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Gender, ICTs, and Productivity in Low-Income Countries: A Panel Study

B. Paige Miller[1], Ricardo Duque[2], and Wesley Shrum[3]

Abstract

This essay presents the first analysis of gender differences in productivity using panel data on scientists in low-income countries. About 540 researchers in Ghana, Kenya, and Kerala (India) were studied using the same survey instrument in 2001 and 2005. Results indicate very few gender disparities in outcomes at either period of the study with one exception: productivity in *international* journals. The authors show that substantial gains in access to technology and higher education by women have not reduced the gender gap on this important career dimension.

Keywords

gender, science, productivity, technology, development

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Within a context of globalization, gender inequality in science has taken on new significance. The mobile telephone, e-mail, and the World Wide Web, technologies that facilitate global processes, are argued to possess the potential to change the way knowledge is produced by removing constraints of time and place from professional activities (Barjak 2006; Koku, Nazer, and Wellman 2001; Nentwich 2005; Scholte 2000; Wellman, Koku, and Hunsinger 2006). Owing to gender segregation and stratification, the use of information and communication technologies (ICTs) to gather data and literature and communicate with distant others could be revolutionary for the gendered nature of scientific work in low-income countries.

Various features of e-mail and the Internet are argued to support women's research productivity, particularly in foreign arenas (Anderson 2007; Anderson and Shrum 2007; Palackal et al. 2006). By acting as a tool women use to circumvent cultural constraints placed on their physical mobility and interaction patterns, ICTs can facilitate collaboration and the creation of professional networks with distant others (Barjak 2004; Barjak 2006; Koku, Nazer, and Wellman 2001; Walsh et al. 2000; Wellman, Koku, and Hunsinger 2006); the sharing of problems, research findings, data, and new literature among people with similar interests through e-mail listserves, online discussion groups, and personal Web pages (Ehikhamenor 2002; Matzat 2004; Nentwich 2005; Zimmerman and Bar-Ilan 2008); and ICTs can facilitate manuscript submission and communication with editors. Furthermore, while not devoid of social status, e-mail is argued by some to contribute to a leveling of social hierarchies as lower status individuals may feel more comfortable interacting with higher status others in a mediated context (Koku, Nazer, and Wellman 2001; Wellman, Koku, and Hunsinger 2006).

Such arguments, however, tend to minimize the importance of cultural context in structuring the practice of science and the use of technology. Reagency (a concept that makes use of time, physical place, and identities to explain why donor projects, such as technology transfers to low-income areas, fail to produce the expected results) suggests researchers act in ways consistent with institutional and group demands. Material or financial resources originating from more developed areas are absorbed by recipients in resource poor environments in ways consistent with their everyday realities, rather than with programmatic expectations (Shrum 2005; Holland 2009). Researchers may incorporate new technologies into their lives by communicating with friends and family, preparing lectures, or especially in the African context, dealing with the expanding student population and staff shortfalls, rather than for research purposes (Sawyerr 2004). As a consequence, the Internet and e-mail may have little to no impact on gender

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differences in research productivity. Indeed, the predicted effect of ICT use on productivity is not supported empirically in recent studies on the topic (Vasileiadou and Vliegenthart 2009). Our own results suggest the optimist projection has not occurred for one widely valued indicator of productivity: publications in foreign journals.

We employ data gathered at two points in time in three low-income areas (Ghana, Kenya, and Kerala, India) to examine the gendered nature of the research career. Specifically, we answer three questions: (1) Do gendered patterns in research output exist? (2) Do observed differences continue to exist once other factors are controlled? and (3) Do ICTs act to mediate observed disparities? Much of the literature that is available has been either speculative in nature, employed a very small sample of women, or pre-dates the spread of the Internet in low-income countries (Campion and Shrum 2004; Chakravarthy 1986; Gupta and Sharma 2002, 2003; Kumar 2001; Miller et al. 2006; Subrahmanyan 1998). Since the above arguments were initially formulated, ICTs have diffused at a rapid rate (United Nations Conference on Trade and Development 2007). The relationship between new technologies and the gendered nature of productivity may now be empirically assessed. This analysis provides an initial step toward answering these questions using panel data to test for gender differences in productivity in low-income areas.

For scientists in government research institutes and universities, the standard measure of contribution to science, specifically to the creation of new knowledge, is productivity as assessed through publications in journals, books, and chapters in edited volumes (Najman and Hewitt 2003).[1] Through publication productivity, researchers share their ideas with others, contribute in a highly visible way to the profession, and develop their careers within an institutional context (Fox 2005; Reskin 1977; Xie and Shauman 1998). Because publications are related to the evaluation of a researcher's efforts, productivity is both a cause and a consequence of academic rank, promotion, and salary, making the study of scientific productivity particularly relevant for the evaluation of gender inequality in science. For researchers in low-income countries, publishing in foreign venues is especially important, as it leads to greater visibility among the core knowledge producing countries and institutions (Drori et al. 2003).

Regardless of gender or geography, science is a stratified institution with a few highly productive researchers representing the majority of the publications produced each year. Most researchers either publish very little (if at all) or the number of papers they publish falls somewhere between the extreme of none to many. Within this context, numerous studies document

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the lower productivity levels of female researchers particularly those working in the periphery (Fox 1995, 1996, 1999, 2005; Long 1992; Long and Fox 1995; Xie and Shauman 2003). In a classic statement on the subject, Cole and Zuckerman (1984) term this phenomenon the "productivity puzzle," reflecting its persistent presence in spite of changing gender roles.

The bulk of the literature on gendered productivity patterns focuses on women in highly functioning scientific systems such as those found in the United States, Western Europe, and some Asian countries (Burrelli 2008; Clewell and Campbell 2002; Fox 1995, 1996, 1999; Xie and Shauman 2003). Among the studies conducted on science and gender in the periphery, findings indicate that increasing numbers of women are entering graduate school and progressing to a research career. According to a report issued by Beintema and Di Marcantonio in 2009, the number of women entering agricultural research and higher education in many African countries has steadily increased since 2000, a trend that had been occurring for some time in many Asian countries. In spite of the increasing numbers of women entering the scientific career, gender differences in promotion and pay, particularly within higher income countries, have persisted (Leahey 2006). Part of the gender disparities in academic rank and pay is attributable to a gender gap in productivity. Explaining *why* women are less productive has produced less consistent results.

A number of explanatory variables, broadly related to individual and institutional factors, have been employed to explain gender disparities in publication productivity. We argue, there are broadly two views of gender differences along these dimensions: the first regards differences between men and women as relatively pervasive; that is, on the vast majority of career, status, and familial dimensions, there are important and statistically significant gender disparities. The second view is that differences between men and women are actually few and/or small. While there are differences, most of the factors traditionally measured are not useful for distinguishing between men and women. Rather, a very small, but significant, number of gender differences contribute to both the perception and the reality that science and most other areas of social life are gendered (Campion and Shrum 2004; Long 1990, 1992; Xie and Shauman 1998).

Focusing on institutional factors, organizational affiliation or sector is often an important predictor of output measured in terms of publications (Allison and Long 1990; Fox 1991; Fox and Mohapatra 2007; Mahlck 2001; Nakhaie 2002; Sonnert, Fox, and Adkins 2007; Xie and Shauman 2003). Expectations for productivity, service, teaching responsibilities, and collaboration are dependent upon whether one is employed in a research

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institute or university.[2] For the purposes of this study, what is crucial about university employment is that productivity in the form of publications is directly tied to promotion and salary. Individual status characteristics such as age, marital and parental status, human capital signaled by the PhD, and technological access have also been identified as predictors of career attainment (Astin and Milem 1997; Burrelli 2008; Cole and Zuckerman 1987; Fox 1995, 1999, 2005; Kyvik and Teigen 1996; Long 1990, 1992; Sonnert, Fox, and Adkins 2007; Xie and Shauman 2003).[3]

On the rare occasions where gender and scientific careers have been examined in low-income countries, differences between men and women are quite small (Campion and Shrum 2004; Kumar 2001). Over time, these differences appear to be diminishing. Miller et al. (2006), using longitudinal but non-panel data gathered on researchers in Ghana, Kenya, and Kerala, India, found that in 1994 women were significantly less likely to possess the PhD than their male counterparts. By 2001, women were equally likely to possess the PhD indicating that women choosing to pursue a career in science were closing the gap in human capital. This same study found marked increases in access to e-mail and personal computers for both males and females with no statistically significant gender disparities. However, what has not been examined is whether women are able to convert educational and technological resources into productivity to the same extent as men. Trends in more developed areas examining gender differences in publication productivity note diminishing disparities between men and women later in the career, but whether a similar pattern will emerge in this context is far from certain (Cole and Zuckerman 1984; Long 1992).

While very few significant gender differences emerge on most traditional measures, female researchers do display a more local orientation to their careers, defined primarily in terms of travel and educational experiences (Palackal et al. 2006; Campion and Shrum 2004; Miller et al. 2006). Women travel far less then men, limiting their opportunities to develop professional contacts with others who have similar research interests, which might indirectly contribute to lower publication levels in comparison to their male counterparts, particularly in foreign journals. According to the circumvention argument, however, new ICTs may have some impact on these processes. Palackal et al. (2006) suggest that ICTs may act as tools of circumvention by serving as a means for women to bypass the constraints placed on their physical mobility. In this way, ICTs possess features that may change not only the informal and formal communication patterns of developing area researchers but also their productivity levels (Ynalvez et al. 2005).

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Although the data are generally old and not gender focused, there is some evidence that the relationship between technology use and productivity is positive. Costa and Meadows (2000), using a sample of sociologists and economists noted in the Brazilian context that technology use increased publication productivity. Other studies suggest that the impact of the Internet in developing areas is not a simple issue of connectivity (Ehikhamenor 2002; Ynalvez et al. 2005). Instead, the effect of Internet access on productivity is closely associated with the *type* of Internet use, based on the amount of time spent employing a technology and the diversity of activities engaged in while online. The complexity of this relationship is compounded when one considers both regional and organizational variations and the rapid shifts that have occurred in the spread and development of technology.

We use panel data in three locations to examine the nature of the relationship between gender and productivity as well as the mediating effect of e-mail use. First, we review selected contextual differences between Ghana, Kenya, and Kerala and describe the structure of the panel data and the dimensions measured in our first and second waves. Following this, we summarize the important results to emerge from our data by first looking at the differences in the institutional and technological environments in which men and women live and work. The bivariate association between gender and productivity is examined in phase 1 and again in phase 2 in order to track both gender differences and within group changes. Finally, we present multivariate results predicting research productivity on four dependent dimensions: the number of papers written, presentations at international conferences, and publications in foreign and domestic journals.

Context and Method

The three locations were chosen in 1994 to represent diverse levels of social, economic, and technical development (Ghana—low; Kenya—medium; and Kerala—high).[4] While the ranking of the Indian location still holds relative to the two African locations, Ghana and Kenya are now virtually similar in their communications and scientific infrastructure as well as broadly similar on many socioeconomic indicators. Although selecting different countries might produce different results, the potential but unknown costs and benefits of doing so seem small in comparison to the advantage of having long-term data from the same locations.

The recent selection of Ghana for the July 2009 Presidential visit to Africa was widely viewed as a snub to Kenya, the birthplace of Barack Obama's father. The choice was intended to send an important message to the leaders

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of the East African country, many of whom were implicated in the post-election violence. Famous for its climate, wildlife, and its pro-Western orientation, Kenya struggled with dictatorship and corruption in its first three decades and the laudable democratic election in 2002 was followed by rigging and violence in the 2007 election. Historically, Kenya possessed one of the larger and most developed research systems in Africa, but in recent years, this system has deteriorated due to corruption and financial problems. Ghana, the first country in Sub-Saharan Africa to attain independence in 1957, seemed to represent a beacon among African countries. Following an economic crisis in the 1970s, much of the initial enthusiasm waned and the country experienced a bloody military coup. However, the country has now experienced several peaceful elections, which, combined with its economic progress, led to the recent U.S. presidential visit. Our third research location, Kerala, was selected to represent a relatively high degree of social and economic development. It is characterized by far less dependence on foreign aid and famous for what has been called the Kerala Model of development: high levels of social progress but relatively lower levels of economic advancement (Shrum and Ramanathaiyer 2000). Kerala is often discussed in the development literature as a paradox among developing areas.[5]

To analyze changes in the careers of women scientists, we employ quantitative data that is part of a multiwave survey of the scientific community. The data used were gathered through face-to-face interviews with 540 respondents representing individuals who were interviewed in both 2001 and 2005.[6] Due to the clustering of research institutions near urban areas, principal universities or national research institutions located within or close to Nairobi, Accra, or Trivandrum were selected for inclusion in both waves of the study.[7] In selecting the sample of researchers, we employed a demand-side approach, defining scientists as those with jobs in scientific fields (most of our researchers were working in fields related to agricultural, environmental, or natural resource management, although a minority were working in the social sciences; Xie and Shauman 1998). All academic faculty (including assistant, associate, and full professors) and researchers employed within the organization and working in a scientific field were interviewed.

In addition to the benefits of using panel data, such data also present a number of challenges.[8] To model changes over time using a two-wave panel design, one approach is to employ a first difference model to predict research productivity (also known as the unconditional change score model) in which the regressor variables and the dependent variable are a series of change scores. The basic model for change scores is as follows:

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$$\text{Model 1} \quad \Delta Y = \Delta\beta_0 + \beta_1 \Delta X_1 + \Delta\varepsilon.$$

In this model, the value of the dependent variable at time 1 is subtracted from the value of the dependent variable at time 2 ($Y_t - Y_{t-1}$) and the value of the independent variables at time 1 are subtracted from the value of the independent variables at time 2 ($X_t - X_{t-1}$). An alternative is the static score approach, also known as the conditional change model. In the static score or conditional change design, the model for change takes this form:[9]

$$\text{Model 2} \quad Y_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 Y_{t-1} + \varepsilon_{t-1}.$$

In this model, the time 2 dependent variables are regressed on the time 1 dependent variables and the time 1 values of the independent variables (Allison 2005; Finkel 1995; Johnson 1995).

Choosing between these two models typically involves theoretical rather than methodological considerations. Use of the first difference or unconditional change score model is favored under certain conditions due to the fact that time-invariant but unmeasured variables are differenced out of the regression equation. In most sociological research, some predictor variables do not change over time (gender, race, etc.). Using a first difference, model of change controls for their influence.[10] There are, however, a number of issues constraining the use of the unconditional change model. First, the model does not include the lagged dependent variable as a predictor of the time two outcome. If it is assumed that the time 1 value of the dependent variable has some causal relationship with the time 2 value of the dependent variable, including the lagged dependent variable is appropriate (Allison 1990; Finkel 1995). For instance, if a model's dependent variable is productivity, one might assume that every time a researcher publishes an article, the likelihood that he or she will publish again increases (Allison, Long, and Krauze 1982). In addition, the alleged benefit of using the unconditional change score model (i.e., time invariant predictors need not be included because they are implicitly controlled) is problematic where one's primary interest is in predicting the relationship between such time-invariant predictors as gender, country of origin, and organizational context and research output. While the effect of these variables is indirectly controlled, one is unable to directly assess their importance in the model. For these reasons, the conditional change score design is more appropriate and 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 (Crenshaw 1991; Lyson et al. 2001).[11]

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Because count variables, including measures of productivity, tend to be highly skewed, our regression models use the logged values of the self-reported productivity counts. Rather than using cumulative measures (those assessing a researcher's publications, for instance, over his or her entire career) of research productivity, which often distort gender differences due to the relatively recent entry of women into research careers and the greater likelihood of career interruptions, we employ eight *short-term*, continuous measures of research output (Fox 2005; Xie and Shauman 1998). The first six variables measure the number of papers published in foreign and domestic journals, the number of chapters published in edited volumes, and the number of reports and bulletins written in the previous five years, that is, since 2000.[12] We classify journal publications as domestic and foreign as previous studies have noted these two venues represent two distinct productivity phenomena in terms of career orientations (international recognition vs. local research development) and in terms of the review processes, acceptance criteria, and institutional prestige associated with the two types of publications. Additionally, publishing in foreign journals is likely to be aided by the use of e-mail to a greater extent than publishing in domestic journals (Ynalvez et al. 2005). Although publishing in both venues is likely made more efficient by the use of technology, the ease and speed of computer-mediated communication with nonlocal editors and submission through online formats may differentially impact foreign journal publications.

The next two indicators of productivity are the number of papers presented at local or national workshops as well as the number of papers presented at international conferences, again within the five-year time frame. Finally, we examine the number of research papers written in the twelve months preceding the interview, regardless of whether or not the papers were published.[13] Although each of these areas of productivity is of interest, prior research has noted that the most significant distinction between male and female researcher's productivity levels emerges in the comparison of foreign and national journals, international conference presentations, and the number of papers written (Campion and Shrum 2004; Miller et al. 2006). As such, we are particularly interested in the gender differences over time for publications in these venues and focus on these in the multivariate analyses. By including a number of measures of productivity, we address the fact that publication counts overlook other types of output. Publication is often the last step in the research process. The first three measures of productivity examined here correspond to earlier stages of research.[14]

The primary independent variable of interest for this study is gender (0 *female*, 1 *male*). However, we are also interested in examining the way

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in which technology mediates between gender and research productivity. To examine technology use, we employ two measures of e-mail practice. We focus on e-mail, rather than other forms of technology, in order to assess the notion that women will use the technology to circumvent constraints on their physical mobility. Consistent with Ynalvez et al. (2005), we employ an e-mail diversity scale. Comprised of six dichotomous variables (1 = *yes*; 0 = *no*) this scale assesses the extent of e-mail use by asking whether or not the respondent has engaged in the following activities using e-mail as the medium: (1) participated in 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 ranges from none—a score of 0—to maximum diversity of use—a score of 6. The second component of this dimension reflects the intensity of e-mail use: an ordinal variable assessing the number of hours in a typical week spent sending and receiving e-mail messages (0 = *none*, 1 = *low*, 2 = *medium*, 3 = *high*).[15]

Five control dimensions were identified as important to predicting research productivity: age, family structure, human capital, localism, and context. Family structure is measured using three variables: (1) a dummy variable indicating the respondent's marital status (1 = *married*; 0 = *not married*); (2) the respondent's number of children;[16] and (3) a dummy variable for the occupation of the respondent's spouse (1 = *researcher*; 0 = *other*). The third and fourth dimensions identified as relevant to career outcomes are human capital and localism. We use one dichotomous measure of human capital assessing the possession of a PhD (1 = *PhD*, 0 = *no PhD*). Localism is measured by looking at the number of years spent outside of the country of origin for higher education and training. Finally, two measures of context are included as control variables: country of employment (Kenya or Kerala with Ghana as the reference category) and sector of employment (0 = *university*, 1 = *national research institute*).[17]

In the sections that follow, we present a series of tables measuring the bivariate relationship between gender, time, and the relevant outcome variables. We first examine intergroup changes—comparing men to women at time 1 and then at time 2. Mean differences between males and females in both phases are tested using independent samples *t*-tests and the *F* statistic (for those variables measured at the interval level) and the chi-square test for significance (for variables measured at the nominal or ordinal level).

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For the second component of our analysis, we compare the mean scores for women at time 1 to women at time 2 and men at time 1 to men at time 2 by employing a paired samples *t*-test. In this way, we are able to examine significant gender differences at times 1 and 2, as well as examine whether or not there have been any significant changes in the careers of female researchers as a group and in comparison to male researchers. Finally, using Ordinary Least Squares (OLS), we present three models for each measure of time 2 productivity to answer the question, "does gender and technology use influence research output (Y_t) for fixed levels of productivity (Y_{t-1})?" (Finkel 1995). The first model, presents the regression results for the full sample, while the second and third models disaggregate the results by gender.

Table 1 presents relationships between the gender of our respondents and the research context within which they are employed, including country, sector, and field.[18] Most of our 119 female respondents (58 percent) work in Kerala.[19] The large percentage of women scientists in Kerala is consistent with the historical and cultural conditions in this south Indian state, which has the highest female literacy rate in India. A slight majority of our respondents are from the academic sector (297 respondents are employed in the academic sector and 242 in research institutes). Women are more likely to be employed in academic institutions than in the research sector (66.4 percent compared to 33.6 percent) and are concentrated in a biology or biotechnology field. Consistent with trends in the United States, nearly half (approximately 44 percent) of all women in both waves of the study are working in these areas. They are least likely to be working in an IT, engineering, mathematics, or physical science field (approximately 7 percent and 11 percent, respectively). While a slight majority of men are employed in the academic sector (52 percent) and within the field of agriculture (27.6 percent), the distribution across sector and field is relatively even for males (with the exception of the social sciences in which very few men are employed).

Results

In Table 2, we present the chi-square tests and independent samples *T*-tests for gender differences in age, family structure, human capital, localism, and e-mail use. Women are significantly younger than their male counterparts by approximately two years. Consistent with the extant literature on female researchers in more developed areas, women in Ghana, Kenya, and Kerala are significantly less likely in both waves of the survey to be married (84.9 percent of women in wave 1 were married compared to 93.3 percent

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Table 1. Chi-Square Test of Contextual Differences between Male and Female Scientists: Country, Organization Type, and Field Differences

	2005		
Variable	Male	Female	*N*
Context			
1. Country	***		540
Ghana	34.2	12.6	
Kenya	38.5	29.4	
Kerala	27.3	58.0	
2. Organization type	**		540
Academic	52.0	66.4	
Research Institute	48.0	33.6	
3. Field	***		539
Agriculture	27.1	26.3	
Physical Sciences	20.9	11.0	
Biology/Biotech	27.6	44.1	
IT/Engineering/Math	20.2	6.8	
Social Sciences	4.3	11.9	

* $p < .05$.
** $p < .01$.
*** $p < .001$.

of males and 85.7 percent in wave 2 compared to 96.7 percent of males). Women have significantly fewer children than male scientists in both waves (2.05 children in wave 1 compared to 2.42 for males and 2.10 children in wave 2 compared 2.61 for males).

Gender roles prescribing domestic responsibilities for women (particularly for those married and with children) are generally viewed as the important factor in delaying family formation for female researchers, while men are less likely to feel such pressure. Although the results should be interpreted with caution, as close to 80 percent of male researchers report working wives, the data on spouse's occupation provide limited support for this argument. Nearly 20 percent of men (18.1 in wave 1 and 19.4 in wave 2) report a spouse whose primary occupation is domestic labor, while none of the women's spouses stay at home. Women often report being married to a spouse who is also a researcher (approximately 20 percent in wave 1 and 17 percent in wave 2).

While women represent a minority of our sample (and a minority of all researchers in Ghana, Kenya, and Kerala), the women who make it through the educational pipeline to a scientific career are slightly more likely to

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Table 2. Independent Samples *T*-Test and Chi-Square Test of Differences between Male and Female Scientists in Wave 1 and Wave 2: Age, Family Structure, Human Capital, and Localism Differences

	2000-2002			2005		
Variable	Male	Female	*N*	Male	Female	*N*
1. Age	45.09**	42.85	540	48.70*	46.97	540
Family structure						
2. %Married[a]	93.3**	84.9	540	96.7***	85.7	538
3. #Children[b]	2.42**	2.05	535	2.61***	2.10	533
4. %Domestic Laborer	18.1***	—	540	19.4***	—	536
5. %Researcher	9.6**	20.2	535	7.7**	16.8	536
Human capital						
6. %PhD	55.3	56.3	540	60.3	66.4	540
7. %Masters	35.4	34.5	540	34.4	27.7	540
Localism						
10. %Any DC Education[c]	64.4***	28.6	508	73.6***	37.5	536
11. #Yrs outside country for ed.	2.23***	.95	529	2.52***	1.11	536
12. #Yrs spent abroad altogether	2.48***	1.14	532	2.77***	1.41	539
13. #Days away from parent org.	36.15**	22.16	496	35.65	34.10	519
14. %Access to e-mail	67.2	67.5	532	92.6***	82.4	538
15. #E-mail Diversity[d]	2.35**	1.81	522	3.04**	2.54	532
16. #Hours spent using e-mail[e]	1.52***	1.08	528	1.88**	1.63	525

Note: a. Significant differences for variables preceded by a % were tested using a chi-square test.
b. Significant differences for variables preceded by a # were tested using a *t*-test.
c. 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.
d. Diversity ranges from none—a score of 0—to maximum diversity of use—a score of 6.
e. Hours of e-mail use is an ordinal variable ranging from 0 = *none*, 1 = *low*, 2 = *medium*, 3 = *high*.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

possess the PhD in both waves (56 percent of women compared to 55 percent of men in wave 1 and 66 percent of women compared to 60 percent of men in wave 2). By wave 2, female researchers are, if anything, opening a gap between themselves and male scientists in their possession of the PhD.[20] This trend will have to be tracked in the coming decades to determine if a genuine gap in education actually does emerge for men and women in research careers. Whether or not women are able to turn this investment into scientific output will be addressed below.

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In addition to family structure and human capital, the literature also suggests that travel experiences outside of the immediate environment are an important gender difference in resource poor areas. Indeed, female researchers in both waves of the study spend significantly fewer years outside of their respective countries either for educational purposes (0.95 years in wave 1 and 1.11 years in wave 2 for women, compared to 2.23 and 2.52 years, respectively for men) or for more general reasons (1.14 years in wave 1 and 1.41 years in wave 2 for women compared to 2.48 and 2.77 years, respectively for men). These differences are reflected in the fact that women are also significantly less likely to possess a degree from a developed country (28.6 percent report this status in wave 1 compared to 37.5 percent in wave 2, while 64.4 percent of men report this status in wave 1 and 73.6 percent in wave 2).

On the majority of the variables measured, then, female researchers are more locally oriented than their male counterparts, regardless of the time period—although they seem to be becoming less so. The number of days spent away from the parent organization emerges as an exception to this rule. In wave 1, female researchers spent significantly fewer days away from their organization compared to men (22.16 days compared to 36.15 days). By wave 2, male and female researchers spend about the same number of days away from their parent organization (approximately 34 days for women and 36 days for men).

In addition to greater travel experiences and greater investments in human capital, Table 2 indicates that technological changes in these three countries have been extensive. From time 1 to time 2, both men and women are reporting dramatic increases in their access to e-mail and their diversity and intensity of e-mail use. Although men and women both appear to be heavier users of e-mail by the second wave of our study, it is also clear that in both waves, female researchers are less technologically oriented than men. In both waves of the study, women are not as diverse in their use of e-mail (out of a six-point scale, women have a score of 1.81 compared to a score of 2.35 for men in wave 1 and a score of 2.54 for women compared to 3.04 for men in wave 2) and use it less intensely (1.08 compared to 1.52 in wave 1 and 1.63 compared to 1.88 in wave 2) than their mail counterparts.[21] Further, by wave 2 of our study, gender differences in access to e-mail emerge, with women being *significantly less* likely to report such access (82.4 percent of women report access compared to 92.6 percent of men). So while significant gender differences exist, it is within the context of progressively greater use of ICT for women.

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Table 3 shows the extent to which gender differences exist in productivity levels over the two waves of our study.[22] Panel A shows the extent to which men and women differ at each of two time points, while panel B shows the extent to which women have changed from time 1 to time 2. Two broad findings emerge from Table 3. First the *only* significant gender differences are in foreign publication productivity and presentations at international conferences. Second, men, but not women, are improving their research output. This suggests that over time, the productivity levels of males and females may begin to diverge, as women are not reporting higher productivity levels to the same extent as men.

For most of our output variables, few gender differences exist in either wave of the study. Male and female researchers in both time periods produce virtually the same output in nearly all of the venues examined. However, the two gender differences that do emerge are not only persistent across waves but they are also in those venues generally supposed to be most affected by the use of ICTs. (1) Female researchers present significantly fewer papers at international conferences in both waves of the study (1.24 articles in wave 1 compared to 1.80 articles for men; 1.38 articles in wave 2 compared to 2.08 articles for men). (2) Women publish fewer articles in foreign journals in both waves (0.94 articles in wave 1 compared to 2.10 articles for men; 1.01 articles in wave 2 compared to 3.33 articles for men). This gender difference in foreign journal publication actually appears to be growing over time. While both men and women report an increase in foreign journal publications from time 1 to time 2, the increase for women is negligible, more so than any other venue.

Panel B of Table 3 shows that women report very few significant changes over this time period. There are slight increases in research output, but indicators are not significantly different with two exceptions. In the second wave, women are significantly more productive in terms of the number of research papers written, whether published or unpublished (3.13 papers in the first wave compared to 3.66 papers in the second wave), and women are publishing more chapters in edited volumes over time (0.59 chapters in the first wave compared to 0.91 chapters in the second wave). Otherwise, the research output of women has been relatively stable.

Men, on the other hand, report a significant increase in research output on all but two of the indicators examined: the number of bulletins for extension and the number of articles published in national journals. Male researchers are more productive in terms of the number of papers presented at national and international workshops and conferences, the number of reports, research papers written, and book chapters. Finally, they are much

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Table 3. Panel A: Independent Samples *T*-test: Differences in Productivity Between Male and Female Researchers in Wave 1 and Wave 2

	2001			2005		
Variable	Male	Female	*N*	Male	Female	*N*
Productivity[a]						
#Papers at state or national workshops	4.27	4.41	487	5.53	5.50	532
#Papers at international conferences	1.80*	1.24	468	2.08**	1.38	520
#Reports	4.68	4.98	481	6.71	5.91	526
#Bulletins for extension	1.15	1.05	440	1.75	0.91	513
#Research papers written in past year	2.95	3.12	482	3.99	3.56	517
#Articles in foreign journals	2.10***	0.94	447	3.33***	1.01	525
#Articles in national journal	2.50	2.81	466	2.75	3.15	521
#Chapters in books	0.68	0.59	424	1.01	0.90	515

Panel B: Paired Samples *T*-Test: Changes in Male and Female Productivity Over Time

	Female			Male		
Variable	2001	2005	*N*	2001	2005	*N*
Productivity[a]						
#Papers at state or national workshops	4.44	5.56	113	4.29***	5.85	368
#Papers at international conferences	1.24	1.38	111	1.77*	2.21	345
#Reports	5.00	6.04	112	4.69***	6.65	359
#Bulletins for extension	1.04	0.94	109	1.14	2.04	319
#Research papers written in past year	3.13*	3.66	106	2.97**	4.17	358
#Articles in foreign journals	0.94	1.02	109	2.11**	3.70	331
#Articles in national journal	2.83	3.34	109	2.52	2.92	345
#Chapters in books	0.59*	0.91	108	0.69*	1.00	312

Note: a. Except for the number of papers written, the measures of research output is for the period between 2000 and 2005.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

more productive in terms of articles in foreign journals (2.11 compared to 3.70). In sum, Table 3 reveals geographic differences in research productivity, suggesting men and women are largely similar but distinctly different in international venues.

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Tables 4 and 5 present multivariate analyses predicting logged productivity for the number of research papers written and presented at international conferences and the number of publications in foreign and domestic journals. Gender is the primary independent variable, along with technology and our control variables. In all four models, the lagged dependent variable is the most consistent predictor of time 2 output. This indicates a stable pattern of productivity and is consistent with the literature coming out of a more developed context: those who are more productive at earlier points in time continue to be more productive later in their careers (Allison, Long, and Krauze 1982; Cole and Zuckerman 1984; Long 1978, 1990; Reskin 1977; Zuckerman and Cole 1975). The relationship between early productivity and later productivity appears to be stronger for men than women, as the lagged dependent variable is significant in all four models for men but is only significant in two models for women. Those women who publish more in foreign journals and write more research papers in time 1 are more productive in these venues at time 2.

Contextual differences in research output include location and sector, but not family structure. For the full sample and for men as a group, researchers from Kenya tend to publish less in national journals than do researchers in other locations, while Indians publish more in foreign journals (for both the full sample and for men). Respondents employed in a research institute are less productive in national journals, and this pattern holds for both the full sample and for men. However, those employed in a research institute are *more* productive in terms of the number of papers presented at international conferences, probably because of the greater availability of travel funds. Surprisingly, family structure is not a significant predictor of research output in this context. However, older respondents do write fewer research papers than do younger researchers ($b = -.005$).

In Table 3 we saw that two types of research output emerged as statistically different by gender and across both waves: the number of articles published in foreign venues and papers presented at international conferences. Consistent with the bivariate relationship, significant gender differences emerge for research output in foreign journals: women, controlling for other factors, are significantly less likely than men to publish in international venues ($b = .116$). In the bivariate analysis, men were significantly more likely to present at international conferences. However, when human capital and technological behavior are controlled, the relationship disappears. Based on the results in tables 4 and 5, men and women write approximately equal numbers of research papers, present approximately equal numbers of

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Table 4. Time 2 Productivity Counts: Research Papers Written and Presented at International Conferences for the Full Sample, Males, and Females

	Number of Research Papers Written in the Past Year 2005 ($N = 429$)			Number of Papers at International Conferences 2005 ($N = 420$)		
Independent and Control Variables	Full Sample	Males ($N = 327$)	Females ($N = 102$)	Full Sample	Males ($N = 314$)	Females ($N = 106$)
Constant	.554*** (.101)	.501*** (.125)	.738*** (.190)	.220 (.120)	.300 (.156)	.102 (.224)
Gender (1 = *male*)	−.010 (.032)	—	—	.033 (.036)	—	—
Age (years)	−.005* (.002)	−.006* (.003)	−.002 (.004)	−.002 (.002)	−.003 (.003)	.000 (.004)
Education (1 = *PhD*)	.103** (.032)	.087* (.039)	.134* (.057)	.148*** (.037)	.184*** (.044)	.073 (.067)
Family structure						
Married (1 = *yes*)	.019 (.049)	.056 (.064)	−.087 (.083)	−.011 (.057)	.022 (.077)	−.053 (.095)
Number of children	.003 (.011)	.012 (.013)	−.031 (.023)	−.010 (.013)	−.014 (.016)	.027 (.029)
Spouse a researcher (1 = *yes*)	.045 (.037)	.051 (.048)	.106 (.063)	.011 (.043)	−.019 (.055)	.095 (.074)
Localism						
# years abroad	−.004 (.006)	−.002 (.007)	−.017 (.014)	−.013 (.007)	−.014 (.008)	−.006 (.016)
Context						
Kerala[a]	.014 (.044)	.025 (.050)	−.068 (.122)	−.026 (.052)	−.041 (.059)	.019 (.147)
Kenya	−.065 (.036)	−.061 (.040)	−.090 (.104)	.000 (.044)	−.005 (.050)	−.003 (.125)
Sector (1 = *research institute*)	.000 (.027)	.017 (.032)	−.058 (.052)	.063* (.031)	.058 (.037)	.060 (.061)
Technological behavior						
Extent of e-mail use	.012 (.008)	.014 (.010)	.005 (.018)	.035*** (.010)	.037*** (.011)	.011 (.022)
Intensity of e-mail use	.041* (.017)	.049* (.020)	.013 (.036)	.007 (.021)	.000 (.025)	.034 (.043)
Time lag	.110*** (.016)	.130*** (.020)	.074** (.026)	.100*** (.017)	.108*** (.020)	.070 (.037)
R	.273	.291	.312	.256	.276	.199

Note: a. Ghana is the reference category.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

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articles at international conferences, and publish equal numbers of papers in domestic journals.

Does the extent of e-mail use (in terms of the six types of e-mail activities measured) and intensity (measured by low, medium, and high hours of e-mail use) relate to productivity? For female researchers as a group, neither technology measure is significantly related to productivity in time 2, and this pattern holds across all four measures of research output. Interestingly, the only measure for research output not associated in any way with technology use is productivity in *domestic* journals. According to the first models in tables 4 and 5, those using e-mail more intensely are more productive in foreign journals ($b = .077$) and write more research papers ($b = .041$). The effect of time spent using e-mail, furthermore, is also significant for men as a group. Looking at the second models in tables 4 and 5, men who use e-mail more intensively are more productive in foreign journals ($b = .086$) and they write more papers ($b = .049$). Using e-mail for a wider variety of purposes is also significantly related to the number of articles presented at international conferences for both the full sample ($b = .035$) and for males as a group ($b = .037$). The association of e-mail use with research output is restricted to men.

Outside of the stability effect measuring time one research output, our measure of human capital is the strongest predictor of productivity in all four models. For the full sample, having a PhD is significantly and positively related to the number of papers written ($b = .103$), the number of papers presented at international conferences ($b = .148$), and the number of papers published in foreign ($b = .125$) and domestic journals ($b = .136$). When disaggregated by gender, however, the effect of having a PhD is only significant for males. Investment in human capital pays off for men in greater output, as those possessing a PhD are more likely to publish in domestic and foreign journals, and they write and present more papers. One exception does emerge. Both men and women with a PhD write more papers. Human capital appears to contribute to the authorship of papers but does not translate into visible publications for women.

Discussion

We sought to answer three questions in the context of three scientific communities in low-income countries: (1) To what degree do gender differences in research output exist in Ghana, Kenya, and Kerala? (2) Do observed differences continue to exist once other factors are controlled? and (3) Are gender disparities in productivity explained by differences in ICT use?

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Table 5. Time 2 Productivity Counts: Research Papers Published in Foreign and National Journals for the Full Sample, Males, and Females

	Number of Articles in foreign Journals 2005 ($N = 412$)			Number of Articles in National Journals 2005 ($N = 424$)		
Independent and Control Variables	Full Sample	Males ($N = 307$)	Females ($N = 105$)	Full Sample	Males ($N = 319$)	Females ($N = 105$)
Constant	.112 (.133)	.248 (.180)	.197 (.194)	.250 (.141)	.221 (.169)	.202 (.330)
Gender (1 = *male*)	.138*** (.040)	—	—	−.039 (.042)	—	—
Age (years)	−.003 (.003)	−.004 (.003)	.000 (.004)	.001 (.003)	−.002 (.003)	.006 (.006)
Education (1 = *PhD*)	.125** (.042)	.150** (.054)	.069 (.055)	.136** (.043)	.159*** (.049)	.037 (.089)
Family structure						
Married (1 = *yes*)	−.074 (.065)	−.074 (.093)	.041 (.080)	.081 (.071)	.176 (.093)	−.095 (.134)
Number of children	.004 (.015)	.003 (.018)	.011 (.024)	.017 (.015)	.023 (.017)	−.005 (.038)
Spouse a researcher (1 = *yes*)	.018 (.047)	−.002 (.064)	.072 (.059)	−.019 (.050)	−.023 (.060)	.056 (.100)
Localism						
# years abroad	−.004 (.008)	−.005 (.009)	.001 (.014)	−.015 (.008)	−.011 (.009)	−.051* (.023)
Context						
Kerala	.129* (.061)	.147* (.072)	−.152 (.136)	.030 (.062)	.046 (.066)	.120 (.215)
Kenya	.085 (.050)	.099 (.059)	−.123 (.115)	−.137** (.050)	−.153** (.053)	−.001 (.184)
Sector (1 = *research institute*)	−.006 (.034)	−.004 (.044)	−.022 (.051)	−.076* (.036)	−.090* (.041)	−.118 (.084)
Technological behavior						
Extent of e-mail use	.020 (.011)	.018 (.014)	.017 (.018)	.009 (.011)	.007 (.012)	.020 (.029)
Intensity of e-mail use	.077*** (.023)	.086** (.028)	.042 (.035)	.011 (.023)	.009 (.025)	.004 (.058)
Lagged Dependent	.171*** (.017)	.170*** (.020)	.160*** (.029)	.080*** (.017)	.084*** (.019)	.067 (.036)
R	.411	.371	.478	.261	.289	.240

Note:
*$p < .05$.
**$p < .01$.
***$p < .001$.

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Using panel data and controlling for time 1 research output, our findings suggest very small but significant differences between males and females in this context. Four important findings emerged from our bivariate and multivariate analyses: first, those measures of the research career traditionally used to explain gender disparities in productivity (family structure and localism) do not emerge as significant factors within these three locations; second, investments in education do have a fairly consistent effect upon productivity; third, substantial increases in access to e-mail have occurred but have not reduced gender disparities; and fourth, gender differences in productivity are small overall but quite significant for the type of output with the greatest consequences for international visibility—publication in foreign journals. Productivity in foreign journals is not only the most visible to the scientific community at large, but it is often the standard for providing career rewards in developing countries (Drori et al. 2003).

Consistent with Miller et al. (2006), our results suggest that the trend of increasing investments made in education has not abated. Moreover, productivity is directly tied to the possession of a PhD. Researchers with this credential are generally more productive in mainstream scholarly venues such as foreign and domestic journals and they present and write more papers. Not only is possession of a PhD associated with the type of employment one acquires, it is also associated with accumulating expertise and developing a skill set conducive to increased research output. The fact that women have invested so heavily in acquiring the PhD may be one reason why the bivariate relationship between gender and productivity reveals few differences. However, based on the results of our multivariate analyses, it may be men benefit more from education than women. Men consistently translate higher education into writing, presenting, and publishing. No such relationship emerges for women as a group.

A similar effect characterizes the association between gender, technology use, and productivity. Access to and use of technology has increased dramatically within all three countries. Regardless of gender, researchers in Ghana, Kenya, and Kerala have more access to ICTs now than in the recent past. Women continue to lag behind their male counterparts in such access, and while their use of technology has changed, it is changing at a slower rate. Outside the scientific community, women tend to be slower adopters of such technology, but within the scientific communities examined here, this pattern is directly tied to resource distribution. In environments where resources are limited, those with greater status are likely to garner a greater share of the resources, but it is important to note the differences here are small and access is widespread.

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As with our human capital measure, the association of e-mail use with research output occurs for men but not women. In other words, it is not enough to simply provide the technology. Even with far greater access to ICTs, women have not translated this resource into research output in the one area that should be directly impacted by technology use: foreign productivity. In fact, not only do our bivariate analysis show that over time women's productivity levels have not expanded to the same extent as men's, but there appears to be an *increasing* gap favoring men in foreign journal publications. One question that requires further investigation is whether or not the increase in research productivity for men and relative lack of an increase for women will continue over time, particularly in foreign journals. If so, the gender divide that is diminishing in the area of ICT access, will become *more* significant for inequality in productivity. While controlling for human capital and technology use eliminated gender differences in international presentations, differences remained in foreign journal output. Even with greater access to e-mail, a technology that can make communication and collaboration easier and more efficient, and even with greater investments in education and training, female researchers in Ghana, Kenya, and Kerala are less productive in foreign journals than their counterparts.

We are not arguing for any simple causal connection between ICT use and research productivity. Contemporary STS shows that available technologies are captured by users in multiple and unforeseen ways. As Holland (2009) and Shrum (2005) note in their discussion of reagency, the unpredictability of technology use is especially evident within the context of donor sponsored information technology transfers to low-income areas. When research or development projects funded primarily by outside agents enter an environment of resource scarcity, the projects are subject to historical, institutional, cultural, and political demands that are often inconsistent with donor expectations. It is quite possible that other, unmeasured activities are of greater interest to the women in our study, as the original reagency and circumvention arguments suggested (Palackal et al. 2006; IDREF1; Anderson 2007).

It is also possible e-mail is not the most appropriate technology measure for predicting research productivity, particularly in the context of a low-income country. Indeed, more recent studies on the spread and use of technologies suggest the mobile phone may be a more appropriate tool within this context, as it is less expensive to use and does not face the same infrastructural constraints (James and Versteeg 2007). Other studies have found a positive impact of noncommunication applications (such as remote login software, ftp and Kermit) on publication output (Barjak 2004).

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Conversely, the relationship between e-mail use and productivity may operate in the opposite direction with e-mail activity being indicative of other social statuses. Those who use e-mail more frequently and more diversely may actually be more productive and of higher professional status to begin with. Perhaps, researchers attending more conferences, writing more research papers, and publishing more in foreign and domestic journals are embedded in more geographically dispersed professional networks providing incentive to use computer-mediated communication to maintain such contacts.

Even if ICT use is associated with research productivity in the direction we have examined here, the relationship may be an indirect one operating through the creation of social capital. A central tenant of social studies of science links knowledge production to communal activities. Researchers collaborate and network with colleagues in the sharing of information and ideas, the publishing of articles, and the evaluation of each other's work. In their discussion of gender differences, Campion and Shrum (2004) suggested that women were more locally oriented then men, which led to the conclusion that the important gender differences lie in social rather than material resources. In short, establishing and maintaining formal and informal professional contacts is an integral part of the scientific career.

These professional relationships, however, are formed and maintained within a given organizational and social context (technologies themselves are not entering an empty space). Work environments marked by greater competition among or isolation from fellow faculty members, disproportionate work loads in terms of the percentage of time spent on research, teaching, or administration, and conflict between work and domestic responsibilities can be more or less conducive to women's incorporation into formal, informal, and technologically mediated professional networks (Fox 2010). It follows, then, that disparities in publication productivity may be linked to gendered experiences within professional networks, which are linked to gendered experiences within an organizational environment. Research examining the social–organizational experiences of women employed in preeminent research institutions within the United States suggests women experience greater professional isolation, benefit less from human and material resources within their respective organizations, and experience greater intrusions of family life upon work life (Fox 2010; Fox and Mohapatra 2007). How might the organizational environments in Ghana, Kenya, and Kerala structure women's research productivity?

Whether social and organizational work environments or measures of network size and structure are examined, this study demonstrates that shifts in education and communication technologies have yet to alter the primary

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productivity difference (publications in foreign journals) between men and women in low-income areas. The central tenet of circumvention was that new ICTs would eventually help women scientists in low-income countries to narrow important career divides by altering the relationship between localism and the research career (Campion and Shrum 2004; Palackal et al. 2006). We note that women are not only traveling more but are also reporting far greater access to communication technologies. What is not clear is whether women are effectively using these new technologies to circumvent mobility constraints since their research output—not just in foreign journals but in general terms—has remained somewhat static. These findings suggest that mediation processes by which technology and education are translated into productivity gains should be viewed as the root of the problem for policy purposes.

As ICTs continue to diffuse and assume greater centrality in the production of new knowledge, it is more important than ever that the gendered nature of ICT use be tracked. Based on the analysis in this article, it appears that circumvention processes involving ICTs have not born fruit in narrowing the gender gap that may be most central to the scientific career. However, future studies must examine the organizational environment, as identified by Fox (2010), in order to determine the extent to which new technologies are used to alter institutional constraints and to what extent they are simply incorporated into the existing social milieu.

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Notes

1. Publication productivity may be a simple measure of scientific output, but it is not uncontroversial (Shrum 1997). A number of problems inhere in the

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measurement of scientific output through productivity. In particular, such a measure does not distinguish between sole and multiauthored publications or between articles published in first, second, or third tier journals. By including a variety of measures of research output and not simply work that has been published, the findings reported here provide a broader reflection of research productivity. In addition, publications in journals or books are not the only or even necessarily the most important aspect of productivity in either developed or low-income areas, which is why we have included a variety of measures of research productivity not simply publications. Having said that, publications are the institutionalized means of making ones research visible to the scientific community and this is reflected in both developed institutions as well as institutions in low-income areas (Arunachalam 2003; Drori 2003; Eshiwani 1999; Xie and Shauman 1998). For instance, an article published in the Indian newspaper, the Indian Express, noted the move among colleges and universities toward requiring research publications for promotions (Shukla 2010). In addition, a non-profit organization in South Africa has established a centralized online database for peer-reviewed African published scholarly journals in the hopes of reversing the historical flow of scholarly knowledge from North to South. Finally, based on our own sample of researchers, when asked whether or not research is the most important aspect of their career, close to 90 percent of both men and women in both waves agreed or strongly agreed that their research is the most important aspect of their career. Although not necessarily an indicator of institutional pressure to publish or even a desire to publish, the end product of research is often a scholarly presentation and/or publication in some venue.

2. Our project has examined field of research in a number of analyses. In this study, we classify fields into six categories: (1) agriculture, (2) chemistry/physics, (3) geology, (4) biology/biotechnology, (5) information science/engineering/statistics, and (6) the social science. Regardless of the number of field categories examined, this dimension has not been significantly related to productivity.
3. Age tends to be negatively associated with productivity, particularly for female researchers. Due in part to the fact that it is only within the past couple of decades that women have made significant advances in postsecondary scientific education, these studies suggest not only do older women publish less than younger women but they also publish less than men who are of a comparable age. There is a general consensus that female researchers postpone family formation at rates greater than their male counterparts, but there is very little consensus regarding the effect of family formation on productivity, with some noting either a slightly negative but insignificant effect (Long 1990), a noneffect (Fox 2005), or even a positive effect of the presence of children on career outcomes for female researchers (Fox 2005).

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4. Regarding technology access and connectivity, Ghana, in 2005 reported 18.4 Internet users and 5 personal computers per 1,000 people. Ghana has a higher connectivity rate than many African countries, although it lags behind Kenya. In 2005, Kenya reported more extensive diffusion of the Internet and personal computers than Ghana—32.4 and 9 per 1,000 people, respectively. The country of India as a whole reported 54.8 Internet users and 16 personal computers per 1,000 people.
5. Kerala goes against the dominant strand of thought in economics, which contends economic growth is needed *before* social development can occur. The characteristic of high social progress and low-economic development, combined with a politically active population and radical land reforms comprise the dominant features of the Kerala model of development (Franke and Chasin 1994).
6. The first wave of data was gathered in 1994, the second over the period 2000-2002, with a midpoint of 2001, and the third in 2005. In the third wave of our study, we interviewed a total of 860 researchers. Efforts were made to interview as many of the respondents from the second wave of the survey as possible. In instances of sample attrition, those respondents no longer willing or able to participate were replaced. Of the 860, 540 were interviewed in both the second and the third waves of the survey for a panel of nearly two thirds (63 percent) of the original sample. Cases of sample attrition were due primarily to retirement or to respondents being away from their respective institutions during the time interviews were taking place.
7. In Kerala, five institutions were selected for inclusion: Kerala Agricultural University at Vellayani, the University of Kerala at Karryavotam, the Center for Earth Science Studies, the Central Tuber Crops Research Institute, and the Regional Research Laboratory (now the National Institute for Interdisciplinary Science and Technology). Respondents from Ghana were selected from the University of Ghana, the University of Cape Coast, the Science and Technology Policy Research Institute, the Institute for Science and Technical Information, and a number of subsidiary organizations under the Council for Scientific and Industrial Research. Finally, in Kenya, four institutions were selected for inclusion: Egerton University, the University of Nairobi, Jomo Kenyatta University of Agriculture and Technology, and the Kenya Agricultural Research Institute.
8. Specifically, there are five basic panel analysis models: (1) structural equation models with reciprocal and lagged effects, (2) repeated measures analysis of variance, (3) growth curve and hierarchical effects models, (4) fixed and random effects regression estimators, and (5) regression using change scores (which includes lagged dependent variables, residual change score models, lagged panel models, and first difference models of change; Johnson 1995).

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9. In order for the model to be considered a Conditional Change Model, one simply includes the time 1 value of the dependent variable on the right side of the regression equation. The model can also predict a change in Y, using the time 1 value of the dependent and time 1 values of the independent variables. The model can also be specified to predict the time 2 value of the dependent variable using the time 2 values of the predictors or some variation thereof (Finkel 1995).
10. Examples of time invariant measures abound. For instance, a nation's history, culture, economic system, religious composition, organizational environment—including expectations for collaboration, productivity, and resource availability—and field of study are all important context for productivity.
11. The decision of whether to include X_t or X_{t-1} is one of the most difficult decisions when using panel data. In general, if the time between the waves of the survey is sufficient enough for the time 1 values of the independent variable to have an effect on the time 2 dependent variable than lagged X_{t-1} variables are preferred. However, it is difficult to theoretically determine how much time is necessary for the lagged independent variables to have an impact on the time 2 dependent variables (Finkel 1995).
12. Reports measure two related things: for academics reports typically result from consultancies as a product of project work for donors. They are the same for those at national research institutes, only the projects may be funded from larger pools of money (e.g., money originating from the World Bank). Most of the reports in this study stem from researchers working in national research institutes (in 2001, 6.18 reports published for scientists in national research institutes compared to 3.60 reports for those in universities. In 2005, the corresponding figures were 10.13 reports compared to 3.53 from universities).
13. The two productivity time frames (Twelve months and five years) were selected for two reasons: first, we measure papers written in the last year, as we already include 2 items on formal research article publications (foreign and national), which capture the number of articles for the last five years. Second, and most importantly, the number of research papers written is independent of publications in the sense that it measures actual activity. Researchers may have their names on published papers that they have not personally worked on. Restricting this measure to a one-year time frame makes it less likely the respondents will have forgotten the non-published work they have done.
14. We also examined other measures of productivity, including the number of masters and PhD students supervised, and professional activities more generally. Men and women are not significantly different from one another on these measures.
15. Respondents classified as using e-mail a low number of hours include those people using it less than one hour per week. Those classified as medium users

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reported using e-mail between one and five hours per week, and those classified as high users include those using e-mail more than five hours per week. Although this classification would not work today, in 2001 and 2005, it was a relatively accurate assessment of e-mail use.

16. This variable measures the number of children, regardless of age. In the first wave of the study, our survey did not include a measure distinguishing age of children. By the second wave, we included a question measuring the number of children and the number of children below the age of twenty-one. Because we did not make this distinction in the first wave, we do not use the age-specific variable here.
17. We also present the bivariate relationship between gender and localism in terms of the percentage of respondents with a developed country education, the number of years spent abroad for any reason, and the number of days spent away from one's parent organization (defined as the institution in which a respondent is employed). The bivariate relationship between the field of study (a nominal variable with five categories: 1 = *agriculture*, 2 = *physical sciences*, 3 = *biology/biotechnology*, 4 = *information science/engineering/math-statistics*, and 5 = *social sciences*) and gender is also presented. This factor is not included in the multivariate analysis since analysis show a lack of significance between field of study and measures of career outcomes.
18. Because the distribution of researchers based on country, research sector, and field does not change dramatically from one wave of the survey to the next, we present only the time 2 gender distribution by country, sector, and field.
19. In comparison to Kenya, Ghana (and a number of other West African countries) consistently reports both a smaller percentage of female participation in agricultural research and a smaller share of female students enrolled in and graduating from agricultural education at the bachelors, masters, and doctoral levels (Beintema and Di Marcantonio 2009; Stads and Beintema 2006). This may be in part a reflection of Ghana's lower level of agricultural research and development expenditures in terms of salaries, operating costs, and capital costs.
20. Research compiled by Agriculture Science and Technology Indicators (ASTI) initiative point to a trend of increasing participation on the part of women in agricultural science and technology research but a decreasing trend regarding men's participation. Furthermore, women's level of education has been steadily increasing over the last decade, along with their participation in agricultural science and technology careers (Beintema and Di Marcantonio 2009; Stads and Beintema 2006).
21. These differences are particularly striking when you consider the mode for women's e-mail diversity use in wave 1 was 0, indicating never having used the

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technology, while the mode for men's e-mail diversity use in wave 1 was 2. By wave 2, both increased (women's mode to a 2, men's to a 3). While the gap is certainly closing, with women essentially "catching up" to men, men's diversity score mode is a full one point larger on a six-point scale.

22. The disparity in productivity counts for men and women across tables 3 and 4 are the result of the dropping of missing values owing to respondents not providing information on publication patterns either in panel 1 (2001) or panel 2 (2005).

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