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When do scientists "adopt" the Internet? Dimensions of connectivity in developing areas

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We examine the diffusion of information and communication technologies (ICTs) in the knowledge production sectors of three developing areas. Using interviews with 918 scientists in one South Asian and two African locations, we address three fundamental questions: (1) To what degree has the research community in the developing world adopted the Internet? (2) How can the disparities in Internet adoption best be characterized? (3) To what extent is Internet use associated with research productivity? Our findings indicate that while the vast majority of scientists describe themselves as current email users, far fewer have ready access to the technology, use it in diverse ways, or have extensive experience. These results are consistent with the notion that Internet adoption should not be characterized as a single act on the part of users. The rapid development of the Internet and the cumulative skills required for its effective use are equally important, particularly its impact on productivity. These findings lead us to qualify crude generalizations about the diffusion of the Internet in developing areas.

Introduction

With the globalization of science, both developed and developing societies are increasingly knowledge-based, presenting new social realities.[1] To understand these realities, social analysis should pay proportionate attention to the nature and functioning of scientific institutions.[2] The research reported here examines these institutions in terms of their access to and utilization of new information and communication technologies (ICTs). The Internet is of particular interest because its recent diffusion has been viewed both as the much needed "elixir" that will free Third World science from its relative isolation and conversely as an "affliction" that fuels the engine of global inequality. This latter impact comes in the form of an insidious new dependency creating technology gaps between the developed and developing worlds, a scientific "digital divide".[3]

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While studies of ICT diffusion in developed areas have gained momentum,[9–13] the diffusion of ICTs and their effects on developing world science have not yet been studied in any systematic way. To date, no comparative study has examined the use of the Internet by individual scientists in the developing world. This study examines the structure of Internet use and its association with publication productivity for three cases in Africa and south Asia. We address three basic questions. First, to what degree has the research community in these developing areas adopted the Internet? Second, how can we best characterize disparities in Internet adoption in the scientific communities? Third, to what extent does Internet use influence research productivity?

The first two questions pertain to the diffusion of technological innovations, many of which originated within the scientific community itself. ICT diffusion in the US and Western Europe enabled rapid and continuous access to information and shared databases.[3] It has also enhanced "real time" opportunities to share findings and support the exchange of ideas within the scientific community in the developed world. These seemingly universal benefits of ICTs have led some to argue that the diffusion of ICTs in developing areas will lead to the globalization of science. More importantly, some suggest it will lead to local integration, universal participation, and global visibility of Third World scientists (the "elixir" argument).[4–7] Others are skeptical about the positive impacts of ICTs (the "affliction" argument).[8] They argue that ICTs form a new basis for social differentiation and social evaluation that can exacerbate existing problems and create new social inequities on a global scale. Our approach is not to view the Internet as either an elixir or affliction, but rather an essential tool in the conduct of research. As the Internet becomes a pre-requisite for research and international collaboration, it is essential to understand its impact on developing scientific communities.

While the concept of Internet "adoption" in the developed world context seems straightforward, it is not so clear in the developing world context. In answering our first question, we recast the notion of Internet adoption and move away from the idea that 'adoption' is a single, instantaneous behavior. While some authors emphasize the issue of access in defining the digital divide,[14–17] others emphasize that access does not imply use. The latter, many feel, should be the primary focus of adoption studies.[18] For example, Lenhart and Horrigan[19] question the validity of studies that treat Internet adoption as an issue of binary access (access/no access) and use (user/non-user). Their call for a more specific understanding of the qualities of technology access and behavior is based on a concern that the way an issue is labeled constrains and shapes our responses to it.[19] Robinson[1] argues that Internet studies should move beyond the usual definitions of the divide in the sense of simple access and use, and focus instead on social processes and behavior once access has been achieved. Robinson[1] alludes to finer divisions in access and use than the usual binary categories. In short, the divide might best be viewed as a digital spectrum based on multiple dimensions, rather than a digital dichotomy.

This analysis begins to address the criticisms of Internet diffusion studies within the context of research institutions in the developing world. During the last decade of surveys, interviews, and field studies on the scientific communication system in developing areas such as Ghana, Kenya, and India, it has been impossible to ignore the progressive development of connectivity initiatives by international donors as well as the private sector. Aid agencies and multinational telecommunications firms have dramatically increased both emphasis and investment in the research and educational sectors of Latin America, Asia, and Africa. Yet our observations in the scientific organizations we have studied reveal that the process of connectivity is complex, difficult, and circuitous. To take one example, several agricultural research institutes in Kenya had greater facility for email communication in the late 1990s than in early 2000.

In broad terms, the Internet refers to a range of communication and information retrieval technologies, a distinction that is broadly captured by the concepts of email and Web. In what follows, we use this distinction to refer to two separable dimensions involving interpersonal and collective communication practices (e.g., using email to communicate with scientists in developed countries, discuss research with funding agencies, review, or submit a manuscript) as well as information exchange and retrieval (e.g., using the Web to find electronic journals and accessing research reports and articles). This distinction is important because scientific activities involve both individual activities (e.g., data management and bibliographic searches) and social transactions (e.g., consultations and discussions with other scientists and communication with funding agencies and journals).

We conceptualize Internet adoption in terms of four primary dimensions.* The first dimension refers to the degree to which individuals define themselves as users of telecommunications technology – specifically, whether one defines oneself as an “email user”. The second dimension is explicitly contextual. It refers to the degree to which a particular technology is present and available for use within the environment. For the individual, this is a matter of access, that is, the degree to which there is a functioning Internet connection within the organizational, domestic, or community context. The third dimension pertains to personal experience. Clearly, differences exist between a first time user and one who has interacted with a technology for years, who through repeated and continuous exposure has incorporated a technological practice into a pattern of daily life. The fourth dimension pertains to the social and cultural practices that constitute Internet use – that is, the diversity of behaviors associated with the employment of contemporary email and Web technology.

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* The ‘Internet’ is often characterized dichotomously as a combination of email technology for communicating and Web technology for information gathering. The empirical analysis in this paper focuses largely on email technology especially along the dimensions of current use and ready access. Our survey also included information on web use, which is presented in Table 3.

We distinguish these dimensions because while many individuals report having used the Internet, this does not mean that they have ready access to the Internet or that they use the Internet in varied ways, or have used it repeatedly for long periods of time. Conversely, ready access does not necessarily imply either current usage or diversity of purpose and use. Current usage may or may not translate to overt and sustained Internet use. In the following analysis, we measure these four dimensions through *current use*, *ready access*, *Internet experience*, and *Internet practice.*

A "current user" is an individual who defines themselves as such, regardless of the frequency or practices of use. This criterion is important because a self-defined current user can range from someone who has been using, is using, and will continue using the Internet in everyday transactions to someone who has become familiar with email through their experiences in graduate training, but may have low levels of access in their current situation. "Ready access" is also a perceptual measure: individuals define themselves as having accessible, available, and/or reasonable connectivity within their immediate environment. This qualification is relevant because access can either be within the organization (e.g. personal office, library, and laboratory) or outside the organization (e.g. home, friend, public terminals, Internet café).

Our third dimension, "Internet experience," refers to the period of time during which an individual has used the Internet. We use two indicators of Internet experience representing the communication aspect and the informational retrieval aspect of the Internet. "Email experience" refers to the length of time between the survey and the year the respondent began using email. "Web experience" refers to the time interval between the survey and the year of first browsing the World Wide Web. Our fourth dimension, "Internet practice," designates the variation among individuals in terms of the ways they use the Internet. For example, for what purpose does an individual scientist use the Internet? Is it simply and primarily for personal communication? Or is connectivity also used to communicate findings and exchange ideas with colleagues or discuss research activities with scientific organizations, research foundations, funding organizations, and other institutions in a system of innovation?

The second major question for this analysis centers on the disparities in ICT adoption among developing world scientists. Recent studies show that socio-demographic factors such as age, gender, and education determine the likelihood of ICT adoption in the developing world. With respect to age, the largest proportion of Internet users is in the 35-45 age group.[20] However, in the absence of any sociological explanation, it is reasonable to hypothesize that the 35-45 age group typically represents mid-career individuals who are more likely than members of other age groups to have access to the Internet. This is because they are established in their jobs, are the ones who process and filter data, and have the most training and exposure to the Internet.

Gender analysis of the digital divide remains inconclusive.[21] The Pew Internet and American Life study[22] reports that the gender-gap in terms of access has all but disappeared in the U.S. Other surveys indicate that in 2000, there were more women than men on the Internet and that women spent more time on-line than men.[14] The educational divide, on the other hand, has been quite consistent: those with higher education are more likely to have access to the Internet. Wilheim[23] found that education is a stronger determinant of Internet connectivity than any other socio-demographic variable. However, systematic research on the nature of disparities in ICT adoption in developing world science communities is absent. The answer to our second question will begin to fill this gap in the literature.

The third question pertains to the opportunities and rewards implied by the digital divide.[14,24,25] Of the few studies that have investigated the relationship between the Internet and scientific productivity,[26–30] few have been conducted in the developing world and virtually none have included comparisons among developing countries. In scientific communities, disparities in utilization of ICTs are presumed to lead to inequalities in access to international databases and information,[29] scholarly communication,[31] collaboration and scientific publication productivity.[27,32,33] With the exception of Ehikhamenor,[27] studies of scientific productivity have examined individual and demographic characteristics of scientists,[34–36] but do not address the question of Internet adoption directly.

Hence, our third question focuses on the influence of Internet adoption and scientific productivity in domestic and international journals. The distinction between these two types of publication productivity is relevant because in developing areas their association has been shown to be weak or absent. This suggests that there may be no single underlying productivity dimension. Domestic and foreign productivity translate into two distinct phenomena, reflecting the priorities of careers in international science versus local development interests, or at least the advantages of training in the developed world.[37] We further contend that the review process, acceptance criteria, and prestige are not the same for local journals in the developing world and foreign journals in the developed world.

The analysis below elaborates Internet use and access patterns for a sample of scientific and educational institutions in Kenya, Ghana, and the State of Kerala in southwestern India. In the next section, we describe the three locations in which this research was conducted. We then describe the sample and method. In the analysis that follows, the dynamics of ICT adoption are treated in terms of current usage, ready access, Internet practice and experience. After describing the availability of computers, email access and Web use in some detail, the social structural characteristics associated with these technologies are examined. Finally, we test for an association of Internet use and publication productivity in both domestic and foreign journals.

Study contexts

Because research in developing areas is mostly conducted in universities and in government research institutes, the sample of scientists for this study was drawn from these two sectors within each of the three study locations. These locations were selected to represent low (Ghana), medium (Kenya) and high (Kerala, India) levels of scientific and socioeconomic development. In 2002, per capita gross national income for Ghana, Kenya and India were $270, $360, and $480, respectively; while aid per capita were at $33, $15 and $2, respectively.[38] For ages 15 and above in 2002, India had the highest illiteracy rate (41.2%), followed by Ghana (26.2%) and then by Kenya (15.7%). In terms of Internet diffusion, Ghana, Kenya and India had 1.9, 16.0 and 6.8 Internet users per 1000 people, respectively.[39] A somewhat different ordering among the three countries is observed for the diffusion of personal computers (India 5.8, Kenya 5.6, and Ghana 3.3 per 1000 persons) and combined fixed phone lines and mobile phones (India 43.8, Kenya 29.6, and Ghana 20.8 per 1000 persons).[38]

In India, we focus on the southwestern State of Kerala. Kerala is distinctive in that the level of social development is higher than one would expect based on its level of economic development; a phenomenon often cited as the "Kerala Model".[40–44] Although capital investment and economic growth in Kerala remain low and unemployment high;[45,46] social indicators, including literacy rates, demographic trends, the presence of social programs and the status of females suggests a state that is similar to many developed countries. With Kerala's strong emphasis on literacy and education,[41,44] it is not at all surprising that it supports an independent system of research institutes and statewide programs dedicated to the generation of scientific knowledge about local conditions. Moreover, while the level of external investment might lead one to predict a reduced rate of diffusion compared with the national average, the literacy rate and education of Malayalis have led to early awareness and high demand for ICTs.

For nearly 20 years after it gained independence in 1964, Kenya was seen as the "African success story". Its average annual GDP growth rates was at 6.5 percent, the economy was buoyant, investor confidence was high and international donor support was generous.[38] Kenya also possesses one of the largest scientific communities in the region. With the rapid expansion of its university system in the 1970s, its scientific output continued to increase.[47] However, by the 1980s Kenya started to experience an economic downturn. By the 1990s there was a steady decline of development assistance owing to donor perceptions of poor governance and mismanagement of both public resources and development aid.[38] Tribal politics and widespread government corruption persist in spite of steadfast efforts to stimulate reform by the donor community. Despite its socioeconomic situation before the change of national leadership in 2002, Kenya is one of seven African countries with more than 10 Internet service providers and a high-speed national Internet backbone is under development.

Ghana was the first sub-Saharan African country to gain independence, but also the first to experience violent military coups and witness promising developmental prospects deteriorate through economic depression.[38,48] Yet, the authoritarian rule of its military leader made it possible to impose the stringent financial measures required to receive continuous structural adjustments loans since the early 1980s. As a result, Ghana remains one of the leading countries in the region in terms of economic progress.[49] Academic and state research facilities in Ghana were inherited from colonial period, but economic and political difficulties throughout the 1980s led to scientific out-migration and a significant decline in output. In terms of most indicators of development Ghana trails Kenya. In spite of this, Internet connectivity is relatively equal, owing to Ghana's liberalized telecommunications sector and VSAT connection to the international backbone. Ghana was one of only a few sub-Saharan African states to have Internet access, as well as three commercially operational Internet Service Providers by 1996. Since 2000, Ghana has experienced high growth in ISP services[50] and in the Internet Café' industry. Although recent findings allude to a standstill in the diffusion of the Internet in the last three years, Ghana has actively sought ways to fund telecommunications deployment that would connect peripheral areas.[51]

Data and method

Face-to-face surveys of scientists in Kerala (n = 303); Kenya (n = 315); and Ghana (n = 300) were conducted in 2000, 2001, and 2002, respectively. Respondents represented a variety of research fields (i.e., agriculture, biological science, engineering, mathematics, information technology, chemistry, physics, geology, and social science) in two organizational types: government research institutes (also referred to as the 'state' or 'governmental' sector) and university faculties (also called the 'academic' or 'educational' sector). Since research institutions are generally concentrated in urban centers, we selected the capital cities as a base for our data collection (Nairobi, Kenya; Accra, Ghana; Trivandrum, Kerala). As a result, our sample is not representative of the complete range of research institutions in each of these countries, since respondents are in or near the urban centers. We argue that our sample is broadly representative of the population of scientists in the system of government research institutes and university organizations in these countries. However, the research community in the urban centers of these countries may be better connected than more remote institutions.

Surveys were directed by national collaborators in each of the three research locations and administered, face-to-face, by current or recent postgraduate students. Each research institution contacted was located within the city or not more than two hours by vehicle. The final sample consists of 918 scientists, about half from universities and half from government research institutes.* The questionnaire consisted of nearly 200 questions on social and demographic background factors, professional activities, organizational structure, access to technology and Internet use. Data entry and preliminary data validation were carried out in Kenya and Kerala. Project research assistants based at Louisiana State University carried out the second and final data validations.

We consider six dimensions relating to Internet adoption and several control variables indicating the social, educational and professional characteristics of respondents. Internet adoption measures include dichotomous measures of ready access to email (1=access; 0=no access) and current email use (1=current user; 0=nonuser), two indicators of Internet experience (years of email and years of Web use) and two indices of Internet practice (email use diversity and Web use diversity). Email diversity is constructed as the sum of dichotomous (1=yes; 0=no) responses to six questions regarding scientists' uses of email (e.g. has been a member of science and technology (S&T) discussion group, has sent a message to an S&T discussion group, discussed research with someone in a developed country, started a professional relationship with someone met on the Internet, discussed research proposal with funding agencies, submitted or reviewed manuscripts for journals). Web diversity is constructed as the sum of thirteen dichotomous (1=yes; 0=no) items regarding scientists' use of the World Wide Web (e.g. order a product or service for research, created a Web page, conducted an information search, used an electronic journal, acquired or used data, collaborated on a scientific project, found and examined reference materials, accessed research reports or scientific papers, participated in chat groups, used job listings, used maps, downloaded software, published a paper).

Control variables for our analyses are derived from previous research on diffusion of innovations[52] and on scientific productivity. For example, studies by Duque et al.[32] and Garg and Padhi[53] have shown the effect of contextual factors on productivity. Many authors.[35,36,54] have found gender differences in scientific publication while others[55] found no significant difference between productivity distributions of male and female scientists. Previous research on the effect of age structure on productivity has shown that age has a depressing effect on productivity.[34] Control variables in this analysis include sector (1=research; 0=academic), gender (1=male; 0=female), age, marital

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* For purposes of sampling, and because staff size is often similar, we consider a university department as an organization in the same sense as a research institute, most of which are under a common administrative body. It is not possible to calculate a response rate in the conventional sense. Although a percentage figure could be generated, we are reluctant because we cannot interpret it ourselves. We did not experience any refusals in the usual sense, but owing to the conditions of conducting personal interviews in these areas, we defined the population of eligible respondents as those individuals who were physically present during the data collection interval at their institutions. Individuals who are on study leave, seconded to other areas, and so forth were not considered eligible members of the population.

status (1=married; 0=not married), educational credential (1=doctorate; 0=non-doctorate), possession of a degree from a developed country (1=yes;0=no) and professional involvement (1=member of a professional organization yes; 0=no). Because we are interested in Internet adoption variables, we also include immediate access to a computer (1= computer in personal office; 0=no). Immediate PC access translates into architectural privacy, which is hypothesized to be an important facilitating condition for Web use.[56] Conceptually, architectural privacy refers to the physical and visual surroundings that lead to the privacy a person experiences.

Previous studies[32,53] and our own exploratory data analyses reveal statistically significant interaction effects between location and sector. Hence, in presenting descriptive statistics for PC, email and Web access and use, we define context as the intersection of location (i.e., Kerala, Kenya and Ghana) and organizational type (government research institute and academic). Although we generate all possible significant differences for the six contexts using LSD tests at the 10% level of significance, we present our results in such a manner that comparisons are made only between sectors within a location.* Furthermore, because of the presence of a location/sector interaction, we perform multivariate regression analyses for each location with sector as control variable within locations.

In contrast with studies of scientific publication productivity that use bibliometric techniques, we use self-reported publication productivity. The adequacy of bibliometric measures as indicators of scientific productivity outside the developed world is of some concern because international databases include few developing world journals.[37] Furthermore, publication outlets in the developed world may structurally exclude some of the substantive questions explored and methodologies used by developing world science.[3,57–59] As such these measures may not be robust indicators of the indigenous breadth of scientific inquiry in the developing sphere.[60] Our dependent dimensions are the number of articles published in national and in foreign journals. Interviewers asked each respondent scientists how many articles they have published in foreign and in national journals during the last five years. Because the distribution of publications is positively skewed, we employ natural logarithms of self-reported productivity in our analyses.**

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* Fisher's least significant difference (LSD) test is a sequential mean comparison technique wherein an F-test is performed first. If resulting F-test is significant then pair wise comparisons based on a t-distribution are carried out.

** Because productivity is positively skewed, we obtained the natural logarithm of number of publications. This yields a valid test of hypotheses based on a normal error regression model.

Results

In this section, we first present a profile of scientists' access and use of personal computers, email and the Web. We then describe differentials in email use, ready access, email and Web use diversity and Internet experience by a variety of social and professional characteristics. Finally, we present the results of multiple regression analyses that examine the link between scientific productivity in local and foreign journals with dimensions of Internet adoption.

Personal computer access and use

Personal computer technology predates Internet technology and is a *precondition* for it. A profile of personal computer access and use for this sample of African and Indian scientists is presented in Table 1. Three quarters of these scientists have access to computers at work, while fewer than half (45%) have a home PC (Rows 1 and 6). Workplace computers were generally acquired in 1996, about two years prior to home computers. Whether at the workplace or at home, our respondents use these computers about five hours each week. While these figures are somewhat low by international standards, the most pertinent finding for questions of access may be in rows 3 and 4. Only 42% possess a computer in their personal office, and over seven people, on average, use each computer at work.

The six main columns of Table 1 show differences between research sectors (academic and government research institutes) within each of the three study locations (Kerala, Kenya and Ghana). In the workplace, Kerala leads in the distribution of PCs, ahead of Kenya and Ghana (Rows 001-002). Not only do more scientists in Kerala have access to a computer, but also those who did report that it was first available in 1995, compared with 1996 for Kenya and 1997 for Ghana. Still, such access differences are not straightforward: Malayali scientists are *least* likely and Ghanaian scientists *most* likely to have personal computers in their offices (Row 003). That difference is reflected in computer sharing, which is extremely high among scientists in Kerala and Kenya, especially among academics. Although fewer Ghanaian researchers have access to personal computers, those who have access are less likely to share (Row 004). For each location except Ghana, government scientists are more likely to have access to computers than academics. However, this difference is somewhat mitigated by the pattern of home use: in all locations, university scientists are more likely to own computers at home (Row 006). By location, home computer sharing is highest among Kenyans, followed by Malayalis, and then by Ghanaians. By sector within each location, we observe no significant differences between scientists in universities and state institutes with respect to their home computer-sharing behavior.

Table 1. Personal computer access and use profile of respondent scientists by location-sector combination

	Kerala[1]		Kenya		Ghana		Full	
	Academic	Research	Academic	Research	Academic	Research	Sample	N
At Work								
001 Does R have a PC at work? (1-yes,0-no)	78% a	94% b	76% a	80% a	69% a	59% b	76%	916
002 If yes, in what year was this PC first available?								
002a Average year reported	1996 a	1994 b	1997 a	1995 b	1998 a	1997 b	1996	676
002b Median year reported	1996	1995	1998	1995	1998	1998	1997	676
002c Earliest year reported	1978	1982	1978	1985	1990	1984	1978	676
002d Latest year reported	2000	2000	2001	2001	2002	2002	2002	676
002e Difference between latest and earliest years	22	18	23	16	12	14	24	676
003 If yes, where is this PC located? (1-personal office, 0-not in personal office)	14% a	36% b	39% a	50% b	74% a	55% b	42%	689
004 If yes, how many people use it including R?	12.68 a	5.66 b	10.36 a	6.13 b	3.30 a	3.51 a	7.43	671
005 If yes, is this computer connected to the Internet? (1-yes,0-no)	24% a	65% b	43% a	29% b	43% a	26% b	40%	696
At Home								
006 Does R have a PC at home? (1-yes, 0-no)	55% a	47% a	47% a	32% b	43% a	40% a	45%	902
007 If yes, in what year did R acquire a home PC?								
007a Average year reported	1998 a	1997 a	1997 a	1997 a	1997 a	1999 b	1998	403
007b Median year reported	1998	1998	1997	1997	1998	1999	1998	403
007c Earliest year reported	1993	1984	1987	1987	1984	1982	1982	403
007d Latest year reported	2000	2000	2001	2001	2002	2002	2002	403
007e Difference between latest and earliest years	7	16	14	14	18	20	20	403
008 If yes, how many people use it including R?	3.16 a	2.94 a	3.15 a	3.41 a	2.84 a	2.92 a	3.06	398
009 If yes, is R's PC connected to the Internet? (1-yes,0-no)	74% a	75% a	31% a	26% a	18% a	15% a	43%	404
PC Use								
010 In a typical week, about how many hours does R use a PC for job (whether at home or at work)?[2]	1.96 a	2.91 b	2.74 a	3.29 b	2.84 a	2.96 a	2.76	900
011 How often does R use a PC for fun or play? (1-frequently,4-never)	3.50 a	3.30 b	3.37 a	3.31 a	3.47 a	3.20 b	3.36	903
012 How comfortable does R feel uisng PCs in general? (1-very comfortable, 4 not comfortable)	1.40 a	1.19 b	1.48 a	1.47 a	1.36 a	1.39 a	1.38	890

[1] For each location, pairs of sector means (percentages) followed by different letters (e.g. a, b, c) are significantly different at the 10% level.

[2] 0=not at all, 1=less than one hour, 2=between one and five hours, 3=between five and ten hours, 4=between ten and twenty hours, 5=over twenty ho

Table 1 also shows systematic differences among locations and between sectors in computer use, as distinct from access. Put differently, regardless of whether there is a computer at home or work, who else has access, or how many people use it, the question remains: *how frequently do individual scientists use the computer as a research tool?* Row 010 shows that, regardless of location, government scientists spend more hours each week using computers and there are no large differences among locations. In the case of university scientists, on the other hand, African scientists report significantly more time using computers than Indian scientists.

The primary focus of our analysis is not the use of computers as stand-alone tools, but rather their potential to facilitate global science. Our next question concerns the extent to which scientists make use of email and Web browsing. Rows 005 and 009 of Table 1 reveal that approximately two fifths of both work (40%) and home (43%) computers are connected to the Internet. We observe very different patterns between sector for our Indian and African locations at work. Scientists in Kerala are more likely to be connected in research institutes than in universities, while academics are more likely to have connectivity in both Ghana and Kenya [Row 005]. However, what seems clear is that Malayali professionals in both sectors have domestic access to the Internet: three quarters of those with home computers are connected.

Email access and use

Whether a computer is "connected to the Internet" is subject to a variety of technological and social meanings that can be best disentangled by asking directly about email and Web use. A profile of email access and use is presented in Table 2. Ninety-four percent of scientists identify themselves as current email users (Row 002) who, on average, began using the technology in 1997 (Row 004). In a typical week, scientists in our sample spend about 1.5-2.0 hours emailing (Row 011) and send about 3-4 emails (Row 008).* More than half (or 58%) report inability to access email for at least a week during the past year (Row 005), generally for technical rather than financial reasons. By location, African scientists are more likely to have email access problems.

Rows 12-18 show the variety of things respondents do using email. Less than one third of scientists use email for membership in S&T discussion groups (27%), to start a professional relationship with someone met on the Internet (28%), or submit manuscripts (30%). Fewer than half use email to send messages to S&T discussion groups (43%) and to discuss proposals with funding agencies (48%).

* About three quarters of these are research-related. To estimate number of hours, we take the midpoint of each category. For the last category, which is open ended (over twenty hours per week), we simply assumed the upper limit to be about 40 hours per week.

Table 2. Email access and use profile of respondent scientists across location-sector combination

	Kerala[1]				Kenya				Ghana				Full	
	Academic		Research		Academic		Research		Academic		Research		Sample	N
R's Email Access														
001 R has ready access to email (1-yes, 0-no)	80%	a	93%	b	57%	a	43%	b	66%	a	64%	a	67%	908
002 R is currently using email (1-yes, 0-no)	90%	a	98%	b	97%	a	90%	b	99%	a	91%	b	94%	840
003 Last time R sent an email	2.02	a	1.62	b	1.80	a	2.27	b	1.72	a	1.97	b	1.88	833
004 Year R first used email														
004a Average year reported	1998		1997		1997		1996		1997		1998		1997	827
004b Median year reported	1998		1997		1997		1997		1997		1998		1998	827
004c Earliest year reported	1986		1989		1985		1987		1981		1989		1981	827
004d Latest year reported	2000		2000		2001		2001		2001		2002		2002	827
004e Difference between latest and earliest years	14		11		16		14		20		13		21	827
005 R has been unable to access email for at least one week (1-yes, 0-no)	26%	a	43%	b	69%	a	63%	a	80%	a	59%	b	58%	793
006 Primary reason for not being able to access email														
006a Technical Reasons	76%		90%		77%		68%		86%		58%		76%	463
006b Financial Reasons	0%		0%		15%		24%		4%		12%		10%	463
006c Other Reasons	24%		10%		7%		8%		10%		30%		14%	463
R's Email Use														
007 If R wanted to send an email, which would R most likely do?														
007a Use Internet at home	42%		25%		14%		2%		11%		11%		17%	805
007b Use Internet at work	45%		68%		37%		65%		59%		58%		55%	805
007c Use public terminal (library or café)	11%		4%		35%		17%		24%		24%		20%	805
007d Use someone elses at home or at work	0%		2%		6%		5%		4%		1%		3%	805
007e Ask someone to send (secretary, assistant, or friend)	3%		2%		8%		12%		2%		6%		5%	805
008 How many email messages does R send in a typical week?[3]	1.63	a	2.12	b	2.05	a	1.90	a	2.07	a	2.02	a	1.98	818
009 How many of these are related to R's research?[3]	1.49	a	2.09	b	1.80	a	1.81	a	1.90	a	1.81	a	1.82	813
010 How many email messages does R receive in a typical week?[3]	1.65	a	2.17	b	1.99	a	2.08	a	2.36	a	2.31	a	2.10	822
011 Hours in a typical week R spends sending and receiving email?[4]	1.35	a	1.60	b	1.44	a	1.41	a	1.96	a	1.79	b	1.59	817
Things R's does using email (1-yes, 0-no)														
012 R has been a member of an S&T discussion group	28%	a	33%	a	26%	a	16%	b	29%	a	26%	a	27%	828
013 R has sent a message to an S&T discussion group	39%	a	52%	b	45%	a	37%	a	44%	a	38%	a	43%	831
014 R discussed research with someone in developed countries	46%	a	68%	b	73%	a	65%	a	58%	a	47%	b	60%	829
015 R started a professional relationship with someone met in the Internet	31%	a	38%	a	24%	a	10%	b	36%	a	27%	b	28%	828
016 R continued email contact with someone met personally	63%	a	79%	b	88%	a	71%	b	81%	a	72%	b	77%	829
017 R discussed proposals with funding agencies	44%	a	56%	b	59%	a	57%	a	44%	a	28%	b	48%	834
018 R submitted or reviewed manuscripts for journals	15%	a	35%	b	45%	a	26%	b	33%	a	21%	b	30%	831
019 Email Use Diversity Index (0-no diversity, 6-max diversity)	2.03	a	2.82	b	2.67	a	2.13	b	2.38	a	1.86	b	2.34	837

[1] Numbers followed by lower case letters (e.g. a, b, c) indicate results of statistical mean comparisons based on a Fisher's least significant difference test. For each location, pairs of sector means (or percentages) followed by different letters are significantly different at the 10% level.

[2] To assign an interval level data, we use the midpoint of each of the categories.

[3] 1-less than 1 per week, 2-between 1 and 6 in a week, 3-usually 1 or 2 daily, 4-more than 1 daily

[4] 0-not at all, 1- less than an hour, 2-between 1 and 5 hours, 3-between 5 and 10 hours, 4-between 10 and 20 hours, 5-over 20 hours

More than half use email to discuss research with someone in developed countries (60%) and to continue email contact with someone met personally (77%). Put another way, the only functions of Internet communication reported by more than half of our email users are continuing contact with someone met personally and discussing research with someone in developed areas.

Web access and use

As indicated above, use of the World Wide Web and use of email have different functions and may have different usage patterns. The former is often associated with information search while the latter is more directly linked to interpersonal or inter-group communication. Table 3 (Rows 001-003) provides support for this assumption, by comparison with Table 2 (Rows 001, 003, 004). A significantly smaller fraction of scientists have ever used the Web (71%) than email (91%). Scientists began using email earlier (1997) than the Web (1998). Most had sent their most recent email within the past week, while most had accessed the Web sometime between the past week and the past month (Row 002). Finally, the typical scientist spends less time each week sending and receiving emails than browsing the Web (Table 2, Row 011 and Table 3, Row 004).

Our respondents report a variety of activities on the Web, centering on information search and retrieval (Rows 011 – 023). By frequency, information search, retrieving data, finding references and downloading reports are the most common activities. Producing Web pages, publishing and chatting are extremely uncommon activities, indicating that both African and Indian scientists use the Web for *acquisition* but not typically *transmission* of information. Slightly over one third of those who use the Internet have collaborated on a scientific project. However, if we replace the denominator of this fraction with the sample size – that is, if we consider not simply those who use the Web, but *all* respondents – the "best guess" of collaborative activity would be closer to 20%.

As with computer access and email use, there are differences in Web use by location and sector. As indicated Rows 004 - 009, Ghanaians spend the most time accessing the Web, followed by Malayalis and then by Kenyans. University scientists are more likely to use the Web than those in government, a difference that is more pronounced in Kenya than Ghana. In contrast, Indian academics are *less* likely to have used a Web browser than their counterparts in research institutes.

Our qualitative observations and interviews with professionals conducted in the late 1990s made it clear that a variety of problems were encountered among first and later adopters of ICTs. We included a range of items designed to address the most common issues and constraints experienced by scientists. Indian professionals have fewer concerns and they are fundamentally technical in nature. For our sample of Malayali scientists, concerns center on connection time and wait times for page loading. African professionals experience more problems of all types, both technical and financial. Not only do they have the same technical problems as scientists in India, but they are also fundamentally worried about resources required by use of the Internet.

Table 3. Web access and use profile of respondent scientists across location-sector combination

	Kerala[1]		Kenya		Ghana		Full	
	Academic	Research	Academic	Research	Academic	Research	Sample	N
001 R has ever used a browser (1-yes;0-no)	57% a	75% b	78% a	57% b	85% a	71% b	71%	909
002 Last time R browsed the web								
002a today or yesterday	22%	51%	24%	12%	36%	35%	31%	643
002b within the past week	36%	36%	31%	23%	42%	33%	34%	643
002c within the past month	23%	11%	28%	21%	14%	16%	19%	643
002d within the past six months	13%	0%	9%	23%	5%	8%	9%	643
002e longer than six months	6%	3%	9%	21%	3%	9%	8%	643
003 In what year did R first use the web?								
003a Average year reported	1998	1998	1998	1998	1997	1998	1998	636
003b Median year reported	1999	1999	1998	1998	1998	1999	1998	636
003c Earliest year reported	1989	1983	1990	1991	1981	1989	1981	636
003d Latest year reported	2000	2000	2001	2001	2002	2002	2002	636
003e Difference between latest and earliest years	11	17	11	10	21	13	21	636
004 Hours in a typical week R spends using the web[2]	1.4 a	1.8 b	1.5 a	1.0 b	2.0 a	2.0 a	1.7	629
Frequency R accesses the web from (1-daily, 2-weekly, 3-monthly, 4-less than once a month, 5-never)								
005 from home?	3.5 a	3.9 b	4.4 a	4.8 b	4.7 a	4.4 a	4.3	595
006 from work?	3.3 a	2.2 b	3.7 a	3.6 a	2.5 a	2.8 a	3.0	616
007 from public terminal?	4.7 a	4.8 a	4.4 a	4.5 a	4.5 a	4.6 a	4.6	616
008 from cyber cafe?	5.0 a	4.8 a	3.8 a	3.9 a	3.8 a	3.2 b	4.1	607
009 from a friend?	4.8 a	4.9 a	4.7 a	4.4 b	4.7 a	4.7 a	4.7	591
010 How comfortable does R feel using the Internet (1-comfortable, 2-somewhat comfortable, 3-slightly comfortable, 4-not comfortable)	1.4 a	1.4 a	1.7 a	1.8 a	1.2 a	1.3 a	1.5	596
Actvities R has done on-line (1-yes, 0-no)								
011 Ordered a product/service for research	31% a	50% b	37% a	47% a	37% a	35% a	39%	643
012 Created a web page	21% a	27% a	16% a	2% b	8% a	24% b	17%	640
013 Conducted an information search	91% a	95% a	95% a	91% a	88% a	85% a	91%	646
014 Used an electronic journal	47% a	60% b	73% a	67% a	57% a	50% a	59%	645
015 Acquired/used data	86% a	92% a	81% a	80% a	75% a	64% b	79%	641
016 Collaborated on a scientific project	31% a	39% a	41% a	38% a	43% a	26% b	37%	639
017 Found and examined reference materials	92% a	89% a	80% a	86% a	65% a	74% b	80%	642
018 Accessed research reports/scientific	77% a	85% a	85% a	86% a	63% a	66% a	77%	642
019 Participated in chat groups	16% a	21% a	20% a	6% a	16% a	24% a	18%	638
020 Used job listings	11% a	8% a	41% a	27% b	18% a	26% a	23%	641
021 Used maps	16% a	25% a	30% a	26% a	15% a	21% a	22%	639
022 Downloaded softwares	23% a	42% b	60% a	55% a	70% a	55% b	52%	645
023 Published a paper	9% a	14% a	24% a	3% b	16% a	13% b	15%	642

[1] Numbers followed by lower case letters (e.g. a, b, c) indicate results of statistical mean comparisons based on a Fisher's least significant difference test. For each location, pairs of sector means (or percentages) followed by different letters are significantly different at the 10% level.

[2] 0-not at all, 1- less than an hour, 2-between 1 and 5 hours, 3-between 5 and 10 hours, 4-between 10 and 20 hours, 5-over 20 hours

Indeed, the issues listed as significant problems for Africans (too much time to connect, waiting time for a page to appear, costs, loss of connection, and sites that require payment) can be interpreted as involving a cost component in each case.

Correlates of ICT access and Use

To this point in the analysis, we have only considered contextual differences in ICT access and use. Table 4 shows different dimensions of the digital divide based on social, educational, and professional characteristics. Specifically, we report disparities in ICT behaviors based on gender, age, marital status, education, degree from a developed country, membership in professional organizations and computer access, as well as location and sector. We present percentages for current email use and ready access, as well as averages for email and Web diversity and experience. The first column in Table 4 shows extremely small differences in the extent to which scientists define themselves as current email users across most social and professional dimensions. Indeed, there are virtually no differences among social categories *except* by gender and age and even these are not large. The reason is the sheer pervasiveness of email use: over 90% of *every* category of respondent defines themselves as current email users.

However, as shown in the second column of Table 4, there are still wide gaps in ready access to email by locations (Rows 001-003) and level of education (Rows 013-014). In effect, those who define themselves as current email users have, in varying degrees, problematic access to email facilities. Not only are there fewer who report ready access, but there are also large and significant differences between categories by location, age, education, location of degree and professional involvement. For example, 86% of Malayalis report ready email access, compared to only 65% of Ghanaians (Column 2, Row 003), and 51% of Kenyans (Column 2, Row 002). In terms of education, 75% of those with doctorates report ready access compared to only 58% of those without. The location of the doctorate matters as well, but in an unexpected direction: those with a Ph.D. from developed countries are less likely to have ready access (Column 2, Row 016). The much larger number of Malayali scientists, who have ready access to email compared to the Africans in the sample (Column 2, Rows 001-003), with doctorates obtained almost exclusively in India rather than in developed countries, explains this unexpected result.

The third column of Table 4 shows a relatively low level of diversity in email use, an average of two practices out of six. Despite these low levels significant disparities in email use diversity exist and tend to favor scientists in relatively advanced locations (i.e., Kerala and Kenya, men, those with better education (e.g. doctorates, scientists trained in advanced countries, who are professionally involved, and who have PCs in their personal offices. As evident from the fourth column of Table 4, similar patterns of disparity are observed for diversity in the use of the World Wide Web. Disparities in Internet experience are shown in columns five (email) and six (Web).

Table 4. Current email use, ready access, and diversity of use by social characteristics

Table 4. Current Email Use, Ready Access, and Diversity of Use by Social Characteristics.

	Current Email User 001		Ready Email Access 002		Email Use Diversity[2] 003		Web Use Diversity[3] 004		Years Using Email 005		Years Using Web 006	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Location[1]												
001 Kerala	94% [a]	253	86% [a]	303	2.45 [a]	253	6.03 [a]	199	2.7 [a]	251	1.9 [a]	199
002 Kenya	94% [a]	299	51% [b]	310	2.47 [a]	297	6.47 [b]	217	4.2 [b]	296	3.1 [b]	213
003 Ghana	95% [a]	288	65% [c]	295	2.10 [b]	287	5.62 [a]	233	4.7 [c]	280	4.4 [c]	224
Sector												
004 Universities	95% [a]	444	67% [a]	487	2.41 [a]	440	6.03 [a]	361	3.9 [a]	439	3.4 [a]	353
005 Government Research Institute	93% [a]	396	68% [a]	421	2.26 [a]	397	6.03 [a]	288	3.9 [a]	388	3.0 [b]	283
Sex												
006 Female	90% [a]	177	65% [a]	215	2.11 [a]	177	5.50 [a]	143	3.2 [a]	176	2.6 [a]	139
007 Male	95% [b]	656	68% [a]	686	2.40 [b]	653	6.18 [b]	501	4.1 [b]	644	3.4 [b]	492
Age												
008 20 years to less than 35 years	97% [a]	99 [a]	68%	107	2.25 [a]	99	5.99 [a]	90	3.796 [a]	98	2.822 [a]	90
009 35 years to less than 50 years	94% [a]	520 [a]	66%	563	2.45 [ab]	517	6.18 [ab]	413	3.977 [a]	517	3.246 [a]	410
010 50 years and above	94% [a]	215 [a]	70%	232	2.09 [ac]	215	5.54 [ac]	140	3.728 [a]	206	3.183 [a]	130
Marital Status												
011 Not-Married	96% [a]	93	60% [a]	95	2.25 [a]	91	6.18 [a]	78	4.1 [a]	92	3.6 [a]	75
012 Married	94% [a]	747	68% [a]	813	2.35 [a]	746	6.01 [a]	571	3.9 [a]	735	3.1 [a]	561
Education												
013 Non-PhD	94% [a]	394	58% [a]	427	2.05 [a]	391	5.71 [a]	294	3.6 [a]	387	2.9 [a]	289
014 PhD	95% [a]	443	75% [b]	478	2.61 [b]	443	6.30 [b]	353	4.2 [b]	437	3.5 [b]	345
Degree from a developed country[4]												
015 No	95% [a]	453	73% [a]	514	2.22 [a]	450	5.70 [a]	352	3.0 [a]	445	2.3 [a]	346
016 Yes	94% [a]	341	59% [b]	349	2.54 [b]	343	6.44 [b]	258	5.1 [b]	336	4.4 [b]	253
Member of Prof. Organization												
017 No	92% [a]	132	53% [a]	153	1.56 [a]	131	4.81 [a]	100	3.1 [a]	130	2.5 [a]	96
018 Yes	95% [a]	705	70% [b]	754	2.49 [b]	704	6.26 [b]	548	4.1 [b]	694	3.3 [b]	539
PC located in Personal Office												
019 No	94% [a]	361	76% [a]	396	2.22 [a]	360	5.99 [a]	276	3.3 [a]	357	2.5 [a]	274
020 Yes	97% [a]	286	72% [a]	285	2.85 [b]	284	6.50 [b]	245	4.9 [b]	281	3.9 [b]	238

[1]Columnwise in each category, means followed by different letters (e.g. a, b, c) are signficantly different at the 10% level.

[2]Email use diversity index ranges from 0 (no diversity) to 6 (high diversity).

[3]Web use diversity index ranges from 0 (no diversity) to 13 (high diversity).

[4]When respondents were asked about academic degrees obtained from developed countries, we were not particular as to whether it was for their doctorate degree or not. A respondent who, for example, obtained his/her masters degree in a developed country and obtained a doctorate degree locally was classified as having an academic degree in a developed country.

While there might seem to be a negative association level of development and experience, the likely explanation is that our survey was conducted in Ghana in 2002 while the Kerala survey was conducted in 2000. That aside, disparities in both email and Web use experience tend to follow the same lines as Internet practice. Those with greater experience tend to be men with doctorates or degrees from developed countries (Column 5, Rows 007, 014 and 016), who are involved in professional organizations (Row 018) and have PCs located in their personal offices (Row 020).

It is clear from these results that there are large differences in Internet adoption depending on the dimension under consideration. Over 90% are self-defined users, but closer to half actually has easy access to Internet facilities. Statistics relating to Internet practice are generally low across categories of location, sector, social, and education categories, ranging from 1.99 to 2.85 for email use diversity, and from 4.81 to 6.47 for Web use diversity. Scientists with degrees from developed countries are the earliest adopters of Internet. Disparities in experience tend to favor males, academicians, doctorates, members of professional organizations and those with PCs in their personal offices. Indeed, the distributions for current use, ready access, Internet practice and experience are varied and indicative of different phases of Internet adoption.

Given these general results, we observe that the distribution and variation in Internet practice and experience, together with measures of ready access and current use, provide more reliable indicators of digital inequality in the developing world. In these three developing areas, we observe high rates of ICT adoption in terms of current use, moderate rates for ready access, low diversity in communication practices and limited experience with ICTs. These pieces of information taken together give a more accurate description of ICT adoption.

ICT and scientific productivity

The four aspects of Internet adoption have not been linked to outcomes. Publication productivity exhibits a great deal of variability. The total number of articles published during the past five years is about 4.5 for both academic and government researchers. However, the average ranges from 7.0 articles in Kerala, to 3.6 in Ghana and 2.5 Kenya. In this section, we examine whether Internet adoption influences the rate of local and foreign publication productivity. We perform two sets of regression analyses: first for the full sample (Table 5), followed by analyses for each location separately (Tables 6a and 6b). For these analyses, the log of articles published in local and foreign journal are dependent dimensions. We use the Internet adoption indicators (self-defined use, ready access, diversity of use, and experience) as independent dimensions and control for the dimensions analyzed in the previous section (sector, gender, age, marital status, having a doctorate degree, having a degree from a developed country, PC in personal office and membership in professional organizations).

Table 5. Standardized regression results for log number of publications in the last 5 years

	Local Publication			Foreign Publication	
Contextual Factors					
001 Kerala (1-yes;0-no)[1]	0.175	**		-0.379	***
002 Kenya (1-yes;0-no)[1]	-0.248	***		-0.054	
003 In research sector (1-yes;0-no)	-0.036			-0.066	
004 Kerala X research sector	-0.074			0.267	**
005 Kenya X research sector	0.016			-0.076	
Personal Factors					
006 Gender (1-male;0-no)	-0.037			0.011	
007 Age (years)	-0.083			0.253	
008 Age squared (years squared)	0.205			-0.201	
009 Married (1-yes; 0-no)	0.109	**		0.055	
Educational Factors					
010 Doctorate (1-yes;0-no)	0.117	**		0.240	***
011 Degree from a developed country (1-yes;0-no)	0.062			0.000	
Professional Factors					
012 Has PC in personal office (1-yes;0-no)	-0.026			-0.033	
013 Member of professional organization (1-yes;0-no)	0.087	**		0.075	*
Aspects of Internet Adoption					
014 Has ready email access (1-yes; 0-no)	-0.019			-0.004	
015 Current email user (1-yes; 0-no)	0.014			0.021	
016 Email use diversity (6-high diveristy;0-no diversity)	0.067			0.193	***
017 Number of years using email	-0.054			0.081	*
R-squared	0.256			0.229	
N	511			499	

*, **,*** significant at the 0.10, 0.05, and 0.01 level, respectively

[1] Ghana is reference category.

[2] When we asked respondents about academic degrees obtained from developed countries, we were not particular as to whether it was for their doctorate degree or not. A respondent who, for example, obtained his/her masters degree in a developed country and obtained a doctorate degree locally was classified as having an academic degree in a developed country.

Table 5 (Column 1, Rows 001 and 002) shows the effect of contextual differences on publication in local journals. Compared to Ghanaians, Kenyan scientists generally tend to be less productive (b =–0.248), while Malayalis, on average, tend to be more productive (b = 0.175). This rank order in local publication productivity, especially in the case of Kenya and Ghana, is a reversal of expectations based on the level of scientific development in these locations. Sectoral differences between academic and state organizations do not seem to affect local productivity in general. In addition to the influence of location, show that being married (b = 0.109), having a doctorate (b = 0.117) and membership in professional organizations (b = 0.087) enhance local productivity.

The first column of Table 5 provides no indication that Internet adoption influences local productivity. However, we find significant evidence linking increased foreign productivity with Internet adoption, primarily through the dimension of Internet practice. That is, the greater the diversity of email use (b = 0.193), the greater the number of publications in international journals (Column 2, Row 016). Other aspects of ICT diffusion such as ready access, current use, and email experience appear to have no links with number of publications abroad. Table 5 does not reveal any difference between Kenyan and Ghanaian scientists in terms of foreign productivity, though Malayalis are less productive than their African counterparts (Column 2, Row 001). As indicated by the interaction term, there is another "productivity divide" among Malayalis themselves: academics are significantly less productive than their counterparts in government research institutes (Column 2, Row 004). Just as we found for local productivity, having a doctorate (b = 0.240) and involvement in professional organizations (b = 0.075) enhance publication in foreign journals (Column 2, Rows 010 and 013).

From the regression results in Table 5, we are able to show the presence of interaction between location and sector in the case of foreign productivity but not for local productivity. What this means for local productivity is that there is no consistent difference in output between sectors for all three locations. That is, the productivity ranking between sectors is stable across locations. However, in the case of foreign productivity there are differences in the rank order of sectors from one location to another. Thus, in the analysis that follows, we examine local and foreign productivity for each location separately.

The regression results in Table 6a show that the effect of ICT adoption on local productivity varies among developing world scientists depending on location. Among Malayali scientists, local productivity is associated with current use (b = 0.147) and email experience (b = -0.174) but there is no evidence that ready access and diversity of use determine productivity (Column 1, Rows 011 and 013). Malayali women (b = –0.163) and Ph.D. holders (b = 0.123) have greater local productivity (Column 1, Rows 002 and 006). Among Kenyans, neither current use or ready access or experience is associated with local productivity. Diversity of email use (b = 0.261), however, has the strongest impact of any factor regardless of the sectoral affiliation of scientists (Column 2, Row 012). Unlike the Malayali case, we observe that being male (b = 0.127) and involvement in professional organizations (b = 0.127) enhance local productivity among Kenyan scientists (Column 2, Rows 002 and 009). Finally, for Ghanaian scientists, we find no significant ICT effects on local productivity, though there are positive effects for marriage (b = 0.272) and having a degree from a developed country (b = 0.229) (Column 3, Rows 005 and 007).

Table 6a. Standardized regression for log number of publications in local journals during the last 5 years

	Kerala		Kenya		Ghana	
Contextual Factors						
001 In research sector (1-yes;0-no)	-0.044		-0.012		-0.036	
Personal Factors						
002 Gender (1-male;0-no)	-0.163	**	0.127	*	-0.056	
003 Age (years)	-0.122		-0.072		1.297	
004 Age squared (years squared)	0.298		0.140		-1.225	
005 Married (1-yes; 0-no)	0.081		0.097		0.272	***
Educational Factors						
006 Doctorate (1-yes;0-no)	0.123	*	0.094		0.119	
007 Degree from a developed country (1-yes;0-no)	0.038		0.013		0.229	**
Professional Factors						
008 Has PC in personal office (1-yes;0-no)	0.006		-0.028		0.003	
009 Member of professional organization (1-yes;0-no)	0.092		0.127	*	0.065	
Aspects of Internet Adoption						
010 Has ready email access (1-yes; 0-no)	0.086		-0.048		0.003	
011 Current email user (1-yes; 0-no)	0.147	**	-0.111		-0.091	
012 Email use diversity (6-high diveristy;0-no diversity)	0.021		0.261	***	-0.113	
013 Number of years using email	-0.174	**	-0.087		0.124	
R-squared	0.159		0.174		0.286	
N	224		188		99	

*, **,*** significant at the 0.10, 0.05, and 0.01 level, respectively

From these results, we observe that factors affecting local scientific productivity are largely configured by variations in location. In the three locations we studied, different combinations of personal, educations, professional, and ICT dimensions affect productivity. Although gender is associated with local productivity, the effect is mediated by location. Among Kenyan scientists, men have higher local productivity, while the effect is *reversed* for Malayalis. These results indicate that in terms of local ICT impacts, the developing world is far from homogeneous.

Our final models in Table 6b show that factors associated with output in foreign journals also differ by location. However, the effect of the doctoral degree is an important positive determinant of foreign publication regardless of location (b = 0.206 for Kerala, b = 0.278 for Kenya, and b = 0.279 for Ghana). In contrast, the effect of sector is specific for at least two locations: Malayali government researchers and Kenya academics are more likely to produce internationally than their sectoral counterparts (Columns 1 and 2, Row 001). As we saw earlier, government scientists tend to be more productive than their academic counterparts in Kerala, a trend that is reversed in the case of Kenyan scientists. The influence of Internet adoption on foreign productivity varies with location, but diversity in email use has a positive impact in two of the three locations (Row 012). For Malayalis, there is no evidence that disparity in ready access and current use influence productivity. However, we do find that number of articles published in foreign journals by Malayalis is positively associated with diversity of email use (b = 0.137) and email experience (b = 0.143) (Column 1, Rows 012 and 013). In the case of Kenyan scientists, only diversity of email use (b = 0.346) influences foreign publication behavior (Column 2, Row 012).

Table 6b. Standardized regression for log number of publications in foreign journals during the last 5 years

	Kerala		Kenya		Ghana	
Contextual Factors						
001 In research sector (1-yes;0-no)	0.222	***	-0.148	**	-0.082	
Personal Factors						
002 Gender (1-male;0-no)	0.005		0.050		-0.012	
003 Age (years)	-0.013		0.310		2.622	**
004 Age squared (years squared)	0.118		-0.299		-2.821	**
005 Married (1-yes; 0-no)	0.095		0.065		0.069	
Educational Factors						
006 Doctorate (1-yes;0-no)	0.206	***	0.278	***	0.279	**
007 Degree from a developed country (1-yes;0-no)	-0.014		-0.048		0.195	*
Professional Factors						
008 Has PC in personal office (1-yes;0-no)	-0.096		-0.041		0.233	**
009 Member of professional organization (1-yes;0-no)	0.016		0.131	**	0.051	
Aspects of Internet Adoption						
010 Has ready email access (1-yes; 0-no)	0.032		-0.037		0.114	
011 Current email user (1-yes; 0-no)	0.046		-0.091		0.137	
012 Email use diversity (6-high diveristy;0-no diversity)	0.137	*	0.346	***	0.014	
013 Number of years using email	0.143	*	-0.006		0.030	
R-squared	0.196		0.353		0.373	
N	225		190		84	

*, **,*** significant at the 0.10, 0.05, and 0.01 level, respectively
[1]When we asked respondents about academic degrees obtained from developed countries, we were not particular as to whether it was for their doctorate degree or not. A respondent who, for example, obtained his/her masters degree in a developed country and obtained a doctorate degree locally was classified as having an academic degree in a developed country.

For Ghanaian scientists, none of the four ICT aspects plays any role in foreign productivity. Among Ghanaians, age (b = 2.622), possession of a doctorate (b = 0.279) and a degree from a developed country are associated with international output (b = 0.195), as well as immediate access to a personal computer (b = 0.233). Again, the effect of Internet adoption on foreign productivity is mediated by the differences among research locations. For scientific communities in locations with low socioeconomic development, ICTs have no impact on scientists' productivity in local (Column 3, Rows 010 -013) *or* foreign (Column 3, Rows 010 -013) journals. For scientific communities in locations characterized by high socioeconomic development (e.g. Kerala), ICTs generally influence scientific output in both local and foreign journals.

Discussion

We first addressed the degree to which scientists in the developing world have adopted the information and communications technologies that are now a prerequisite for participation in global scientific communities. We addressed the diffusion of both hardware (computers) and connectivity (the Internet). Apart from variations by level of development (location) and organizational setting (sector), two features stand out from our descriptive findings on adoption. First, personal computers are a pre-requisite for the use of the Internet, but in the developing world this does not yet translate into "personalized" computers. In the early 1990s PCs were already prevalent throughout the scientific community in the developed world, so the diffusion of the Internet was, in large measure, a matter of connecting extant computers. Our results show that even the presence of computers as research tools in the developing world is relatively recent: personal computers. While most scientists now have access to a computer at work, only a minority can boast of a PC in their personal office. In fact, an average of over seven people uses each computer. Programs that seek to provide connectivity to the research institutions of the developing world should recognize at the outset that the basic technology to implement the Internet is itself scarce: PCs are not so much "personal computers" as "public computers". Although our re-conceptualization of Internet adoption treats access and use as two separate but correlated dimensions, our results are consistent with Ehikhamenor's view that scientists in the developing world have limited access and use due to a variety of technical, institutional, cultural, economic, and political reasons.[27*]

A second important feature is the substantial discrepancy between scientists' view of themselves as Internet users and the extent to which they actually have the opportunity to use the Internet. This was indicated by what we have labeled "ready access". While nine in ten scientists in our study consider themselves current email users, only six in ten report such access. Indeed, our observations since 1994 suggest that this is actually an optimistic assessment. The large gap between user definitions and ready access further supports the claim that current use status is largely attained through sharing of computers connected to the Internet. In developing areas, an individual may be an "email user" without the implication of being able to engage in a scientific collaboration that requires reliable or continuous access. One of our own project collaborators, as we wrote the final version of this essay, admitted that Internet connectivity had been absent in his department for a period of four months and he had been using other means to communicate – much less frequently. In our study locations,

* Ehikhamenor's research on Internet use among scientists in Nigerian universities is the only empirical survey of which we are aware that examines the diffusion of ICTs in developing world scientific communities.[26,27]

this gap is partly bridged by the coping mechanism of shared computer and Internet use. But even this is misleading owing to frequent technical problems. Sharing resources, especially with a large number of other scientists, translates into the low individual usage that indirectly affects the development of sophisticated Internet practice and relevant Internet experience.

Our second question pertains to the disparities in Internet adoption *within* the research communities of the developing world. Statistically significant disparities in aspects of Internet adoption exist along contextual, personal and professional dimensions of developing world science. Disparities in ready access, practice and experience are associated with differing levels of socioeconomic development among our research locations. Differences between universities and government research institutes are not generally large. Gender remains a durable source of inequality in Internet adoption. This is especially true with respect to the aspects of current use, practice and experience, where men typically have higher rates of adoption than women. But despite the traditional deference given to older and married members of society in these locations, age and marital status do not constitute major sources of digital inequality in the scientific communities of developing areas.

Education is perhaps the most consistent dimension defining the digital divide among developing world scientists, especially in terms of Internet practice and experience. Where the highest degree is a doctorate from a developed area, there seem to be clear advantages. For a scientist earning a Ph.D. in the U.S. or Europe within the past ten years it is almost inconceivable that Internet use would not be a significant part of this experience. The advantage is twofold: based on direct association, learning and modeling from those who use the Internet and the acquisition of a network of communication partners.

Professional involvement and the convenience of having PCs in personal offices also favor sophisticated Internet practice and extensive Internet experience. This relationship seems intuitive, given that membership in professional organizations – like training in developed countries – translates into opportunities for interaction with other scientists, who may exchange information at the same time that they learn Internet skills. The enhancing effect of having immediate PC access on sophisticated Internet practice and extensive Internet experience is also intuitive given that having a PC in one’s personal office implies a degree of architectural privacy that serves as a facilitating condition to explore, experiment, and familiarize one with the various functionalities of the Internet. We note that increasing disparities among social characteristics as one moves from current use, to ready access, then to practice and finally to experience. We conclude that the digital divide pertains more to aspects of practice and experience than adoption in any simple sense. Current use and access may become less relevant aspects of the digital divide in the future. In other words, as developing areas steadily become knowledge societies, the concept of the digital divide moves away from the simple inequalities in hardware-software access and use and moves toward the more complex inequalities of hardware-software-user interaction skills.

Our final question is the extent to which Internet adoption influences research productivity in the developing world? Part of the eagerness to connect Third World research organizations is the assumption, stated or unstated, that higher levels of connectivity will result in increased productivity, as in the developed world.[32] Consistent with the findings of Ehikhamenor,[26] our findings offer limited support for this view. What seems clear from our findings is that the developing world cannot be viewed as a homogeneous entity and the influence of Internet connectivity on productivity is far from predictable. We find that scientific productivity is sensitive to variations in level of development (location) and organizational setting (sector). Research communities differ substantially, while the circumstances surrounding and constraining scientific production generate conditions that may not favor any direct impact of Internet connectivity. The volume of scientific output disseminated through foreign journals is conditioned by the joint effect of level of development and organizational setting. However, foreign productivity between organizational settings within each location also changes as one goes from less developed to more developed areas. In African locations, there is a general tendency for scientists in academic settings to be more productive than their counterparts in government research settings, but the opposite holds true in our Indian location. Local productivity is sensitive to variations in level of development but not to organizational setting. Locations situated at both extremes of the development spectrum exhibit higher local publication productivity.

Our results show that different aspects of Internet adoption come into play in influencing productivity depending on location. In locations such as Ghana, characterized by a low level of development, for both local and foreign productivity; ready access, current use, Internet practice and Internet experience do not translate to any detectable differences in the volume of scientific output. This implies that certain prerequisites (e.g. manpower skills and competencies, ICT infrastructure) must be first satisfied before any clear advantages associated with the Internet can be realized. In locations with higher levels of development, there are indications that aspects of Internet adoption do influence productivity, but the relationship is complex and merits further study. Among the four aspects of Internet adoption, disparities in what we have called Internet practice are associated with scientific productivity. Variations in Internet practice generally enhance foreign productivity, but influence on local productivity is strongly mediated by variations in location. Disparities in ready access and current use do not generally influence either foreign or local productivity. *The digital divide that has direct bearing on scientific output is the divide that pertains to practice and experience, not access and use.*

Though we focus primarily on the Internet as a research tool, our results provide some support for both “elixir” and “affliction” arguments about the diffusion of the Internet in developing areas. As the “elixir” argument suggests, there are indications that the Internet may increase the visibility of developing area scientists in foreign journals, yet the effect is not uniform across locations. As the “affliction” argument suggests, the diffusion of the Internet has introduced a new set of inequalities (practice and experience) even as the old inequalities (in particular, self-defined use) have been reduced. These new dimensions have assumed more complex forms characterized by increased sophistication and extensive exposure (or the more complex form of “hardware-software-user skills” usually acquired through prolonged use and more personal use of computers) compared to the earlier and easier forms characterized by access and use (categories denoting superficial skills).

As a research tool, the efficacy of the Internet is constrained not only by whether a PC is a “personal computer” or a “public computer”, but also by the time and space (architectural privacy) for research transactions that include information search and personal communication. Scientists in the developing world must have *personal time* (more time to use the PC alone) and *personal space* (more space to use the PC alone). These temporal and spatial dimensions constitute workplace privacy. This facilitating condition does not occur when a large number of scientists share PCs in public spaces of research centers. Although the Internet has altered communicative conditions to allow information interchange among spatially dispersed actors in real time, developing world scientists do not have the luxury of *personal* time and space for gaining the sophistication that might transform Internet connectivity into a collaborative research tool, and thereby make science a truly global enterprise.

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References

1. ROBINSON, J., Introduction to Issues 4 and 5 digital divides: Past, present and future. *IT&Society,* 1 (5) (2003) i–xiv.
2. STEHR, N., Modern societies as knowledge societies. *Handbook of Social Theory*. Thousand Oaks, CA, USA, Sage Publication, 2000.

3. DAVIDSON, T., R. SOORYAMOORTHY, W. SHRUM, Kerala connections: Will the Internet affect science in developing areas? In: *The Internet in Everyday Life*. B. WELLMAN, C. HAYTHORNTHWAITE (Eds), Malden, MA, USA, Blackwell, 2002.
4. DI MAGGIO, P., E. HARGITTAI, W. R. NEUMAN, J. P. ROBINSON, Social implications of the Internet. *Annual Reviews of Sociology*, 27 (1) (2001) 307–336.
5. CASTELLS, M., *The Information Age: Economy, Society and Culture: The Rise of the Network Society*. Malden, Massachusetts, USA, Blackwell Publishers Inc., 2000.
6. ESCOBAR, A., Welcome to Cyberia: Notes on the anthropology of cyberculture. *Current Anthropology*, 35 (3) (1994) 211–231.
7. UIMONEN, P., *Transnational.Dynamics@Development.net: Internet, Modernization and Globalization*. Stockhlom, Sweden, Elanders Gotab, 2001.
8. ENGELHARD, R., *State of the Art of the Opportunities Offered by New ICTs in the Building of Cooperation Programmes in Agricultural Research for Development*. European Forum on ARD, Wageningen, The Netherlands, 1999.
9. QUAN-HAASE, A., B. WELLMAN, J. WITTE, K. HAMPTHON, Capitalizing on the Internet: Network capital, participatory capital, and sense of community. In: *The Internet in Everyday Life*. B. WELLMAN, C. HAYTHORNTHWAITE (Eds), Oxford: Blackwell, 2002.
10. FINHOLT, T., G. M. OLSON, From laboratories to collaboratories: A new organizational form for scientific collaboration. *Psychological Science*, 8 (1) (1997) 8–36.
11. ABELS, E. G., P. LIEBSCHER, D. DENMAN, Factors that influence the use of electronic networks by science and engineering faculty at small institutions. *Journal of the American Society for Information Science*, 47 (2) (1996) 146–158.
12. GALIMBERTI, C., S. IGNAZI, P. VERCESI, G. RIVA, Communication and cooperation in networked environments: An experimental analysis. *Cyberpsychology and Behavior*, 4 (1) (2001) 131–146.
13. KOKU, E. F., B. WELLMAN, Scholarly networks as learning communities: The case of TechNet. In: *Designing Virtual Communities in the Service of Learning*. S. BARAB, R. KLING (Eds), Cambridge, Cambridge University Press, 2002.
14. CASTELLS, M., *The Internet Galaxy. Reflections on the Internet, Business, and Society*. New York, USA, Oxford University Press, Inc., 2001.
15. KATZ, J. S., P. ASPDEN, Motivations for and barriers to Internet usage: Results of a national public opinion survey. *Internet Research: Electronic Networking Applications and Policy*, 7 (3) (1997a) 170–188.
16. KATZ, J. S., P. ASPDEN, Motives, hurdles and dropouts: Who is on and off the Internet and why? *Communications of the ACM*, 40 (4) (1997b) 97–102.
17. KATZ, J. S., P. ASPDEN, A Nation of strangers. *Communications of the ACM*, 40 (12) (1997c) 81–86.
18. HARGITTAI, E., Beyond logs and surveys: In-depth measures of people's web use skills. *Journal of the American Society for Information Science and Technology Perspectives*, 53 (14) (2002) 1239–1244.
19. LENHART, A., J. B. HORRIGAN, Re-visualizing the digital divide as a digital spectrum. *IT&Society*, 1 (5) (2003) 23–39.
20. WORLD BANK, *World Development Report*. Washington DC, International Bank for Reconstruction and Development/World Bank, 2000.
21. NORRIS, P., *Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide*. Cambridge, UK, Cambridge University Press, 2001.
22. PEW INTERNET, AMERCIAN LIFE PROJECT, Tracking On-Line Life: How Women Use the Internet to Cultivate Relationships with Family and Friends, 2000.
23. WILHEIM, A. G., *Democracy in the Digital Age: Challenges to Political Life in Cyberspace*. New York, Routledge, 2000.
24. JUNG, J. Y., J. L. QIU, Y. C. KIM, Internet connectedness and inequality. *Communication Research*, 28 (4) (2001) 507–535.
25. KATZ, J. E., R. E. RICE, P. ASPDEN, The Internet 1995-2000: Access, civic involvement, and social interaction. *American Behavioral Scientist*, 45 (3) (2001) 405–419.

26. EHIKHAMENOR, F. A., Internet resources and productivity in scientific research in Nigerian universities. *Journal of Information Science*, 29 (2) (2003) 107–115.
27. EHIKHAMENOR, F. A., Internet facilities: Use and non-use by Nigerian university scientists. *Journal of Information Science*, 29 (1) (2003) 35–48.
28. KAMINER, N., Y. M. BRAUNSTEIN, Bibliometric analysis of the impact of Internet use on scholarly productivity. *Journal of the American Society for Information Science*, 49 (8) (1998) 720–730.
29. OSAREH, F., C. S. WILSON, Collaboration in Iranian scientific publications. *Libri,* 52 (2) (2002) 88–98.
30. WALSH, J., S. KUCKER, N. MALONEY, S. GABAY, Connecting minds: CMC and scientific work. *Journal of the American Society for Information Science*, 52 (14) (2000) 1295–1305.
31. COSTA, S., J. MEADOWS, The impact of computer usage on scholarly communication among social scientists. *Journal of Information Science*, 26 (4) (2000) 255–262.
32. DUQUE, R. B., M. A. YNALVEZ, R. SOORYAMOORTHY, P. MBATIA, D. B. DZROGBO, W. SHRUM (under review), Collaboration paradox: Scientific productivity, the Internet, and problems of research in developing areas.
33. SANGOWUSI, Problems of accessing scholarly publications by Nigerian scientists: A study of the University of Ibadan. *Journal of Information Science*, 29 (2) (2003) 127–134.
34. BONACCORSI, A., C. DARAIO, Age effects in scientific productivity: The case of the Italian National Research Council. *Scientometrics*, 58 (1) (2003) 49–90.
35. GOEL, K., Gender differences in publication productivity in psychology in India. *Scientometrics*, 55 (2) (2002) 243–258.
36. PRPIC, K., Gender and productivity differentials in science. *Scientometrics*, 55 (1) (2002) 27–58.
37. SHRUM, W., View from afar: 'Visible' productivity of scientists in the developing world. *Scientometrics*, 40 (2) (1997) 215–235.
38. WORLD BANK, *World Development Report*. Washington D.C., USA, The World Bank, 2003.
39. UNDP, *Human Development Report*, United Nations Development Programme, 2003.
40. JEFFREY, R., *Politics, Women and Well Being: How Kerala Became a Model*. Delhi, Oxford University Press, 1992.
41. FRANKE, R. W., B. H. CHASIN, *Kerala: Radical Reform as Development in an Indian State*. Oakland, CA, USA, The Institute for Food and Development Policy, 1994.
42. PARAYIL, G., The Kerala model of development: Development and sustainability in the Third World. *Third World Quarterly*, 17 (5) (1996) 941–957.
43. SOORYAMOORTHY, R., *Consumption to Consumerism in the Context of Kerala*. New Delhi, India, Classical Publishing Co., 1997.
44. RAMANATHAIYER, S. R., S. MACPHERSON, *Social Development in Kerala: Illusion or Reality?* Ashgate, Aldershot, 2000.
45. MATHEW, E. T., Educated unemployment in Kerala: Some socioeconomic aspects. *Economic and Political Weekly*, 30 (11 February 1995) 5–35.
46. EPW RESEARCH FOUNDATION, Social indicators of development for India. II: Inter-state disparities. *Economic and Political Weekly*, 29 (21 May 1994) (1994) 1300–1308.
47. EISEMON, T. O., C. H. DAVIS, Universities and scientific research capacity. *Journal of Asian and African Studies*, 27 (1/2) (1992) 68–93.
48. DZORGBO, D. B., *Ghana in Search of Development: The Challenge of Governance, Economic Management, and Institution Building*, Ashgate Publishing Co., 2001.
49. JEONG, H. W., Ghana: Lurching toward economic rationality. *World Affairs*, 159 (2) (1996) 64–71.
50. INTERNATIONAL TELECOMMUNICATION UNION, *Overview of the Internet in Ghana. 2004,* 2000.
51. FOSTER, W., S. GOODMAN, E. OSIAKWAN, The gateway to Africa? The Internet in Ghana (under review), 2003.
52. ROGERS, E. M., *Diffusions of Innovations*. New York, NY, USA, The Free Press, 1995.
53. GARG, K. C., P. PADHI, Scientometrics of prolific and non-prolific authors in laser science and technology. *Scientometrics*, 49 (3) (2000) 359–371.

54. SHRUM, W., P. CAMPION, Gender and science in developing areas. *Science, Technology, and Human Values*, forthcoming, 2004.
55. GUPTA, B. M., S. KUMAR, B. S. AGGARWAL, Comparison of productivity of male and female scientists in CSIR. *Scientometrics*, 45 (2) (1999) 269–289.
56. SUNDSTROM, E. R. E. B., D. KAMP, Privacy at work: Architectural correlates of job satisfaction and job performance. *Academy of Management Journal*, 23 (1) (1980) 101–117.
57. GAILLARD, J., *Scientists in the Third World*. Lexington, University of Kentucky Press, 1991.
58. SANCHO, R., Misjudgments and shortcomings in the measurement of scientific activities in less developed countries. *Scientometrics*, 23 (1) (1992) 221–233.
59. SEN, B. K., V. V. LAKSHMI, Indian periodicals in the Science Citation Index. *Scientometrics*, 23 (2) (1992) 291–318.
60. GAILLARD, J., Use of publication lists to study scientific production and strategies of scientists in developing countries. *Scientometrics*, 23 (1) (1992) 57–73.