The Gender Digital Divide in the Research Sectors of Ghana, Kenya, and Kerala: Are Women More Connected Over Time?

B. Paige Miller & Wesley Shrum

Abstract

This article uses panel data gathered in 2001 and, 2005 to assess the gendered digital divide among researchers employed in three developing countries: Ghana, Kenya, and India (the state of Kerala). We move the digital divide discussion from an early focus on differentials in adoption and access to an assessment of use as measured by the diversity and intensity of internet and email activity. Using both bivariate and multivariate analyses, our results indicate clear gender disparities within an increasingly technologically saturated environment. Over time, both women and men report significant increases in access to and use of various technologies, yet even after controlling for other factors, women continue to be less technologically oriented than their male counterparts. Although women adopt new technologies around the same time and display similar patterns of email use as men, they are less intense users of both email and the web and they use the web less diversely than men. We conclude by suggesting possibilities for future research and significant policy implications for the assessment of the digital divide in low-income areas.

Key Words: Gender, science, digital divide, development

Introduction

This article examines gender differences in access to and use of email and the web among scientists in two countries, Ghana and Kenya, and the state of Kerala in India. We use two-wave panel data gathered in, 2001 and, 2005 from researchers employed in national

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research institutes and universities to address the following questions: 1) what gender disparities exist in access to and use of email and the web; and 2) have gender differences been reduced over time? Our results point to a more technologically saturated research environment over time, but one consistently marked by gender differences in email and web use.

In, 2004, the World Bank's Gender and Development Group issued a report asserting the benefits women in low-income areas stand to accrue from information and communication technologies (ICTs) (Gender and Development Group & Global Information and Communication Technologies Department, 2004). Detailing what it would mean for women to fully participate in the global knowledge society, the report states, "information and communication technology offers enormous potential for alleviating poverty and promoting sustainable, gender-equitable development" (page reference needed).[1] This is one of a multitude of accounts from development agencies, popular media, and academics touting the importance of ICTs for economic and social development and more specifically, for women's empowerment (Gill et al., 2010; Wilson, 2002). According to these reports, the ever expanding and relatively cheap cost of ICTs has ushered in a new global era marked by increased interconnectedness, access to information, and engagement in communication without the constraints of co-presence.

While the emphasis on the role of science and technology in development is not new, the *gender* dimension has taken on new meaning with the production and diffusion of ICTs. Perceived as being more inclusionary than past technologies, some argue ICTs will create the opportunity for women to empower themselves by circumventing and even altering cultural constraints limiting their social roles (Best & Maier, 2007; Choudhury, 2009; Gill et al., 2010; Huyer & Carr, 2002; Palackal et al., 2006).

Given these optimistic assessments regarding ICT use by women, it is critical that empirical studies track the factors determining their online participation over time. While the internet and email may hold a great deal of promise for connecting researchers with others in their field, facilitating information and data retrieval, and making the publication process easier, technology adoption and use are not determined solely by the perceived benefits of technological engagement. Instead, adoption and use are also influenced by the cultural, political, and social contexts in which users live and work

(Bijker, 1995; Drori & Jang, 2003; Wajcman, 1991; Wilson, 2002). Rather than acting as a medium that women researchers use to alter their research careers, preexisting gender disparities may be modeled onto ICT use, reinforcing and deepening inequalities, particularly in resource-poor environments in which a technology may not be widely available.

Tracking the Gender Digital Divide: Are Women Closing the Technological Gap?

Early accounts of the digital divide—a term generally used to describe the cross-national disparity in access to and use of new technologies but which has also been used in reference to within country divisions historically stratified along gender, race, and class lines—examined issues related to adoption of new technologies along a dichotomy of access vs. no-access and adopters vs. non-adopters (Drori & Jang, 2003; Haan, 2004; Hargittai, 2002; IDREF1; Ynalvez et al., 2005). Based on this characterization of the digital divide, the evidence pointed not only to geographic disparities, with low-income areas consistently reporting smaller levels of ICT penetration than more developed areas, but also to women consistently reporting lower adoption rates and less access to technology than their male counterparts (Bimber, 2000; Gill et al., 2010; Huyer et al., 2005). In recent years, the global digital divide seems to have narrowed somewhat (although there continues to be a stark contrast between many sub-Saharan African countries and more developed areas), and some predict the gender divide will follow a similar pattern (Bimber, 2000; Liff & Shepherd, 2004; Zainudeen et al., 2010).[i]

According to the 'mirror hypothesis,' as a technology penetrates deeper within a given context, it becomes cheaper and easier to use. While men tend to be earlier adopters of most technologies, given time, women and men may begin to report similar patterns of email and Internet use. Indeed, a number of studies suggest the disparity between women and men in technology access has virtually disappeared (Liff & Shepherd, 2004; IDREF1; Ono & Zavodny, 2003). IDREF1, using data gathered on scientists in Africa and India, found that researchers reported increased access to email and personal computers, such that what was once a significant gap between women and men had disappeared by the early years of the twenty-first century.

The validity of the mirror hypothesis, however, is not uncontested. A number of studies document a persistent gender divide even in locations with high penetration of various technologies. Employing data gathered in eight African countries, Huyer et. al. (2005) investigated gender disparities in mobile phone use. Rather than a negative, linear relationship between mobile phone diffusion and the gender digital divide, they noted a u-shaped pattern in which high gender disparities existed in those locations where mobile phone penetration was low, began to decline as penetration increased, but rose again in those locations with the highest mobile phone penetration.

Other studies note distinctly different ICT *use* patterns in terms of how intensely women and men use the internet and the types of activities they engage in while online (Boneva & Kraut, 2002; Howard et al., 2002; Huyer et al., 2005; Smoreda & Licoppe, 2000). According to these accounts, men are more likely to use the internet as an information tool, researching or reading the news, and women are more likely to use the internet as a communication tool. Based on data from a number of European countries, the United States, Canada, and South Korea, Huyer et al. (2005) found men use the Internet more than women for most types of activities, and they spend more time accessing the internet than women.

Notably, the one area of technology use where gender differences either do not exist or in which women emerge as *more* technologically oriented, is in terms of email use. Many of these studies suggest women are more frequent users of email, employing the technology to maintain personal relationships with family and friends (Bimber, 2000; Boneva & Kraut, 2002; Jackson et al., 2001). Other studies note that women and men actually use email for similar purposes and with a similar degree of intensity such that no gender disparities exist in this area of technology use. As these studies make clear, it is not enough to simply assume that with the spread of technology, gender disparities will disappear. Instead, the technology itself, contextual factors, and cultural differences must also be examined.

In addition to gender, age, education, family structure, travel experiences, employment status, and ease of use also act to structure women and men's experiences with technologies. The age and education gap in the use of new technologies emerges as a persistent trend with use of technologies declining as one ages, but increasing with one's level of education (Haan, 2004; Hargittai, 2002; Howard et al., 2002; Katz & Rice, 2004; Nie and Erbring, 2000; Rice and Katz, 2003). Cultural norms regarding gendered behavior may limit women's use of technologies by restricting their travel patterns, exposure to new technologies, and use of public terminals as well as imposing constraints on women's time due to domestic responsibilities (Gill et al., 2010; Hafkin and Taggart, 2001; IDREF1; Palackal et al., 2006). In addition, the degree to which one perceives a technology to be available is linked with affective factors related to skill, comfort and anxiety levels (Haan, 2004; Mohsin, 2000; Venkatesh et. al., 2003). The easier it is to use a technology, the more likely a person is to use it, and the more likely he/she is to continue to use it.

While pointing to potential gender differences, the available data assessing the gendered digital divide are problematic for a number of reasons. First, due to the rapidly changing nature of ICTs, it is essential that more recent, longitudinal data be gathered. Is the gendered digital divide decreasing as the cross-national divide narrows? Second, the empirical evidence assessing the digital divide is often based on cross-national, composite indexes (Huyer et al., 2005; Gill et al., 2010). While informative in placing countries in relationship to one another in a global technological hierarchy, these data prohibit an examination of gender disparities in ICT access and use.

Finally, most of the empirical literature assessing the gendered digital divide stem from a more developed context. The evidence that is available from low-income areas is frequently based on rural women, the poor, or women working in the informal sector. Few studies have been done on the way in which women *researchers* use technology. Although there is a wealth of literature suggesting women and men use technologies in ways consistent with gender role expectations, researchers ostensibly have more incentive and opportunity to use ICTs for similar purposes. Do women and men researchers display distinctly different patterns of resource use than the general population?

In the following sections, we examine the nature of the gendered digital divide in Ghana, Kenya, and Kerala, India. We begin with a brief discussion of the three research locations before moving on to discuss the panel data and the three dimensions of ICT use examined in the multivariate analysis. To adequately address the changing nature of the gendered digital divide, we assess not simply access to or adoption of technology but also the intensity of use and the type of activities engaged in while online using two methods (Brown, 2008; Liff & Shepherd, 2004; Shih & Venkatesh, 2004; Ynalvez et al., 2005). First, we analyze the bivariate association between gender and various measures of technology use at times one and two using chi-square and t-tests. Second, we examine the multivariate relationship between various dimensions of the research career, gender, and technology use. We end with a discussion of future research possibilities.

Context and Method

The countries included in this study were originally selected in 1994 to represent varying levels of social and economic development.[ii] Ghana, representing a low level of development, was the first country in Sub-Saharan Africa to attain independence in 1957. Many expected Ghana to emerge as a leader on the path towards post-independence development. Following an economic crisis in the 1970s, however, much of the initial optimism waned. As measured by agricultural research and development spending and the number of staff employed in the countries research institutions, the countries research sector has strengthened in the last ten years. Not only has Ghana's agricultural research and development spending more than doubled, but the staff working at the research institutions in Ghana has also increased. More significantly in terms of our interests, the number of women staff has also increased over the same time period (Flaherty et al., 2010). Ghana's connectivity rate, although higher than many African countries and reflecting a steady increase over time, remains quite low. In, 2000, the number of internet subscriptions and internet users per 100 inhabitants in Ghana was .05 and .15 respectively. By, 2005, the corresponding figures were .05 and 1.83 (International Telecommunications Union, 2010). The growth rate in Ghana's internet penetration between the period of, 2000 and, 2009, however, was among the highest growth rates in sub-Saharan Africa at 3,223 percent (Internet World Stats, 2010).

The East African state of Kenya, representing a middle level of development, struggled during the first three decades after gaining independence in 1963, and most recently, the country was thrown into turmoil over the disputed election held in late 2007. While the countries agricultural research and development spending has fluctuated since the early nineties, in recent years the number of employed researchers, and women researchers in particular, has increased (Flaherty et al., 2010). Kenya's internet penetration is higher than Ghana's but has not increased to the same degree. From 2000 to 2005, the number of Internet subscriptions increased from 0.13 to 0.22, while the number of Internet users per 100 inhabitants increased from 0.32 to 3.10 (International Telecommunications Union, 2010). Although consistently reporting a higher level of penetration than Ghana, the Internet growth rate between 2000 and 2009 was 1,580 percent, approximately half Ghana's growth rate (Internet World Stats, 2010).

Finally, the Southwestern Indian state of Kerala was selected to represent a high level of social and economic progress. The country of India as a whole reports a highly productive scientific community. Not only does India report among the highest levels of PhD degrees held by agricultural research staff in low-income areas, but it also ranks fourth in its agricultural investments in the world (Beintema et al., 2008). In both, 2000 and 2005, India was the most technologically developed area of the three locations included in this study, with 0.28 Internet subscriptions in 2000, 0.61 in 2005 and 0.53 users in 2000 compared to 2.39 in, 2005 (International Telecommunications Union, 2010). Between the years, 2000 and, 2009, India's Internet penetration increased by approximately 1,520 percent (Internet World Stats, 2010). The state of Kerala, though not representative of India, is famous for its unique model of development, which is marked by the unusual combination of high social progress but low economic advancement.

Our data are drawn from a two-wave quantitative survey of the scientific community in three low-income areas. The first wave was conducted across a three-year period in 2000 (Kerala), 2001 (Ghana), and 2002 (Kenya). The second wave was conducted in 2005 in all three locations. Researchers employed in principal universities or national research institutions located within or near the capital cities of Accra, Nairobi, or Trivandrum were selected for inclusion. All members of the selected institutions working in a field related to agricultural, environmental, or natural resource management were interviewed. Of the 862 researchers interviewed in 2005, 544 were also interviewed in 2001 for a panel of nearly two thirds (63 percent) of the original sample.

To measure the gendered digital divide, we assess three aspects of internet and email use: 1) diversity of technology use, 2) intensity of technology use, and 3) experience using technology. The first component, diversity of use, is a measure of the types of activities engaged in while using email or the web. We measure diversity of internet use by employing two scales for email and web practice (Ynalvez et al., 2005). Email diversity is comprised of six dichotomous variables (1 = yes; 0 = no) measuring whether or not the researchers have: 1) been a member of a discussion group concerned with science and technology issues, 2) sent a message to a discussion group concerned with science and technology issues, 3) discussed research with someone in the United States, Europe or another developed country, 4) started a professional relationship with someone they met on the Internet, 5) discussed proposals with a funding agency, and 6) submitted or reviewed manuscripts for journals. Diversity can range from no diversity in use – a score of zero – to maximum diversity of use – a score of six.

Web use diversity is measured by scaling thirteen dichotomous variables (1 = yes; 0 = no) measuring whether or not respondents have: 1) ordered a product or service for their research, 2) created a web page, 3) conducted an information search, 4) used an electronic journal, 5) acquired or used data from the web, 6) collaborated on a scientific project, 7) found and examined reference materials, 8) accessed research reports or scientific papers, 9) participated in online chat groups, 10) used online job listings, 11) used online maps, 12) downloaded software, and 13) published a paper on the web. Web use diversity can range from no diversity – a score of zero – to maximum diversity – a score of 13.

The second component of technology use measures the amount of time spent using email and the web with two ordinal variables. The first variable assesses the number of hours spent sending and receiving email messages in a typical week, and the second variable assesses the number of hours spent using the web in a typical week (0 = no use, 1 = a low number of hours, 2 = a medium number of hours, and 3 = high number of hours). The final dimension of technology use is a measure of email and web experience. Two interval variables reflecting the number of years researchers have used these technologies are examined.

Our primary independent variable of interest is gender (0 = women, 1 = men). We also measure six additional dimensions including age, human capital, family structure, localism, context, and technological antecedents. Human capital is measured using one dichotomous variable assessing the percentage of women and men possessing the PhD (0 = other than PhD, 1 = PhD holder). To measure family structure, three variables are used: marital status (1 = married; 0 = not married), number of children, and spouse's occupation (1 = researcher, 0 = other). Localism is measured by the number of years spent outside the country of origin for higher education and training. Two measures of context are included as control variables: sector (1 = national research institute; 0 = university) and country (Kenya or Kerala with Ghana as the reference category) of employment.[iii]

Finally, we examine one antecedent to technology use: the location of the workplace computer. In the multivariate analyses, we measure consistent access to a PC in one's office (1 = PC in a private office over *both* waves of the survey; 0 = other/no work PC).[iv] This is an important distinction, as those respondents reporting earlier and easier access to a technology may be better able to develop the skills and knowledge required to use the technologies more extensively. A personal computer in one's office also provides unmediated access to the technology, while those without the computer in their office may have to share or use the technology from some other location.

To explore the gendered digital divide, we examine both the bivariate relationship between gender and various technology measures across waves as well as shifts from time one to time two for men and then for women. Intergroup changes are examined using a chi-square test (for nominal variables) and independent samples t-tests (for ordinal or interval variables), while intragroup changes are examined using the McNemar chi-square test (for nominal variables) and the paired-samples t-test (for ordinal or interval variables).[v]

In the multivariate models, we use ordinary least square regression to examine whether or not gender disparities persist after other factors are controlled. To model changes over time we use the static score approach, also known as the conditional change model. In this model, the time two dependent variables are regressed on the time one values of the independent and dependent variables (Allison, 2005; Finkel, 1995). We use the conditional change model rather than the first difference model (which uses a series of change scores for the independent and dependent variables). There are a number of reasons for this design.

First, use of the first difference or unconditional change score model does not include the lagged dependent variable as a predictor of the time two outcome. If it is assumed that the time one value of the dependent variable has some causal relationship with the time two value of the dependent variable, including the lagged dependent variable is appropriate (Allison and Long, 1990; Finkel, 1995). In addition, the alleged benefit of using the unconditional change score model (i.e. time invariant predictors, such as gender, need not be included because they are implicitly controlled) is problematic if one's primary interest is in predicting the relationship between such time-invariant predictors as gender, country of origin, and organizational context and technological behavior. While the effect of these variables is indirectly controlled, one is unable to directly assess their importance in the model. For these reasons, we employ a model in which Y_t is predicted using the lagged value Y_{t-1} and a series of X_{t-1} independent variables.

Table 1: Chi-Square test of Contextual Differences Between Women and Men Scientists: Country, Organization Type and Field Differences[1]

	2005		
Variable	Men	Women	N
Context			
1. Country	***		544
Ghana	34.0	12.4	
Kenya	38.8	29.8	
Kerala	27.2	57.9	
2. Organization type			544
Academic	52.5	65.3	
Research institute	47.5	34.7	
3. Field	***		543
Agriculture	27.2	26.7	
Physical sciences	20.6	11.7	
Biology/biotech	27.7	43.3	
IT/engineering/math	20.3	6.7	
Social sciences	4.3	11.7	

[1] ***p<.001; **p<.01; *p<.05

Table 1 reports the gender differences in wave one on country, sector, and field of employment.[vi] Due to the lack of change over the five-year period on these measures, Table 1 does not include the gender differences on the time two values of these variables. The majority of the women in our sample are from Kerala (57.9 percent), while the largest number of men are from Kenya (38.8 percent). Women are more likely to be employed within a biotechnology field (43.3%) and in a university setting (65.3%). A slight majority of men are also employed within the university setting (52.5%), with the largest number working in a biotechnology field (27.7%). However, men are more evenly dispersed across fields and sectors.

Results and Discussion

Table 2 reports the gender differences in wave one and wave two on the independent variables included in the multivariate analysis. According to Table 2, women are younger than men by approximately two years (row one). Women are also less likely to be married and when married, are more likely to report a spouse who is also a researcher, and are more likely to have fewer children (rows two through four) than men. No women report a husband who stays at home, while close to 20% of men in both waves report a stay-at-home spouse. The evidence regarding family structure is consistent with research based in a more developed context noting that women researchers are more likely to postpone family formation. Women and men are equal, however, in their possession of

Table 2: Independent Samples T-test and Chi-Square Test of Differences Between Male and Female Scientists in Wave One and Wave Two: Age, Family Structure, Human Capital and Localism Differences[1]

	2000-2002			2005		
Variable	Male	Female	N	Male	Female	N
1. #Age	45.07**	42.74	544	48.68*	46.86	544
Family structure						
2. %Married[2]	93.4**	84.3	544	96.7***	85.1	542
3. #Children[3]	2.43**	2.02	539	2.61***	2.06	536
4. %Researcher	9.6**	19.8	539	7.6**	16.5	540
5. %Domestic laborer	18.0***	---	544	19.3***	---	540
Human capital						
6. %PhD	55.6	55.4	544	60.8	65.3	544
7. %Masters	35.2	34.7	544	34.0	28.9	544
Localism						
10. %Any DC education[4]	64.3***	28.1	512	73.7***	37.2	540
11. #Yrs outside country for ed.	2.24***	.89	533	2.53***	1.06	540
12. #Yrs spent abroad altogether	2.51***	1.05	536	2.79***	1.32	541
13. #Days away from parent org.	36.26**	21.41	500	35.76	33.05	523
Technological antecedents						
14. %PC in private office	35.5***	15.7	538	67.1***	40.0	542

[1] ***p<.001; **p<.01; *p<.05
[2] Significant differences for variables preceded by a % were tested using a Chi-Square test.
[3] Significant differences for variables preceded by a # were tested using a t-test.
[4] This item measures any educational experience in a developed country. It includes both those who actually received a degree from a developed country as well as those who may have studied abroad but did not actually receive a degree.

human capital. In both waves, women and men are equally likely to possess both the PhD (55.4 percent of women and 55.6 percent of men in wave one, and 65.3 percent of women and 60.8 percent of men in wave two) and master's degree (34.7 percent of women 35.2 percent of men in wave one, and 28.9 percent of women and 34 percent of men in wave two).

The gender differences on the variables measuring localism and technological antecedents are more dramatic than those measuring human capital. Women less likely to report having developed country educational experience (28.1 percent and 37.2 percent of women report such an experience in waves one and two compared to 64.3 percent and 73.7 percent of men in waves one and two). When they do travel outside their parent country, they spend approximately a year and a half less away for any reason (rows 11-12). There have been some shifts, however. In wave one, women spent significantly fewer days away from their parent organization than men (21.41 days away for women compared to 36.26 days away for men). By wave two, the differences on this measure have disappeared with women and men spending approximately equal number of days away (33.05 days away for women compared to 35.76 days away for men). Looking at the technological antecedent measure, it is clear that men are significantly more likely to have a PC in their private office, and this is consistent across both waves (35.5 percent in wave one compared to 15.7 percent of women, and 67.1 percent of men in wave two compared to 40 percent of women). Fewer than 50 percent of women report having a PC in their private office, but the percentage of women with such access has more than doubled over the period examined here.

Table 3 addresses the gender disparity in access to and use of personal computers, the web, and email using chi-square and independent samples t-tests. Table 4A and 4B address the nature of the gender digital divide over time, using paired samples t-test and the McNemar Test of Symmetry. According to the results in Table 3, the only measures on which gender differences do not emerge are those corresponding to what might be considered the 'early' stages of the digital divide measured in terms of access. Regardless of wave, women and men report similar levels of access to personal computers at work (row 1) and they are equally likely to have ever used the web (row 2). By wave two of the

Table 3: Independent Samples T-Test and Chi-Square test of Gender Differences in Access to and use of Personal Computers, the Web, and Email in Wave One and Wave Two[1]

	2000-2002			2005		
Variable	Male	Female	N	Male	Female	N
Personal Computers						
1. %Ready access to PC at work[2] (1=yes)	77.6	71.7	540	96.7	95.0	544
Web						
2. % Ever used web (1=yes)	71.1	60.3	540	93.3	88.3	539
3. Diversity of web use[3]	4.42**	3.29	516	7.12***	6.03	529
4. Intensity of web use[4]	1.16	.97	529	2.01*	1.73	529
5. Web use experience[5]	2.49***	1.49	531	5.96*	5.02	539
Email						
6. %Currently using email (1=yes)	90.5***	69.4	543	95.3	90.9	543
7. Diversity of email use[6]	2.35**	1.79	526	3.05**	2.56	536
8. Intensity of email use	1.55***	1.09	532	1.96***	1.65	528
9. Email use experience	3.84***	2.37	538	7.18***	5.79	541

[1] ***p<.001; **p<.01; *p<.05
[2]Significant differences for variables proceeded by a % were tested using a chi-square test. All other variables were test using an independent samples t-test.
[3] Diversity of web use is a 13-point scale measuring the types of activities engaged in while online. A score of 0 indicates no diversity of web use, while a score of 13 indicates maximum diversity of web use.
[4] Intensity of web and email use are measures of the number of hours spent using the web or email in a typical week. Values can range from an ordinal variable ranging from 0 = none, 1 = low, 2 = medium, 3 = high.
[5] Web and email use experience are measures of the number of years a respondents has used the two technologies.
[6] Diversity of email use is a six point scale measuring the types of activities one engages in while using email. A score of 0 indicates no diversity of email use, while a score of 6 indicates maximum diversity of email use.

study the gender differences in those who identify as a current user of email also disappear (row 6).

The significance behind the digital divide, however, is not solely measured in terms of *access* to technologies. Instead, as a technology diffuses, resource use becomes a better indicator of gender disparities. When analyzing email and web use experience and the diversity and intensity of email and web use, clear differences become evident. A fairly stable pattern of gender differences emerges across the two waves, with men emerging as more technologically oriented than women on the majority of the measures examined. In both waves, men have more experience using email and the web, they do a wider variety of activities online and while using email, and they spend more time using email (both waves) and the web (wave two).

Men adopt the web approximately one year earlier than women, and they adopt email approximately a year and a half earlier than women (rows five and nine). In wave one, men's web use diversity score was 4.42 out of a possible score of 13, compared to a web use diversity score of 3.29 for women. By wave two, women's web use is more diverse (6.03) but continues to be less than men's (7.12). A similar trend emerges on the gender differences in email activities. Men in both waves engage in more email activities than women. Out of a possible score of six – one being the least amount of email activity, six being the most – men have a score of 2.35 in wave one and 3.05 in wave two compared to 1.79 for women in wave one and 2.56 in wave two. Regardless of the wave or the technology, men are consistently engaged in more online activities than women.

Men also use the web and email more intensely as measured by the time spent with the technologies. Indeed, the gender disparity on web use intensity, while not significant in wave one, becomes so by wave two (1.16 for men in wave one compared to .97 for women and 2.01 for men in wave two compared to 1.73 for women). The gender differences in intensity of email use remains consistent across both waves. Men use email more intensely than women (1.55 compared to 1.09 for women in wave one, and 1.96 compared to 1.65 for women in wave two).

While the gender differences remain across waves, Table 4 makes clear that there have been significant changes in both women and men's technological access and use from wave one to wave two. On every measure of technology examined, women and men both report significant increases in access, experience, diversity and intensity of technology use. In other words, regardless of gender, researchers in Ghana, Kenya and Kerala live and work in a more technologically saturated environment (rows one through six in 4A and rows one through three in 4B).

Table 4A: Paired Samples T-test of Changes Access to and use of Personal Computers, the Web, and Email in Wave One and Wave Two by Gender[1]

	Men			Women		
Variable	2000-2002	2005	N	2000-2002	2005	N
Web[2]						
1. Diversity of web use	4.41***	7.12	388	3.15***	5.88	114
2. Intensity of web use	1.16***	2.05	399	.97**	1.72	116
3. Web use experience	2.48***	6.03	409	1.42***	4.92	117
Email						
4. Diversity of email use	2.36***	3.05	401	1.74***	2.51	117

5. Intensity of email use	1.56***	1.96	405	1.09	1.64	113
6. Email use experience	3.86***	7.24	413	2.30***	5.64	120

[1] ***p<.001; **p<.01; *p<.05
[2] Significant differences are tested using paired samples t-test.

Table 4B: The McNemar Chi-Square Test: Wave One to Wave Two Changes in Access to and Use of Email and Personal Computers[1]

Personal Computer Measures	
1. %Ready Access to Personal Computer at Work:	
Men (N=421)***	
No access to access	20.0% (84)
Access to no access	1.4% (6)
Access to access	74.6% (314)
No access to no access	4.0% (17)
Women (N=119)***	
No access to access	14.3% (17)
Access to no access	1.7% (2)
Access to access	79.8% (95)
No access to no access	4.2% (5)
Web Measures	
2. %Ever used the web:	
Men (N=409)***	
Never used the web to used the web	23.5% (97)
Used the web to never used the web	NA
Used the web to used the web	70.0% (289)
Never used the web to never used the web	5.6% (23)
Women (N=113)***	
Never used the web to used the web	31.4% (37)
Used the web to never used the web	NA
Used the web to used the web	56.8% (67)
Never used the web to never used the web	7.6% (9)
Email Measures	
3. %Currently using email:	
Men (N=421)**	
Not currently using to currently using	7.4% (31)
Currently using to not currently using	2.9% (12)
Currently using to currently using	87.9% (370)
Not currently using to not currently using	1.9% (8)
Women (N=121)***	
Not currently using to currently using	24.8% (30)
Currently using to not currently using	3.3% (4)
Currently using to currently using	66.1% (80)
Not currently using to not currently using	5.8% (7)

[1]***p<.001; **p<.01; *p<.05

Without controlling for other factors, men consistently outpace women in their technological behavior. This pattern persists over time. However, these gender disparities do emerge within a context of increasing technological use for both women and men. Do the gender differences in technology use disappear when other factors are controlled? In Tables 5 and 6, we present the results of the multivariate analyses predicting 1) the intensity and extent of web and email use, and 2) email and web use experience. Four patterns of technological orientation emerge. Men, respondents who are younger, respondents who have more travel experiences, and respondents who have easier access to a personal computer are more technologically oriented than women, respondents who are older, respondents who have fewer travel experiences, and respondents who have less access to a personal computer.

The variables measuring family structure, context, and education do not emerge as consistent predictors of technological orientation. Although respondents with a PhD do use both email and the web for a wider variety of purposes (b = 0.675 for email use and b = 0.840 for web use), these are the only measures for which this relationship emerges. In addition, those reporting a spouse who is also a researcher engage in more diverse activities using the web (b = 0.802), while Kenyan's use email (b = 0.360) for a larger variety of reasons but use the Web (b = 0.417) less than respondents from Kerala or Ghana. Finally, respondents who work in a research institute spend less time using both email (b = 0.226) and the web (b= 0.190) than those who work in a university setting.

After controlling for the stability effect (i.e. the time one value of the dependent variable), gender emerges as a significant predictor in half of the multivariate models. Gender is significantly associated with all of the web measures, but with only one of the email measures. Men use email (b = 0.215) and the web (b = 0.303) for a longer number of hours than women, and they also use the Web for more diverse purposes (b = 0.194). Gender does not, however, emerge as a significant predictor of the types of activities one engages in while using email or of the number of years of experience with the technologies. Women and men adopt email and the web at approximately the same time, indicating a similar degree of experience with the technologies. Women and men are equally predisposed to use email for a variety of purposes. Consistent with research based in the United States, the most consistent predictor of technological behavior is age. Younger respondents use email (b = 0.041) and the web more diversely (b = 0.098) and for more hours (b = 0.019 for email and b = 0.040 respectively for the web). Younger respondents also report more years of experience with both technologies (b = 0.053 for email and b = 0.074 for the web).

The third pattern of ICT behavior relates to the dimension measuring technological antecedents. In all but two of the six multivariate models, the location of one's personal computer is a significant predictor of technological behavior. Consistently having the physical hardware to access the Internet in one's personal office is significantly related to the diversity (b = 0.471) and intensity of email use (b = 0.288).

Table 5: OLS Regression Results for Measures of Email Access and Use[1]

Independent and control variables	2005 Extent of email use[2] (N = 492)	2005 Intensity of email use[2] (N = 488)	2005 # of years using email[2] (N = 504)
Constant	2.425***	2.157***	5.315***
	(.521)	(.296)	(1.12)
Men	.288	.215*	.145
	(.178)	(.099)	(.383)
Age (years)	-.041***	-.019**	-.053*
	(.011)	(.006)	(.024)
Education (1=PhD)	.675***	.179	.626
	(.175)	(.096)	(.375)
Family structure			
Married (1 = yes)	.398	.119	.300
	(.272)	(.147)	(.590)
Number of children	-.034	-.018	.003
	(.059)	(.033)	(.128)
Spouse a researcher (1 = yes)	.101	-.096	-.325
	(.210)	(.116)	(.450)
Localism	.004	.025	.202**
# years in DC	(.032)	(.017)	(.073)
Context			
Kerala[3]	.144	.046	.358
	(.229)	(.127)	(.503)
Kenya	.360*	-.176	.178
	(.173)	(.096)	(.370)
Sector	.206	-.226**	.303
(1 = research institute)	(.147)	(.081)	(.315)
Technology	.471**	.288***	1.194***
antecedents	(.162)	(.088)	(.346)
PC in personal office	.471***	.183***	.612***
	(.040)	(.045)	(.054)
Time lag	.364	.163	.343
R			

[1]***p<.001; **p<.01; *p<.05
[2.] Normal error (OLS) regression results
[3] Ghana is the reference category.

Table 6: OLS Regression Results for Measures of PC and Web Access and Use[1]

Independent and control variables	2005 extent of web use [2] (N=475)	2005 intensity of web use[2] (N=488)	2005 # of years using the web [2] (N=495)
Constant	7.676***	3.139***	6.861***
	(.980)	(.369)	(1.153)
Men	1.194***	.303*	.446
	(.328)	(.121)	(.387)
Age (years)	-.098***	-.040***	-.074**
	(.021)	(.008)	(.025)
Education (1 = PhD)	.840**	.189	.376
	(.325)	(.119)	(.382)
Family Structure			
Married (1=yes)	.021	.011	-.423
	(.516)	(.199)	(.609)
Number of children	.134	.038	.015
	(.112)	(.041)	(.132)
Spouse a researcher	.802*	.077	.151
(1=yes)	(.396)	(.141)	(.462)
Localism	.027	.054*	.167*
# years in DC	(.060)	(.022)	(.074)
Context	.334	.038	.624
Kerala[3]	(.427)	(.155)	(.504)
	.229	-.417***	-.121
Kenya	(.320)	(.120)	(.382)
	-.128	-.190*	-.066
Sector	(.269)	(.100)	(.320)
(1=Research Institute)			
Technology antecedents			
PC in personal office	.156	.086	1.141***
	(.300)	(.110)	(.354)
Time lag	.349***	.222***	.534***
	(.036)	(.046)	(.058)
R	.306	.181	.264

[1]***p<.001; **p<.01; *p<.05
[2] Normal error (OLS) regression results
[3] Ghana is the reference category.

Those researchers with such access use email for a larger variety of activities and for longer periods of time than those without such access. Researchers with a PC in their personal office also adopt email (b = 1.194) and the web (b = 1.141) earlier. The final pattern to emerge from the multivariate models is in regards to localism. Those researchers who travel more outside of Kerala, Ghana, or Kenya are also earlier adopters of email (b = 0.202) and the web (b = 0.167), and they report spending more time using the web (b = 0.054).

Our results demonstrate deeper penetration of the internet and email over the period examined. However, there remains a persistent divide in technological behavior between women and men. Consistent with previous studies, our bivariate analyses make clear the gender digital divide among researchers is no longer marked by *access* to personal computers, email, and the web (IDREF1). Women and men are equally likely to report having access to various technologies. Given the extent of Internet diffusion, a more accurate depiction of the digital divide is of a continuum ranging from those with no access and low skill, to those who are the most frequent, intense and skilled users (DiMaggio et. al., 2001; Miyata, 2002; Warschauer, 2003). Indeed, extending the analysis of the gender digital divide beyond access reveals that men are more technologically oriented than women in terms of their email and web experience, the intensity with which they use email and the web, and the types of activities engaged in while using those technologies.

Even after controlling for other factors, gender disparities remain, with two exceptions. In the multivariate models, gender is not a significant predictor of adoption of either email or the web, nor is gender related to the types of activities engaged in while using email. Researchers, regardless of gender, have a vested interest in using ICTs and so adopt the technologies around the same time. The lack of significant difference in email use, furthermore, may actually be consistent with research on gender differences in email coming out of the United States and Canada. Men tend to use the internet (whether through their use of the web or email) for a wider variety of reasons, while women tend to use online activities for more restricted purposes, primarily relationship maintenance through *communication* technologies.

Men do use email and the web more intensely than women, and while on online, they are engaged in more activities from publishing a paper, to accessing an electronic journal. Women's web and email use may be less intense due in part to familial and institutional constraints limiting women's free time to use technologies more intensely, which may also be associated with developing the skills to use technology for a wider variety of activities. It should be reiterated that women's intensity and diversity of use has increased, so while they continue to lag behind men, it is within the context of greater use.

In addition to gender, we also controlled for age, education, family structure, localism, context, and technological antecedents. Education, family structure, and context are generally unrelated to technological behavior, but four patterns related to age, travel experience, access to a personal computer and gender emerge as fairly consistent predictors of orientation to technology. One of the most consistent findings in the existing literature on technology adoption and use is that those individuals who may be innovative in other respects are also earlier adopters and more intense users of new technologies. In the context of the research and educational sectors in low-income areas, age, education, and localism are indicative of more innovative individuals in the sense that those who are younger, more educated, and with greater travel experiences may be more willing and motivated to adopt and use new technologies. Although education does not emerge as a consistent predictor of technology behavior, our results are based on a sample of highly educated individuals. Possessing a PhD or a master's degree does not distinguish technology users from one another as there is little variation in educational attainment.

However, individuals who are younger are earlier adopters and more intense and diverse users of both email and the web. Due to the timing of technology exposure, younger individuals may feel more comfortable adopting and using a technology, while older respondents may be more resistant to acquiring a new set of skills mid-career. Those respondents spending more time in a developed country are also earlier adopters of the web and email, and they use the web more intensely. Spending more time outside of one's country of origin provides a researcher with the opportunity to use the web where such opportunities may not have existed in less resource rich institutions. In addition, the use of chat rooms and other forms of instant communication available through the web makes it a desirable medium for long-distance communication with family and friends living in Africa and India.

A final pattern to emerge from our multivariate analyses is related to those reporting access to a personal computer in their private office. This measure is an especially strong indicator of the intensity and diversity of email use as well as the number of years one has spent using the web and email. Having a PC in one's own office means one either does not share with other people or that one shares with a smaller number of co-workers, thus providing greater opportunities. This allows more diverse use of email and less social pressure to be expedient than is associated with public terminals.

The results of our analyses, while important, should be interpreted with some caution. First, the use of qualitative interviews would provide more insight into the patterns noted here. The quantitative analysis employed in this article is limited in revealing motivations for and restrictions to women's use of email and the web. In addition, inter-country differences are difficult to detect in a multivariate analysis given the small sample size of women researchers.

Second, the scale we have used to measure email diversity is also limited. While we have included six measures of email activities, additional factors need to be accounted for when considering the way researchers use email. For example, we have measured whether or not women and men use email to discuss research with colleagues located in more economically developed areas. An email diversity scale might also include measures of whether or not respondents discussed research with local scientists. Altering the email diversity scale in this way might produce distinctly different results.

Conclusion

This article contributes to a growing body of empirical literature tracking the changing nature of the gender digital divide in low-income areas by employing longitudinal, quantitative data to examine access to and use of technology among researchers in Ghana, Kenya, and Kerala, India (Best & Maier, 2007; Choudhury, 2009; Gill et al., 2010; Huyer et al., 2005; Zainudeen et al., 2010). Our results raise a number of issues that should be addressed in future research.

First, it is important to remember that the ‘promises’ and ‘threats’ of ICT operate within social structures, not separate from them (Fuchs, 2008). As such, the role of gender as a social structure requires more analytical attention. Women and men occupy multiple and intersecting social positions which stratify their access to and use of the internet and email. Gendered expectations in terms of work and family roles may make it difficult for women to develop the skills needed for diverse use of technology even in environments in which access is virtually complete. While changes in communication technologies may be associated with changes in inequality in resource distribution, gender status beliefs may be slow to follow such social structural changes so that new inequalities might emerge to replace the old.

Second, while the various digital divides may become smaller as internet penetration becomes greater, it is worth examining whether or not there are differential consequences for those researchers who are earlier adopter vs. later adopters, for those who begin using the internet or email more intensely and more diversely early on. What benefits, if any, accrue to those who use email and the web more frequently and for more diverse activities? Is women’s later adoption, less intense, and diverse use reflected in other aspects of their career?

These questions become particularly relevant when one considers that the production of new scientific knowledge is a communal activity. Researchers do not work in isolation, but are instead involved in formal and informal scientific networks. New technologies make gathering data, accessing online literature, and communicating with other researchers easier and more efficient. For this reason, its use by researchers in low-income areas may be revolutionary for the way knowledge is produced and disseminated. What needs to be examined is the extent to which gender disparities in access to and use of ICTs translate into significant differences in network structure and research productivity. If slower adoption within the research career has further consequences in terms of productivity, networking, and collaboration, current gender disparities on these measures may actually widen with time. With this in mind, the degree to which the digital divide exists between women and men may be a critical component to understanding the relative position of women to men within science.

ENDNOTES

Acknowledgements: This article presents findings from a grant issued to Louisiana State University by the National Science Foundation under Grant No. 0113545. The findings, opinions, and conclusions expressed within this document are those of the authors and do not necessarily reflect the views of the National Science Foundation. We owe particular gratitude to Antony Palackal, Paul Mbatia, Dan-Bright Dzorgbo, and Marcus Ynalvez for their work in Ghana, Kenya, and Kerala in 2001 and 2005.

[1] The 2007 United Nations Conference on Trade and Development (UNCTAD), for instance, reported that in 2002 Internet penetration in more economically developed areas was *ten* times higher than in low-income areas. By 2006, Internet penetration was only six times higher in more developed areas. Measures of mobile phone penetration were even more dramatic with the number of mobile phone subscribers in less developed areas tripling over the same period.

[2] The three sites chosen for this study were originally selected by the funding agency RAWOO (Advisory Council for Scientific Research in Development Problems) for the Dutch Ministry for Development Cooperation. The countries were selected to represent three stages of development of the research community – high, medium, and low. While a different selection of countries would likely produce different results, the benefits of having longitudinal, quantitative data outweighs the benefits of gathering data in different locations.

[3] Although we include sector of employment as a control variable, it is important to reiterate that there are different institutional expectations within universities as compared with national research institutes. Respondents employed within research institutes are more likely to work in teams with other researchers and there may be greater expectations for collaboration, a process that may be facilitated by use of communication technologies. Those working in universities are likely to spend a greater amount of time in the classroom, an activity that may take away from research and lead to distinctly different patterns of technology use. However, given the approximately equal percentages of women and men employed in universities and research institutes, we suggest any gender differences that may emerge are not due to a predominance of women in one sector over another.

[4] Other includes respondents who did not have a PC in their private office in the first wave but did in the second; those who did have a PC in their office in the first wave but did not in the second; and those who did not have a PC in their private office in either wave.

[5] The McNemar test operates by testing whether those values above and below the diagonal of a square table are significantly different from one another. Stated differently, this statistic tests the assumption that the marginal frequencies are homogenous. If the McNemar Chi-Square is significant, one can reject the assumption that the frequencies are homogenous. In other words, that there has been no significant change over time (Allison, 2005).

[6] We do not include field in the multivariate analysis due to previous findings that it is a relatively poor predictor of gender differences in this context.

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