shown as a reference point to indicate the countries' relative economic standing. As indicated by the Gini index and ratio of income accruing to the top 10% of households relative to the bottom 10%, the U.S. and Singapore have the greatest income inequality among the five nations. Sweden and Japan have the most egalitarian income distributions. The percentage of the population that has finished the equivalent of high school is considerably higher in the U.S., Sweden and South Korea than in Japan and Singapore. The U.S. and Singapore have the highest and lowest, respectively, fractions of college graduates (or its equivalent).

Gender inequality is generally greater in the three Asian countries. The three Asian nations had lower scores and ranks than the U.S. and Sweden on the UNDP's gender empowerment measure (GEM), a composite indicator of gender equality standardized across countries.[9] Women's average earnings are also closer to men's in the U.S. and Sweden than in the three Asian nations. Our empirical analysis below will evaluate the extent to which these relative inequalities carry over to IT use.

This study examines not only IT access but also IT use. Given the rapid proliferation of IT in developed countries, most individuals are now likely to have access to IT, either in their homes or elsewhere.[10] However, high rates of access do not necessarily imply high rates of usage. More computers may be available in homes, work places and public places

[9] UNDP (2003) calculates the GEM as a composite indicator that captures gender equality in three key areas: (1) political participation and decision-making, as measured by women's and men's percentage shares of parliamentary seats; (2) economic participation and decision-making power, as measured by two indicators—women's and men's shares of positions as legislators, senior officials and managers, and women's and men's percentage shares of professional and technical positions; and (3) power over economic resources, as measured by women's and men's estimated earned income. Other rankings of gender equality are similar. For example, the World Economic Forum's measure of the gender gap shows the following rankings: Sweden (1), U.S. (17), Japan (38) and South Korea (54). We use the GEM in our analysis because Singapore was not included in the World Economic Forum study.

[10] In the U.S., the most frequently identified location of public access to the Internet is the library (Lenhart et al., 2003). Almost 95% of public libraries offered public access to the Internet in 2000, and 98.9% did so in 2004. There were virtually no differences between libraries located in urban versus rural locations (U.S. Census Bureau, Statistical Abstract of the United States, various years).

than previously, but this does not guarantee that all demographic and socioeconomic groups use them. Among households with computers in Japan during 1997–2001, for example, women were less likely to use computers and the Internet than were men (Ono and Zavodny, 2005). Shashaani (1997, p. 46) states that even in the U.S. "the presence of a computer at home, in itself, may not encourage women to use it." In addition, location may matter in terms of quality of use. Many individuals may have more time to use the Internet at home but have a faster connection at work or public places.

Because differential usage is presumed to be an outcome of free choice, it is sometimes viewed as a less important issue than differential access (Van Dijk and Hacker, 2003). To the extent that some individuals choose not to use IT given access, a large number of nonusers in the developed economies are presumably "voluntary nonusers" of IT (Compaine, 2001b).[11] In a study of Internet use in U.S. households, Lenhart et al. (2003) report that 20% of Internet nonusers live with someone who uses the Internet at home, and 60% of nonusers know of a public place in their community where they can access the Internet. There are also substantial numbers of former Internet users in the U.S. (Katz and Aspden, 1998; Rice and Katz, 2003). One could view this as a choice freely made without any constraints or as a choice that is influenced by larger social factors. For example, an individual who has not completed high school might be less aware of what information is available online or how to navigate the Internet. Simply giving such a person a computer would not guarantee use. Many Internet nonusers often remain offline because they have formed misconceptions of what the Internet and email have to offer or because they "doubt their ability to master the complexity of computers and the Internet." (Lenhart et al., 2003, p. 13).

Another factor that influences whether individuals use IT is the perceived benefits from doing so. If women and low-income individuals perceive lower benefits to IT use, they will be less likely to use IT regardless of access. One could argue this is a rational choice. However, both actual and perceived benefits to IT use may be related to larger social forces that are tied in with inequality at the macroeconomic and societal level, the idea we investigate below.

4. Data

Our empirical investigation uses a set of high-quality, cross-sectional microdata known as *Cyber Life Observations* (CLO). The CLO data were collected by the Nomura Research Institute (NRI) and are proprietary. NRI conducted surveys in Japan during the years 1997–2001. In 1997 and 2000, NRI also conducted surveys in the U.S., South Korea and Singapore. Sweden was surveyed in 2000. Identical questionnaires were distributed in all countries, allowing us to make consistent comparisons across countries and over time. The age of the respondents ranges from 15 to 59. Sample sizes vary from 500 to 1400 across countries and across survey years and are reported in the Appendix Table. In Japan, the

[11] Using the October 2003 supplement of the Current Population Survey, Day et al. (2005) report that 31% of people who live in households with a computer do not use the Internet because they feel they do not need it or are not interested. Citing the "Survey of Americans on Technology" conducted by National Public Radio, Kaiser Family Foundation and the Harvard Kennedy School, Compaine (2001a) explains that many nonusers of the Internet do so by choice, not because of cost considerations. Similar findings are reported in the case of Germany from the 1999 German Online Nonusers Survey (cited in Van Dijk and Hacker, 2003).

surveys were distributed and collected in person.[12] In the other four countries, the surveys were conducted by in-person interviews.

Demographic characteristics available in the data include sex, age, education and household income. The regressions include a dummy variable for females, a linear variable for age and dummy variables for three education groups that indicate the highest level of education completed (high school, some college and college, with less than high school as omitted category). The category "college" includes respondents who graduated from college and those who attended or completed graduate school. The category "some college" was not available in South Korea. We measure household income as the log of the household income in each country's currency.[13] Income data are imputed in the U.S., Sweden and Japan data sets for missing observations.[14] Results using different specifications of household income confirmed that results are not sensitive to the missing observations.[15]

We also include dummy variables for marital status, employment status and having any children in all regressions as control variables; those results are not shown here to conserve space. The regressions also include fixed effects for survey years (with the first available year as the omitted category) to control for changes over time in IT access and use.

We use logit regressions to estimate the determinants of several measures of IT access and use: computer ownership, computer use from home, Internet use from any location and Internet use from home. Internet use from any location is defined as Internet use from home, school or work. For ease of interpretation, we report marginal effects from the logit models. We also conduct discrete-time survival analysis using logit regressions to predict the timing of first computer use in order to examine which individuals were early adopters of personal computers.[16]

A comparison of the IT measures in the CLO data with published sources indicates that the CLO data have relatively high rates of computer ownership and Internet use.[17] The percentages of individuals in the CLO who indicate that they live in a household that owns a computer and who use the Internet from any location are consistently above the rates reported in Table 1. This occurs because the CLO is restricted to ages 15–59, an age range that has higher ownership and usage rates than the population as a whole. In addition, the CLO data include Internet use via a mobile phone, which is common in Asia, and this may further boost the Internet usage rates in the CLO. We caution that the relatively high rates of IT ownership and use in the CLO data may cause us to underestimate digital inequality within countries, although there is no reason to think that our estimates of differences

[12] This method—sometimes known as the "visitation method"—yields a higher response rate than postal surveys.

[13] Income was reported in brackets, and the midpoint of the bracket is used to measure income. Because we estimate separate regressions for each country, there is no need to adjust for PPP. The regressions include survey wave fixed effects, which implicitly control for inflation.

[14] The percentage of missing observations was 17% in the U.S., 14% in Sweden, 20% in Japan, 1.4% in Korea and 7.0% in Singapore. Income was imputed based on the other control variables included in the regressions.

[15] To examine the robustness of the results reported here, we used income categories that included a category for missing income. The results showed that ownership and usage patterns were for the most part monotonically increasing with respect to household income categories, and that including income in this manner did not significantly affect the coefficients or standard errors of the other covariates.

[16] The data on timing of first computer use are retrospective; we do not have panel data. For a discussion about the accuracy and use of retrospective survey data, see, for example, Beckett et al. (2001) and references therein.

[17] For a more detailed comparison of the U.S. CLO data to the Current Population Survey (CPS), see Ono and Zavodny (2003a).

across groups over time (such as changes in the gender gap in Japan) will be biased downward. The advantage of the CLO is that it provides reasonably consistent data across countries as well as within countries over time.

5. Analysis and results

We begin by examining rates of IT access and use over time for the U.S., Japan, South Korea and Singapore (Sweden is not included because only data for 2000 are available). Figs. 1 and 2 show rates of computer ownership at home, computer use at home, Internet use from any location and Internet use from home over time from the CLO data. The figures show considerable increases in computer access and use over time in all four countries. The steeper slope observed for South Korea in all four areas is consistent with the nation's tremendous gains in IT access discussed above. The U.S. tops the three Asian nations for most of the measures of computer access and use, although South Korea and Singapore caught up to the U.S. in terms of computer ownership and Internet use anywhere by the year 2000. Japan trails the other countries in all of the measures of IT use and access examined in the figures.

Fig. 3 shows the proportion of the sample who reported they had no prior experience with computers. The U.S. clearly has an advantage over the three Asian countries, with the lowest share of respondents reporting no previous computer use. In Japan and South Korea, the trend line is downward sloping, indicating improvement. In Singapore, the trend line is slightly positively sloped, but a t-test of equality of means shows that the trend is not statistically different from zero.

5.1. Computer ownership and use

We examine patterns of computer ownership and usage at home using separate logit regressions for each country. As shown in Table 3, the estimated marginal effects for the survey year dummy variables are positive in all regressions (and monotonically increasing for Japan), indicating that ownership and use of computers rose over time. The effect is largest in South Korea in both regressions, which is again consistent with their rapid growth in IT penetration.

The results indicate both commonalities and differences across countries in the determinants of computer ownership and use at home. In all five countries, computer ownership and use are positively associated with education. The relationship between computer ownership, use conditional on ownership and education is largest in Singapore, the country with the lowest educational completion rates of the five examined here. Computer ownership is positively associated with income in all countries, and the results suggest a positive relationship between use conditional on ownership and income, significantly so in the U.S. and Singapore.

The results for sex and age are mixed. Being female is not significantly associated with living in a household that owns a computer in any country. However, women are significantly less likely to use a computer at home given ownership in the three Asian nations, a finding that does not hold in the U.S. and Sweden. This gender difference between computer ownership and computer use in the three Asian nations indicates that living in a household that owns a computer does not ensure that women in those countries will use that computer; access does not necessarily translate into use. Age is negatively associated with computer ownership in the U.S.,

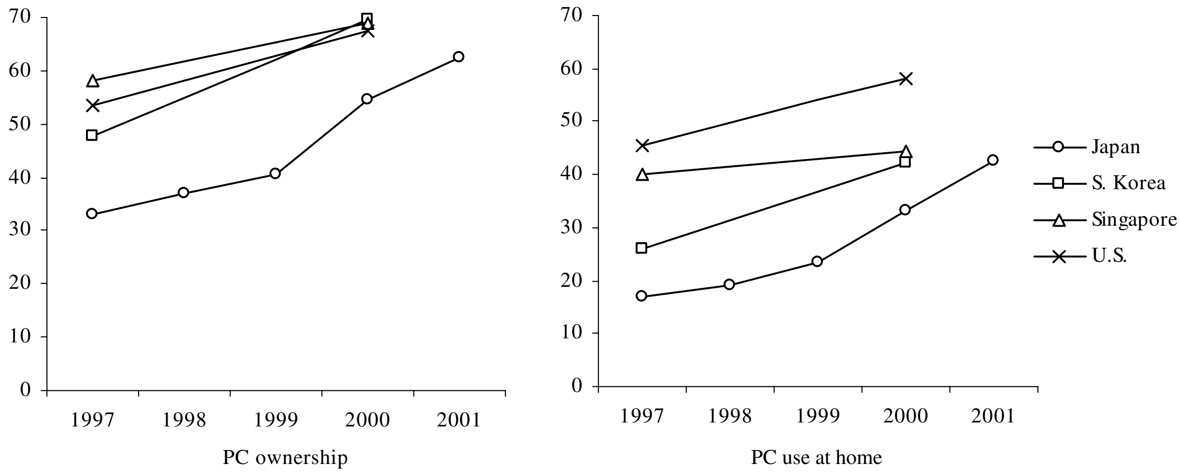

Fig. 1. Computer ownership and computer use at home (%).

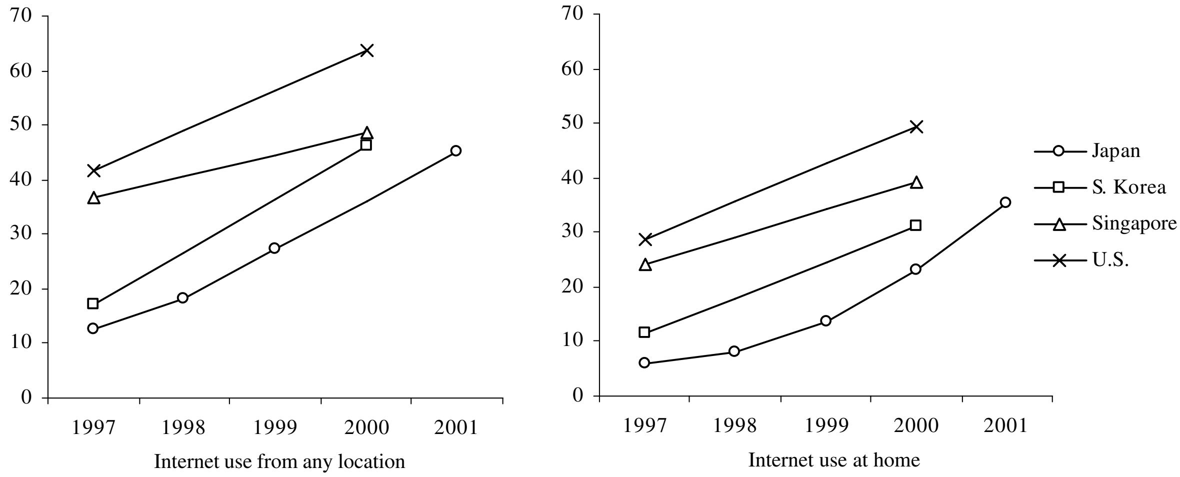

Fig. 2. Internet use by location (%).

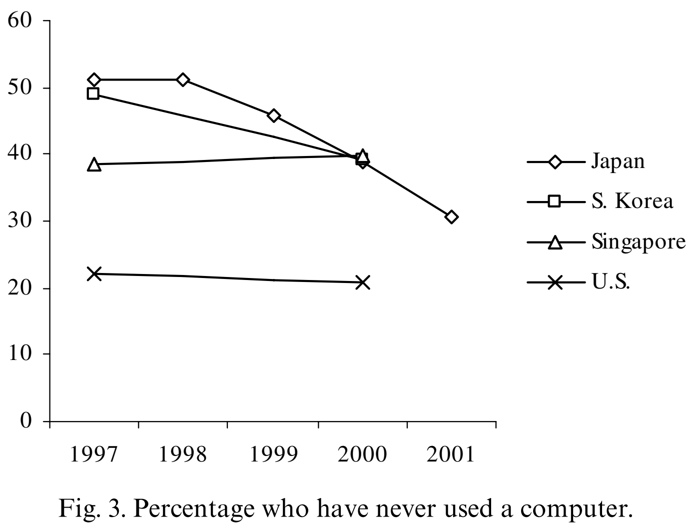

Fig. 3. Percentage who have never used a computer.

Sweden and Japan but positively related to ownership in South Korea.[18] Age is negatively associated with use in all of the countries, although not significantly so in Sweden.

[18] Variations in the age effect in computer ownership across countries may be due to unobserved wealth (independent of income).

Table 3
Computer ownership and use at home

	(a) PC at home					(b) Use PC at home conditional on PC at home				
	U.S.	Sweden	Japan	South Korea	Singapore	U.S.	Sweden	Japan	South Korea	Singapore
Female	0.019	−0.023	−0.001	0.025	0.023	0.002	−0.021	−0.214**	−0.261**	−0.112*
	(0.028)	(0.037)	(0.014)	(0.038)	(0.037)	(0.022)	(0.015)	(0.021)	(0.058)	(0.053)
Age	−0.006**	−0.006**	−0.002**	0.008**	0.002	−0.004**	0.000	−0.010**	−0.022**	−0.020**
	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)
High school	−0.045	0.131**	0.122**	0.035	0.082	0.047	0.013	0.219**	0.199**	0.521**
	(0.044)	(0.050)	(0.029)	(0.048)	(0.045)	(0.038)	(0.024)	(0.053)	(0.066)	(0.126)
Some college	0.096*	0.134*	0.235**		0.335**	0.093*	0.003	0.318**		0.766**
	(0.045)	(0.056)	(0.035)		(0.065)	(0.038)	(0.025)	(0.059)		(0.139)
College	0.183**	0.263**	0.338**	0.249**	0.579**	0.155**	0.048	0.445**	0.453**	0.832**
	(0.052)	(0.060)	(0.032)	(0.056)	(0.097)	(0.040)	(0.030)	(0.055)	(0.072)	(0.154)
Log real income	0.209**	0.145**	0.174**	0.212**	0.220**	0.057**	0.026	0.004	0.059	0.123*
	(0.023)	(0.035)	(0.013)	(0.031)	(0.028)	(0.017)	(0.021)	(0.019)	(0.046)	(0.053)
Year 1998			0.047*					0.011		
			(0.021)					(0.034)		
Year 1999			0.102**					0.056		
			(0.021)					(0.034)		
Year 2000	0.153**		0.244**	0.303**	0.096**	0.027		0.097**	0.186**	0.041
	(0.028)		(0.021)	(0.036)	(0.034)	(0.024)		(0.032)	(0.057)	(0.051)
Year 2001			0.323**					0.176**		
			(0.021)					(0.032)		
Log-likelihood	−823	−231	−4269	−594	−513	−344	−83	−1830	−265	−205
N	1440	500	6884	996	941	905	389	3148	582	592

*$p < 0.05$, **$p < 0.01$. Shown are the marginal effects of the estimated coefficients from logit regressions with the indicated dependent variable. Standard errors are in parentheses and are White-corrected for individual-specific heteroscedasticity. Regressions also include indicator variables for married, working, children and a constant (not shown).

5.2. Internet use

We next examine patterns of Internet use from any location and from home (conditional on computer ownership) in Table 4. As in the computer ownership and use regressions, the marginal effects for the survey year dummy variables are positive in all regressions and again monotonically increasing in Japan, indicating that Internet use increased over time. South Korea had the fastest growth of the five countries in Internet use from any location and second highest (after Singapore) in Internet use at home.

Age, education and income are important factors in determining who uses the Internet, with older, less-educated and poorer individuals less likely to use the Internet from any location in all five countries. In Japan and South Korea, there is a gender divide, with women less likely than men to use the Internet by both measures examined here. Similar to the results for computer use, the relationship between Internet use and education is by far the greatest in Singapore.

With a few notable exceptions, these results indicate that computer and Internet users in all five countries are more likely to be male, young, well educated and have higher incomes than nonusers. Consistent with previous research, our findings indicate that access does not necessarily imply usage. Even among those individuals who have a computer in their homes, we find differences by gender, age, education and income in most of the five countries. Interestingly, these patterns are least likely to hold in Sweden. We do not find evidence of gender gaps in IT usage in the U.S. as well as in Sweden.

5.3. Timing of first computer use

We use survival analysis to examine the timing of first computer use. We use a question from the year 2000 survey that asked, "For how long have you been using computers (regardless of location)?" Possible responses included: have never used computers, less than 1 year, 1–2 years, 2–3 years, 3–4 years, 4–5 years, 5–10 years and more than 10 years. Because the time intervals for the last two categories differ from the others, we employ discrete-time survival analysis to predict the timing of first computer use. We treat time as calendar year, so the timing of first computer use consists of the following year categories: before 1990, 1990–1995, 1996, 1997, 1998, 1999 and 2000. Respondents who said they had never used computers were treated as censored observations. Because the question is asked retroactively, many of the explanatory variables (e.g., income and employment status) are endogenous and are therefore excluded from the analysis. We include education as a regressor because the number of years of education is likely independent of the timing of first computer use.[19] When an individual first used a computer is almost surely affected by education, but it is unlikely that early or late exposure to computers affected whether an individual graduated from high school or college.[20]

[19] This assumption may be less plausible for the small number of individuals who were enrolled in high school at the time of the survey. We ran a separate model that excludes these individuals, and the results were not significantly different from those reported in Table 5.

[20] Beltran et al. (2006) report that young adults in the U.S. who live in households with a computer are more likely to graduate from high school. We nonetheless treat education as an exogenous variable because we are examining the timing of first computer use, not household ownership.

Table 4
Internet use by location

	(a) Use Internet from any location					(b) Use Internet from home conditional on PC at home				
	U.S.	Sweden	Japan	South Korea	Singapore	U.S.	Sweden	Japan	South Korea	Singapore
Female	0.047	−0.045	−0.101**	−0.109**	−0.019	−0.013	−0.055	−0.129**	−0.098*	−0.073
	(0.030)	(0.036)	(0.013)	(0.032)	(0.037)	(0.032)	(0.040)	(0.021)	(0.048)	(0.055)
Age	−0.008**	−0.004*	−0.006**	−0.007**	−0.012 **	−0.004*	−0.001	−0.009**	−0.009**	−0.012**
	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)	(0.002)	(0.002)	(0.001)	(0.003)	(0.004)
High school	−0.054	0.147**	0.167**	0.093*	0.815**	0.023	0.021	0.155*	0.084	0.876**
	(0.048)	(0.050)	(0.035)	(0.046)	(0.127)	(0.062)	(0.069)	(0.062)	(0.066)	(0.220)
Some college	0.144**	0.252**	0.267**		1.068**	0.136*	0.102	0.247**		1.100**
	(0.049)	(0.059)	(0.038)		(0.117)	(0.060)	(0.077)	(0.066)		(0.226)
College	0.276**	0.405**	0.387**	0.366**	1.303**	0.195**	0.174	0.350**	0.286**	1.352**
	(0.057)	(0.062)	(0.035)	(0.049)	(0.125)	(0.066)	(0.076)*	(0.062)	(0.069)	(0.230)
Logged income	0.195**	0.097*	0.074**	0.094**	0.158**	0.102 **	0.145	0.006	0.043	0.133**
	(0.024)	(0.038)	(0.010)	(0.025)	(0.037)	(0.026)	(0.047)**	(0.018)	(0.037)	(0.049)
Year 1998			0.086**					0.058		
			(0.018)					(0.038)		
Year 1999			0.177**					0.198**		
			(0.017)					(0.036)		
Year 2000	0.262**			0.405**	0.230**	0.212**		0.294**	0.321 **	0.367**
	(0.031)			(0.034)	(0.042)	(0.034)		(0.034)	(0.051)	(0.059)
Year 2001			0.314**					0.432**		
			(0.017)					(0.033)		
Log-likelihood	−833	−230	−2489	−410	−384	−528	−189	−1774	−306	−271
N	1443	500	5528	996	941	905	389	3148	582	592

*$p < 0.05$, **$p < 0.01$. Shown are the marginal effects of the estimated coefficients from logit regressions with the indicated dependent variable. Standard errors are in parentheses and are White-corrected for individual-specific heteroscedasticity. The question concerning Internet use from any location is not available in the year 2000 survey in Japan. Regressions also include indicator variables for married, working, children and a constant (not shown).

Table 5
Discrete-time survival analysis predicting timing of first computer use

	Total	U.S.	Sweden	Japan	South Korea	Singapore
Female	−0.018**	0.011	−0.053**	−0.030**	−0.021**	0.002
	(0.005)	(0.013)	(0.020)	(0.007)	(0.008)	(0.009)
Age	−0.003**	−0.004**	−0.003**	−0.002**	−0.004**	−0.002**
	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
High school	0.098**	0.069**	0.162**	0.097**	0.029*	0.146**
	(0.008)	(0.020)	(0.033)	(0.020)	(0.012)	(0.017)
Some college	0.154**	0.163**	0.206**	0.128**		0.217**
	(0.010)	(0.020)	(0.039)	(0.021)		(0.018)
College	0.211**	0.241**	0.350**	0.177**	0.102**	0.252**
	(0.009)	(0.024)	(0.038)	(0.020)	(0.014)	(0.023)
1990–1995	0.047**	0.046*	0.163**	0.028*	0.064**	0.018
	(0.007)	(0.019)	(0.028)	(0.012)	(0.016)	(0.014)
1996	0.016	−0.014	0.036	0.025*	0.034	0.017
	(0.008)	(0.022)	(0.035)	(0.012)	(0.019)	(0.015)
1997	0.008	−0.020	0.115**	−0.032*	0.068**	0.023
	(0.009)	(0.024)	(0.036)	(0.015)	(0.017)	(0.016)
1998	0.069**	0.041	0.146**	0.066**	0.100**	0.034*
	(0.009)	(0.024)	(0.041)	(0.012)	(0.016)	(0.017)
1999	0.104**	0.101**	0.183**	0.079**	0.141**	0.071**
	(0.009)	(0.025)	(0.044)	(0.012)	(0.016)	(0.017)
2000	0.136**	0.101**	0.162**	0.128**	0.179**	0.037
	(0.009)	(0.028)	(0.052)	(0.012)	(0.017)	(0.021)
Sweden	0.037**					
	(0.008)					
Japan	−0.092**					
	(0.007)					
South Korea	−0.096**					
	(0.008)					
Singapore	−0.049**					
	(0.008)					
Constant	−0.272**	−0.223**	−0.338**	−0.239**	−0.114**	−0.239**
	(0.012)	(0.025)	(0.050)	(0.023)	(0.023)	(0.025)
Log-likelihood	−6,894	−1,901	−903	−2,385	−804	−779
N (person–period)	18,049	3853	1736	7180	2831	2449
N valid	3899	1002	501	1379	510	507

*$p < 0.05$, **$p < 0.01$. Shown are the marginal effects of the estimated coefficients from discrete-time logit regressions with the indicated dependent variable. Standard errors are in parentheses and are White-corrected for individual-specific heteroscedasticity.

The first column of Table 5 reports the results for the combined sample of all five countries. The reported coefficients are hazard rates predicting the timing of first computer use. The negative coefficients for the female and age variables indicate that, on average, women and older persons started using computers later than men and younger persons. The education coefficients increase with education, indicating that more educated individuals adopted computers earlier.

The regressions include time period dummy variables to capture the timing of first computer use, where the baseline (omitted) category is before 1990. The model predicts that individuals were significantly more likely to start using computers in 1990–1995 than before 1990, but this may be because the category represents a five-year time interval. The coefficients do not indicate any significant differences for 1996 and 1997 but do become larger in both magnitude and significance after 1997. Overall, the results predict that first computer use was more concentrated in the years after 1997 than before; in other words, more people started using computers after 1997 than before then. Interestingly, this upswing in computer use coincides with the rise of the Internet. The first column of Table 5 also shows average hazard rates for countries relative to the U.S. (the omitted category). On average, Swedes started using computers earlier than people in the U.S. while people in the three Asian countries started using them later.

Columns 2–6 of Table 5 present separate discrete-time hazard results for each country. Computer adoption slows significantly with age in all countries. In the U.S. and Singapore, there are no gender differences in the timing of first computer use, but women were more likely to start using computers later than men in Japan, South Korea, and—surprisingly—Sweden. The effect of education is also positive in all countries, but the magnitude of the estimates varies. Looking at the coefficients for the college category, the pattern of education effects is similar to that in the above analyses of computer and Internet use: the effect is smallest in the U.S. and largest in Singapore.

The results for the time period dummy variables generally follow the same pattern as in the pooled sample, with greater frequency of first computer use after 1996 or 1997. South Korea is particularly notable. The hazard rates there, which are positive and monotonic after 1996, are larger than for the other countries. This pattern indicates that South Korea started with a small base of early users and then experienced a leapfrog effect during the late 1990s. This is consistent with that country's emphasis on making broadband access widely available, as discussed above. Japan follows a similar (albeit less dramatic) pattern, with hazard rates rising after 1996. In the U.S., Sweden and Singapore, the hazard rate peaks in 1999.[21] The growth rate of new computer users appears to have peaked in these three countries in the late 1990s, which is in contrast to South Korea and Japan, where the hazard rate is still increasing in 2000.

5.4. Predictions

We have thus far identified several key determinants of digital inequality in the five countries. We next use the regression results to predict IT access and use in the three key categories of sex, income and education. We also examine the correlation between these measures of digital inequality and the measures of economic and social inequality that we discussed previously (in Table 2). This portion of the analysis uses the data for the year 2000 only.[22] We focus on comparing men with women, college graduates with individuals who did not complete high school, and individuals with household incomes in the top 10% of the distribution with those in the bottom 10%. The denominator (or baseline) group for each comparison is the group usually believed to be less likely to use IT: women, the less-educated and low-income individuals.

Table 6 presents the ratio of the average predicted rates for each group for computer ownership, computer use at home (given ownership), Internet use from any location and Internet use from home (given computer ownership). For example, in the case of computer

[21] In the U.S. and Sweden, the coefficients for 1999 and 2000 are statistically insignificant from each other.

[22] We ran the same regressions as shown in the tables but with the sample restricted to the year 2000. We made this restriction because data for Sweden are only available for 2000.

ownership in the U.S., about 68% of men and women are predicted to live in households that own a computer, resulting in the ratio of one shown in the first row and column in Table 6.

Of the measures we examine, differences tend to be smallest for computer ownership. With regard to gender, the ratios are close to one in all five countries. Ratios of computer ownership by education and income are also fairly small, with all of the ratios less than 3:1. The high penetration rates for computer ownership in all five countries thus appear to have resulted in no large differences in computer access in the home.

There are considerably more differences in most countries in actual usage of computers and the Internet. These results again highlight the discrepancy between access and use. There are considerable gaps in computer use at home by education and in Internet use at home or from any location by education and by income. In general, the largest differences tend to occur by education, with college graduates considerably more likely than nonhigh school graduates to use computers and the Internet in almost all of the countries. The predictions also generally show that low-income individuals are less likely to use IT. We also find that a gender gap remains in some areas of IT access and use, but its magnitude is smaller than the gaps by income and education.

A comparison of the five countries indicates that differences are generally the largest in Singapore, especially in the education category. In particular, Internet use from any location among the least-educated is extremely low (predicted at only 1%) compared with the most-educated, whose predicted usage rate is about 90%. Moreover, a significant gap in Internet use by education persists in Singapore after controlling for computer ownership; the ratio of Internet use at home given ownership among college graduates relative to nonhigh school graduates is greater than 40:1. The relatively low level of educational attainment in Singapore, thus appears to be associated with greater education gaps in IT usage. Overall, the U.S. and Sweden have smaller gaps in IT access and use by sex and education than do the three Asian nations. Among the Asian countries, South Korea tends to have the smallest predicted ratios. This suggests that the country's emphasis on making broadband access widely available encouraged widespread adoption of IT and led to narrower digital differences than in its neighbors.

Our final analysis examines measures of association between digital inequality and pre-existing inequality in other areas of economy and society. For example, if a society is characterized by a high degree of gender inequality, to what extent does this carry over to gender differences in IT access and use? Column (b) of Table 6 reports the correlations between the predicted measures of digital gaps (from column (a)) and the measures of economic and social inequality reported in Table 2. Most of our results for computer ownership at home show a weak correlation, indicating little systematic association between digital inequality and pre-existing inequality regarding access to computers in the home. The exception is that the fraction of the population that has completed high school is reasonably strongly negatively correlated (−0.74) with the ratio of the predicted fraction of college graduates living in a household owning a computer to the comparable predicted fraction among nonhigh school graduates. The negative correlation indicates that countries with higher high school completion rates have smaller education gaps in computer ownership.

Our results regarding the actual usage of computers and the Internet are striking. We find a strong correlation between digital inequality and pre-existing inequality, with correlations greater than 0.6 (in absolute value) in all areas. For example, we find that a

Table 6
Ratio of predictions by gender, income and education

		(a) Predicted digital inequality[1]					(b) Correlation with measures of inequality					
							Income		Education		Gender	
		U.S.	Sweden	Japan	South Korea	Singapore	Gini	Top 10 / Bottom 10	Completed high school	Completed college	GEM score	Gender wage gap
PC at home	Income	2.18	1.37	2.76	1.37	2.38	0.23	0.25				
	Education	1.52	1.64	2.24	1.32	1.85			−0.74	−0.34		
	Gender	1.01	1.04	1.11	0.95	0.93					0.24	0.11
Use PC at home given PC at home	Income	1.17	0.98	0.87	1.10	1.68	0.85	0.86				
	Education	1.17	1.11	2.26	2.57	15.83			−0.82	−0.73		
	Gender	0.98	1.05	1.47	1.38	1.22					−0.87	−0.91
Use Internet from any Location	Income	2.03	1.06	1.98	1.36	4.76	0.71	0.74				
	Education	1.57	2.16	5.42	3.58	97.36			−0.81	−0.71		
	Gender	0.93	1.10	1.72	1.50	1.15					−0.77	−0.80
Use Internet from home given PC at home	Income	1.34	1.15	1.03	1.09	2.17	0.78	0.83				
	Education	1.17	1.33	2.74	2.37	47.50			−0.81	−0.71		
	Gender	0.97	1.13	1.48	1.23	1.25					−0.61	−0.76

Note. [1] Shown are ratios of predicted rates of IT access and use for individuals with incomes in the top 10% versus the bottom 10%, college graduates versus nonhigh school graduates, and men versus women.

higher GEM score (which indicates more gender equality) is negatively associated with the gender gap in computer use at home (given ownership), with a correlation of −0.87. This relationship suggests that gender inequality at the broader societal level is closely associated with the gender gap in computer use at home. Education gaps in IT usage are strongly negatively associated with high school and college completion rates across the five countries while income differentials in IT usage are positively associated with income inequality.

In sum, we find strong evidence that social and economic inequality carries over to IT usage. Greater inequality in income, education and gender at the societal level are closely associated with greater gaps in IT usage along these dimensions. Our findings suggest that pre-existing measures of economic and social inequality are reasonable predictors of inequality in IT usage.

6. Summary and conclusions

This study examined the extent and causes of digital inequality along the lines of sex, age, education and income in the U.S., Sweden, Japan, South Korea and Singapore. The results reveal both commonalities and differences across the countries. In general, the results are consistent with our hypothesis that gaps in IT usage reflect pre-existing social and economic inequalities. For example, gender inequality is lower in the U.S. and Sweden than in the three Asian nations, and this carries over to a smaller gender gap in IT usage in those two countries. Our findings thus imply that gender is a strong determinant of IT usage in a society with high degrees of gender inequality. We draw the same conclusion regarding income and education.

On the other hand, we find no systematic association between pre-existing inequality and differences in computer ownership. In fact, gaps are considerably smaller for computer ownership than gaps between the users and nonusers of computers and the Internet. This may mean that the diffusion of computers has reached a critical mass, and differences across demographics and socioeconomic status have relatively little impact on computer ownership patterns among the economically advanced countries we examine. However, our results also caution that access to IT does not necessarily translate into use. We find that demographic and socioeconomic characteristics are typically still related to whether an individual uses a computer and the Internet even when conditioning on the presence of a computer in the household. This suggests that creating access to a computer may ameliorate but does not necessarily erase all digital gaps.

Our results have several implications for public policy. If gaps in IT usage largely reflect pre-existing inequality, then attempting to reduce these gaps via programs such as providing computers to low-income households or subsidizing Internet access in rural areas seems less likely to have a long-run impact than policies that address fundamental sources of inequality. Another concern about policies aimed at achieving near universal access is that access does not guarantee use. In developed countries, near universal access to computers and the Internet in the public sphere has significantly lowered the barriers to access. However, individuals who are nonusers may be likely to remain so absent broad societal change. We do not suggest that "digital divides" such as those we explore here are not of concern but caution that policymakers consider the larger societal forces that underlie patterns of IT usage when designing policies aimed at reducing digital inequality.

Appendix A

Sample size by country and survey year

	U.S.	Sweden	Japan	South Korea	Singapore
1997	500	—	1409 (70.5%)	500	505
1998	—	—	1431 (71.6%)	—	—
1999	—	—	1410 (70.5%)	—	—
2000	1009	501	1402 (70.1%)	510	507
2001	—	—	1414 (70.7%)	—	—
Total	1509	501	7066	1010	1012

Note. All surveys were conducted by in-person interviews except in Japan, where surveys were distributed and collected. Survey response rates in Japan are reported in parentheses.

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