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Network Decline in the Internet Era: Evidence from Ghana, Kenya, and India, 1994-2010

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Abstract: Has the size of personal networks changed since the invention of the Internet? We use a unique longitudinal survey during the primary period of Internet diffusion in Africa and Asia to address three questions. First, has the overall size of professional networks changed? Second, has there been a shift in the kinds of relationships people maintain? Third, are there identifiable patterns in the nature of the shifts over time? We analyze data on nine professional linkages reported by a population of scientists and educators in Kenya, Ghana, and the Indian State of Kerala over a sixteen year period (1994-2010). Results show that extended personal networks experienced a dramatic decline during the initial diffusion of new communication technologies, followed by partial recovery. An increase in collaboration has been accompanied by a decline in friendship.

Keywords: Internet, science, friendship, collaboration, ICTs, social networks

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We present empirical evidence on the size of professional networks in Ghana, India, and Kenya. The data spans the general time frame from the introduction of new information and communication technologies in sub-Saharan Africa and South Asia through 2010, when diffusion among the population of interest was virtually complete. Contrary to both received opinion as well as the expectations of our team of resident scholars, there is evidence that networks have decreased in size.

While the importance of new information and communication technologies is difficult to exaggerate, convincing evidence on social structural shifts before and after their diffusion is difficult to find. In particular, evidence of the impact on extended personal networks has often been limited to matters on which recent data are readily available. For example, many have examined the quality and characteristics of mediated communication, investigating such issues as relative importance of face-to-face and digital interaction (Ling, 2008; Turkle, 2011, 2015; Wajcman, 2015). One exception to this is the contentious area of core personal networks in the U.S., which were reported to have changed in size using a comparison of two decades of results from a survey of discussion partners (McPherson et al., 2006; Fischer, 2009). Other studies on such specific personal relationships as friendship (Pew) focus on the character of relationships, what people do online, or the role of technology in initiating or sustaining ties (Lenhart, 2015). Such studies lack specific information on shifts in network size for extended networks. Those that focus on social media (e.g., Facebook) often neglect the important face-to-face dimensions of relationships (Olson and Olson, 2000). Absent are studies that investigate a population of individuals using the same questions over the full period of time that the Internet was introduced and spread throughout the world. Apart from the flawed General Social Survey, most prior research on social

1 We use the term 'Internet' as shorthand for the broad range of new information and communication technologies that subsequent became available.

relations has occurred within a single time frame—either the pre- or post-Internet period.²

We fill this gap with new data on networks among the educational and research communities in two sub-Saharan African countries and an Indian state of similar size (Kerala). Our most significant data is based on an indicator of the *average size of professional networks*. We report measures of *extended* rather than core networks since it is the *overall* size of the network that may be most affected by new communications media, not the network of close family and friends. Our baseline survey of scientific relationships was conducted in 1994. True, it is impossible to identify any single moment in which the ‘digital flood’ began to occur (Cortada, 2012). Still, this year represents the approximate beginning of diffusion for new information and communication technologies (ICTs) in these regions. The measurement instrument utilized in this baseline was repeated three times during the decade of the 2000s. We use an ‘organizational inventory’³ to generate an indicator of the size of extended personal networks prior to the phase of rapid diffusion.

Here we do not draw conclusions about other countries and other regions of the globe. But in the absence another baseline, we argue that our data are the best that are available to address the question of whether the diffusion of new communications media is associated with a change in network size. All of our information was collected using face-to-face surveys, administered by faculty and postgraduate students.⁴ In addition to size, information on the type of tie, or relational ‘content,’ is available for both baseline and subsequent waves of the survey. These contents include friendship, collaboration, the receipt of information, and exchange of research materials, as examples of professional relationships. Hence, we not only assess the size of networks, but changes in the relative distribution of social relations over sixteen years. This starts at a time when the workplace environment was one in which even telephones were scarce, and ends at a time when messages could be sent from any location

to any other across the globe. For scientists, educators, and researchers in these locations, this represented an unprecedented opportunity for their professional careers.

Two characteristics of the study are important to note. First, our original project was certainly not intended as a longitudinal effort, at least not originally. While we witnessed this transformation, we by no means claim to have anticipated the speed or momentous nature of the change instigated by the Internet and mobile technology. It was not until, approximately, 1998 that we *experienced* substantial change, though such change was still limited. That same year we also visited a research institute that advised us to contact a nearby *prison* by telephone if we wanted to schedule more interviews. Someone would then travel by bicycle to inform the institute!

Second, this is not (1) a study of the relationship between media use and personal networks, nor is it (2) a study of characteristics that predict network structure. Our prior work has shown that there is no strong relationship between the degree (frequency, intensity) of use of information and communications technology and social networks (Palackal et al., 2011; Shrum et al., 2011). But our group of collaborators lives in these locations. We attest to the striking difference it makes when global communications occur quickly and inexpensively—and information becomes accessible with a few clicks of a web page. The rapid diffusion of the Internet and even more rapid adoption of mobile phones were remarkable, particularly for Kenya and Ghana, which had not previously had reliable phone service.

From the standpoint of developing areas, the issue is not so much who uses new ICTs and how often, but the *context in which relationships are formed*, what we call the ‘network context of connectedness.’ Such a change is a ‘network impact’ of using new communications technology in a situation where *few others* have access, as compared with using that same technology in an environment where *nearly everyone* has access. As the pool of people with whom one may communicate expands, eventually including almost every relevant actor in the system, the value of using the new technology increases. It makes a difference whether you are the only one with a mobile phone (as in 2000) or everyone else has a mobile as well (2010).

To begin, we note the three locations selected by the Dutch agency that sponsored the original study and review our survey procedure, distinguishing between core and extended professional networks. Finally, we examine the size of extended networks during the peak period of change in communication and information technology.

² The U.S. General Social Survey measured core (strong) ties rather than extended networks, so it is not comparable with the problem addressed in this note. It should be mentioned, however, that while this methodology was discredited, the finding of decline in network size is consistent with the evidence here.

³ By organizational or relational inventory (also called the ‘distribution of social ties’) we mean the relative frequency of different tie types such as friendship and collaboration.

⁴ Of course, pre-Internet data cannot be collected through the Internet. As such, studies of social relationships using online data collection methods or data scraping cannot be compared directly with pre-Internet baselines.

Method

We collected data at four points in time, using personal interviews with scientists, educators, and researchers in Ghana, Kenya and the State of Kerala in southwestern India (Franke and Chasin, 1994; RAWOO, 1996; Flaherty et al., 2010). In 1994 the Dutch government initiated this study. These three locations were selected to represent diversity in ‘level of development.’ In brief, Kerala was to represent a high level of socio-economic development, Kenya a medium level, and Ghana a low level. But Kerala is not India and in matters of literacy, education, and technology it is more advanced than most areas of India. Nor is it possible to accept the idea that one indicator or ranking of development will be similar to other indicators. Our four waves of data were collected in 1994, 2000, 2005, and 2010.⁵

The period from 1994 through the early 2000s may be viewed as the liftoff period for new communication technologies. Fewer than 1 in 20 of our informants had access to email and we ourselves had not used web browsers (although early versions were available). In the late 1990s we used Internet cafes (dialup connections) but rarely did our informants have connections at home or even their workplaces.⁶ The early 2000s were the period in which cell phones became known and quickly began to diffuse. This technology was a competitor to the Internet café and, for our population, a better investment of personal resources. The Internet *per se* was viewed by many as a secondary mode of communication in sub-Saharan Africa, if not South Asia, where costs were lower and educators had access to greater resources. The ‘competitive’ period, then, involved a shift in emphasis to mobile telephony. Following 2005 was period we view as routinization, although this term is more appropriate for the institutionalization of the Internet and mobiles than its implication that technology was somehow static.

Our results here are based on personal interviews with the individuals involved in higher education and research at the primary university and government research institutions in each location. We utilized a social network approach to data collection (Fischer, 1982; Marin and Wellman, 2011; Marsden, 2011; Kadushin, 2012; White, 2011). We collected linkage data from scientists and educators in four periods, generally lasting from one to two months, asking about nine types of professional

linkages: friendship, collaboration, exchange of materials, information, funds, workshops, visits, employment, and other. In sum, 65,045 social relationships were reported.⁷ The following section describes the sample, interview procedure, and measures. We indicate how our organizations and respondents were selected, as well as the manner in which specific prompts were combined with respondent nominations to create a set of linkages. Next, the content of those linkages (‘tie types’) was measured for a more detailed description of relational change.

Small differences in procedure characterized each wave, owing to resource availability and shifts in institutional identities over such a lengthy period. Apart from 1994, interviews were conducted in the state research institutes and universities that constitute the core of the national research system in most developing areas. Private research activities were negligible.⁸ The pattern was set in 1994 when we targeted scientists in agriculture, environment, and natural resource management. Teams of three interviewers covered the main universities and research institutes throughout the region but high costs of travel forced us to target subsequent waves closer to the three capital cities: Nairobi (Kenya); Accra (Ghana); Thiruvananthapuram (Kerala).⁹ The second wave of data collection began in 2000 in India (n=303), continuing in 2001 with Kenya (n=313), and in 2002 in Ghana (n=271). The third wave was gathered for all three countries in 2005 (Kerala n=260; Kenya n=305; Ghana n=280). The most

⁷ Owing to these resource constraints, the second wave of data was actually finished in 2002 in Ghana. Until 2005 we did not have sufficient funds to survey the three locations within a single year.

⁸ The 1994 wave included interviews with NGOs and international research organizations. These two sectors were not included in the other waves beginning in 2000 and these links are not included in the analysis.

⁹ This strategy proved crucial, since research institutions tend to be concentrated in the vicinity of the main population centers. Five institutions were selected for inclusion in Kerala including two universities—the Kerala Agricultural University at Vellayani and the University of Kerala at Kariyavattom—and three national research institutes—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 also selected from two universities—the University of Ghana and the University of Cape Coast—and a variety of national research institutions—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, four institutions were selected for inclusion in Kenya including three universities (Egerton University, University of Nairobi, Jomo Kenyatta University of Agriculture and Technology) and the Kenya Agricultural Research Institute.

⁵ In some cases our funds did not allow the entire wave to be completed within the calendar year.

⁶ Limited email access may be contrasted with computer access, which was reported by nearly 60 per cent of the sample, but referred generally to shared access.

recent survey was conducted in 2010 (Kerala $n=263$; Kenya $n=342$; Ghana $n=316$).

In each of these waves, the study team approached the director of each selected department or research institute for permission to interview scientists. We sought to interview everyone with a job title of scientist regardless of degree held. All those working in professional positions involving research were selected for inclusion. The majority of our respondents were employed in research fields related to agricultural, environmental, and natural resource management, with relatively few in the social sciences. Refusals were rare (2-5 per cent), owing to the endorsement of management. Our sample represents the national or regional system of research on agriculture, environment, and natural resource management in three areas at four points in time.¹⁰ The areas were selected for two reasons. First, lower income countries, often focus most of their research attention on two fields: health and agriculture. Apart from the health and medical fields, agriculture (broadly conceived to include natural resources and environment) is the only research area that has multiple research institutes in each country as well as university departments and faculty. Second, some initial support for the project was provided through the International Service for National Agricultural Research (ISNAR), which had conducted preliminary overviews of these countries that helped in the identification of institutions.

We used links reported by all scientists interviewed. Our population, then, is a comprehensive social network of research organizations in the capital areas of Kerala, Kenya, and Ghana focused on agricultural, environmental, or natural resource management (that is, research departments and institutes with substantial recognized expertise in these areas). This does not mean, of course, that every scientist was included, since some researchers operate independently or are affiliated with NGOs, consulting firms, and the private sector. We restricted our sample to the 'formal' organizational research system, institutions with significant expertise in these subject areas.¹¹

¹⁰ It is impossible to calculate a conventional response rate for this population: often the list of staff includes individuals who are no longer present, on extended study leave, or on 'formal' leave even when they have left for a post at another institution. Since the formal list of scientific staff (maintained in the director's office or on poorly-maintained web sites) is inaccurate, our primary issue was the availability of staff during the period allocated for the interviews at the location (typically one to two months). Since the director or chair generally sent a notice of cooperation, the actual number of verbal refusals to be interviewed was trivial during the entire period of the study.

¹¹ More details on the research procedure may be found in Shrum and Beggs (1997).

Survey Procedure

There are two basic approaches for collecting network data in face-to-face interviews. One utilizes name generators ('Who are your best friends?'), open-ended prompts that require the respondent to remember and reproduce those with whom s/he has some kind of social relationship. The other employs a list of names or groups with whom s/he has interacted or is affiliated. The respondent was asked to view, rather than create, an inventory of social actors and indicate that subset with which they are linked. This second interview process involves narrowing down a larger group of potential ties to a smaller group of actualized ties (Hanneman and Riddle, 2011; Marsden, 2011).

Where the population of interest is small (e.g., members of a single family or a classroom in a school) the differences between these two methods may be negligible, but each has its own advantages and constraints in specific applications. The name generator method tends to be more useful for describing close ties or 'core networks,' those relatively smaller sets of links involving intense interaction. But owing to limits of time, attention, and memory this method is less useful for measuring the breadth of an ego-centered network, that is, the entire range of an individual's social ties. The 'total network' of interaction for an individual is quite difficult to assess, even in a single sphere such as professional life. For this purpose the list or roster method may be more effective and reliable. Here the respondent need only recognize, rather than generate, linkage information.

However, the roster method has drawbacks as well, particularly when the population of possible ties is large—as is precisely the case for the digital era. Scientists might require information from across the globe or interact with a diverse group of delegates at an international conference. This population of potential ties is enormous. A list of individual names that the respondent scans for actualized ties is not feasible. Our interest was in the development of an indicator of the total network that could be tracked across waves and included specific information on relational content. We therefore used organizations as the selection criterion, allowing the widest possible scope for reporting relationships across continents and countries, from the local to the global. An individual, in this roster method, is not asked about contacts with other individuals, but contacts with other organizations. While it is impossible to list all conceivable professional contacts, our method utilized a list of the most relevant professional organizations, both nationally and internationally. This list was compiled using the initial lists provided by ISNAR (above), supplemented by

bibliometric surveys of the publication records of these areas, and finalized using the help of informants.

Respondents were presented with an eight-page list of organizations divided into four groups of about two pages each: international organizations, university departments, state and national research organizations, and non-governmental organizations. This guided roster technique uses two passes through the list to provide information about (1) the specific organizations with which the respondent was connected, and (2) the specific kinds of linkages these connections represent. Because we did not want the respondent to be worried about the length of the final list or to preview the specific content of the relationships, we presented the list in sections (international agencies, universities, etc.) and folded the list in half lengthwise, such that the respondent saw only the name of each organization. Interviewers then gave the following instruction as a prompt: ‘For each of these organizations, please indicate whether you have had any relations with it during the past five years...That is, have you had any kind of contact or dealings with it? When I say relations with an organization I include relations with the people who are members of that organization.’

We sought to keep lists identical across years, except where an organization changed names completely or a new organization was added, which was rare. To illustrate, for the 2010 Kerala survey, the roster included 63 international organizations listed, 25 university departments, 84 state and national research organizations (including private firms as well as Ministries and apex organizations), and 22 non-governmental organizations. These nearly two hundred organizations that were presented as potential relations included many of the most important funding agencies, international research institutes, and local universities, research institutes, ministries, and NGOs.¹² Each respondent viewed the list, checking off organizations with which they had interacted during the past five years. Yet even this—a relatively comprehensive list of research, educational, and scientific organizations—does not capture the actual population of possible links (all relevant organizational actors nationally and internationally with whom our respondents could have ties). After each major category, the respondent, with the assistance of the interviewer, was asked to consider other organizations with which they had any type of tie or contact. The roster contained a number of spaces, where these new (unlisted) organizational actors could

be nominated. Such nominations were then penciled in before proceeding, unfolding the pages, and continuing with the procedure.

In this second stage, the respondent was asked to be more specific about the type of interactions or linkages s/he had for each reported tie to an organization. The interviewer read back the names of the organizations that were marked, while the respondent viewed a laminated card listing nine types of relationship in order to say what kind(s) of contact it was. We asked about nine different types of ties to other research organizations, all of which are common in studies of scientific networks: friendship, collaboration, exchange of materials, information, funds (directly or indirectly), workshops, visits, employment, and other. The respondent could list any or all types of content (that is, a minimum of one up to a maximum of nine types of tie).

In the next section we provide the first longitudinal data on the size of extended personal networks during the key period of Internet diffusion in Asia and Africa. In the scientific and educational community in 1994, only the most established international agencies had access to the Internet, through slow connections, with access to the minimal content then available. Many scientists had not heard of some of these new means of electronic communication and information retrieval, still almost non-existent in the late 1990s when we conducted qualitative assessments of connectivity. Yet by 2010 access to technology had become almost universal. What happened to the size of personal networks during this period?

Results

Figure 1 graphs the average number of total ties by year for the respondents in our study.¹³ Most important, our 2010 respondents, with an average of 23 ties, report fewer connections than our original 1994 respondents. Indeed the earliest wave reports an average of 26 ties, more than any other period in the study. The chart shows that the trend is not a linear decline, but a sudden drop-off between first and second waves, followed by a partial recovery in the third and fourth waves, though not to the same level as 1994. The comparison of the first wave with subsequent waves is statistically significant, as well as the comparison of the second wave with subsequent (3rd and

¹² The listing was so complete that many respondents during the course of the study asked if they could keep a copy for personal use after the interview was finished.

¹³ Between the first and fourth wave, this difference is highly significant ($p < .001$), using both the Welch and Brown-Forsythe robust test for equality of means.

4th) waves. While these extended networks in 2010 exhibit a slight decline from 2005 levels. What is clear is that extended professional networks did not grow during the Internet era, and may have declined slightly.

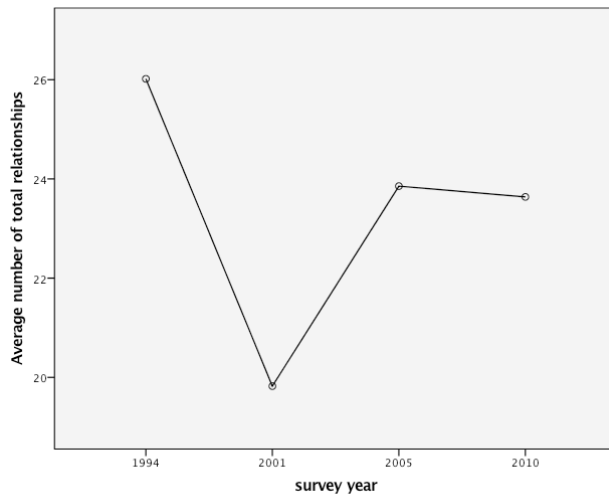


Figure 1: Average Total Relationships Reported by Respondents, 1994-2010

Although this analysis provides some indication of an overall pattern, it tells us nothing about the specific relationships that occurred during this period. Table 1 shows both the overall average for the number of personal ties during the period as well as the averages for the nine tie types measured. Our typical respondent reported an average of nearly 23 ties over the entire four waves. The nine tie types in Table 1 are presented in order from most

to least frequent: the first column of the table shows the average number of ties over the four waves, from friendship to employment, followed by the overall mean. Friendship is the most common relationship for our respondents, with over nine ties reported by the average respondent for the entire period, closely followed by information exchange (8.59). Other relational contents, by descending order of frequency, are collaboration, visitation, scientific exchange (that is, borrowed or lent research materials), and attendance at workshops. Relatively low frequency relationships include receiving funds, employment, and a miscellaneous category.

Averages for specific waves show relative stability in these rankings over time, in the sense that frequent tie types in 1994 are virtually the same in 2010, with few exceptions. Scientific exchange, the third most common type of relationship in 1994, drops to fifth in 2010, while collaboration moves from fourth position to third.¹⁴ Our main interest in this essay is whether there is change in relationship frequencies over time. Examining the difference between first and final waves gives us the best overall indication of whether a particular kind of relationship has increased, decreased, or remained stable for the general period of Internet diffusion (statistical significance is indicated in column one).

Workshops, funding, and employment all exhibit small increases over time (on average, less than .5), but none that reach statistical significance. All other linkage

¹⁴ The least frequent tie types (employment and miscellaneous) switch positions at the bottom of the rankings.

Table 1: Average number of ties by year, 1994-2010¹

	All Years	1994	2000	2005	2010
Friendship**	9.1	12.26	6.56	10.01	9.86
Information**	8.59	10.68	7.82	8.81	8.59
Collaboration**	6.43	5.59	5.16	6.51	7.81
Visits**	5.69	5.37	4.53	6.01	6.6
Exchange**	4.87	7.01	3.96	5.13	4.96
Workshop	3.42	3.87	2.69	3.59	3.86
Funds	2.58	2.62	2.13	2.54	3.03
Other**	1.74	2.75	1.8	1.7	1.47
Employment	1.41	1.49	1.28	1.44	1.5
All Ties*	22.74	26.02	19.82	23.85	23.64

¹ Statistical significance is presented for the difference between 1994 and 2010 using independent samples t-test, using Levine's test to determine equality of variances.

** Significant at the .01 level.

* Significant at the .05 level.

types exhibit some significant increase or decrease over the period. Collaboration and visitation increase, while the other relational types decrease. Of particular note is the *decrease in the two most common relationships, friendship and information exchange*. Respondents in the final wave mention an average of two fewer ties involving receipt or giving of information than their counterparts in 1994, while reported friendships decrease by approximately 2.4, the largest shift of any relational type. Summing across all relational types yields an average of just over 26 total linkages in the first wave, but only 23.64 in the final wave (the same means plotted in Figure 1).

Finally, we note the *pattern* of change. Figure 2 plots the averages in Table 1 for each type of contact. The single common pattern for all nine tie types is the

decline in average frequency between the first and second waves—that is, the period of the introduction of the new information and communications technologies. Not including miscellaneous or uncategorized¹⁵ tie types, which display a nearly linear downward trend, the changes in linkage types over time fall into three basic patterns. The V-shaped pattern is a dramatic decrease followed by consecutive increases ending in approximately similar values. Both employment (the least common relational type) and workshops (intermediate in frequency) display this pattern, and therefore no statistically significant change between 1994 in 2010 in overall levels.

¹⁵ While ‘other’ ties represent a variety of different relationships, the most common meaning that was explicitly mentioned by respondents was ‘student.’

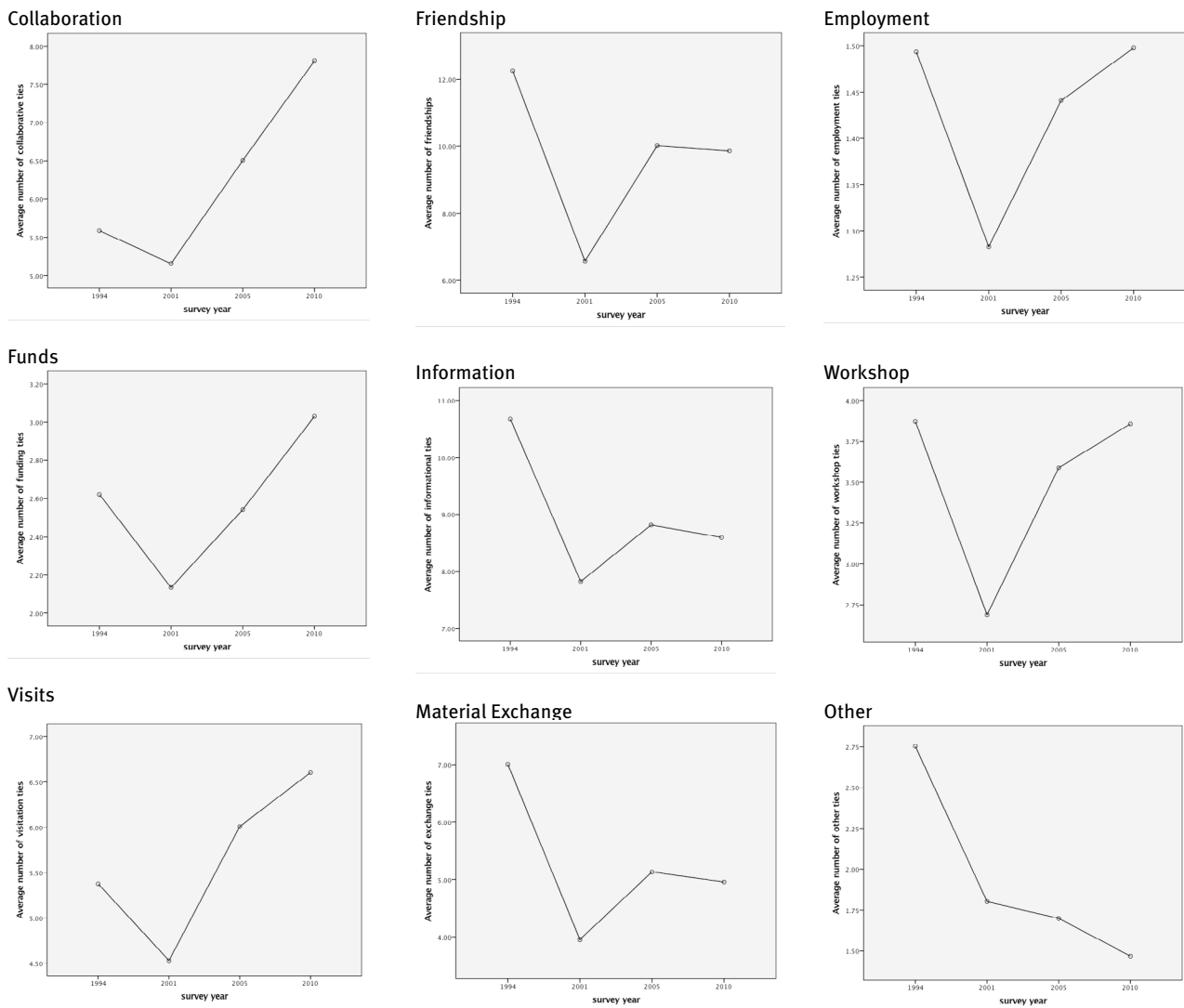


Figure 2: Tie Types by Year, 1994-2010

In order to reveal the similarity of the second and third linkage patterns, we stack them in the first part of Figure 2. For collaboration, funding, and visitation, the shape is a ‘check mark’ (decreasing and then increasing above the original value). These are the linkages that have grown between first and fourth waves. Both collaboration and visitation (‘research or training visit’) more than recover from their initial decrease to produce significant growth in the average frequency of relationships. We note, however, that these ties are not the most important component of the overall tie total, a point to which we return in the discussion. Finally, Figure 2 shows an overall decline for three of the five most common tie types. Friendship, information, and scientific exchange all decrease dramatically with a recovery that plateaus.

Discussion

This essay, the first study of extended personal networks during the primary period of ICT diffusion, examined the professional networks of educators and researchers. Our primary question is whether there is any evidence of change in the overall size of personal networks or the distribution of social relationships. The interest is in one particular period of time, a span of years that witnessed one of the most rapid and dramatic social changes in recorded history: the spread of new information and communication technologies from a base of nearly zero to virtually all of our population of interest (Hillstrom, 2005; Oken, 2010; Mathiesen, 2013; Rainie and Wellman, 2011; Baym, 2015). Has the overall size or character of professional networks changed? Based on this data, our answer is a qualified ‘no.’ In brief, there are offsetting shifts in several types of social relationships but *no support for any general notion of personal network growth and some evidence of decline*. We view three findings as significant for further work.

First, there are clearly *fewer* ties in the extended networks of professionals at the end than the beginning of our 16-year study. This primary finding emerges when we consider the sum of measured linkage contents, including one miscellaneous category as a catch-all for those types of ties that are rare or difficult to define. Our original group of respondents in 1994 had not used the Internet. They had most certainly never heard of a mobile phone. Yet they reported over 26 ties, more than any other group of professionals in the following waves. In fact, no other group reached an average of 24 ties. We were so surprised by this result that during the summer of 2015 two co-authors of this essay completely rechecked the

1994 data on reported ties. We even tried removing cases where something about the administration of the survey made the data uncertain. If anything, the 1994 averages are slightly underreported.

Second, whether we consider total ties or disaggregate specific ties by the content of the relationship, there is a noticeable *decline between first and second waves*. This corresponds to the primary ‘takeoff’ period of the Internet. We emphasize once more that we have not controlled for ICT access by individuals, but the effect at issue is a ‘network effect’ (that is, the degree to which a pool of potential ties has access to the technology) rather than a ‘usage effect’ (that is, the extent to which an individual employs one or another technology to interact). Our interpretation is based on the level of penetration of new information and communication technologies in the countries where we live and work (Ling, 2008; Marin and Wellman, 2011).

Of course, there are many differences between developing countries and within regions of each particular country. By the time we began our second wave of data collection (2000) it is fair to characterize the great majority of Western scientists and educators as largely connected to the web, while the majority of individuals in sub-Saharan Africa and Asia were subject to significant digital poverty. Among our own group of collaborators, digital poverty did not simply mean that we could not access a web site for information without going to an Internet café and incurring significant expense. There were relational consequences as well. For instance, during the *transition* to digital communication it was possible for the Kenyan who had access to the Internet to confer readily with colleagues in the U.S. and Europe. But it would not have been possible (or easy) to communicate with local colleagues in Kenya who might be more significant for her work, but had no access to ICTs. This deficit had largely disappeared by 2010 (Shrum *et al.*, 2014), but during the takeoff period it was real and significant.

Finally, we note that our main indicator of extended personal networks is a summary index, an aggregate of a variety of different kinds of relationships. Given our population of respondents, some relational contents were linkages characterized by specifically scientific/professional matters (e.g., the exchange of materials, samples, papers, or reports). Other linkages are broadly applicable to many areas of social life. Since total network size is a sum of all discrete linkages,¹⁶ the most common tie types have greater impact on the overall size of the

¹⁶ That is, a relationship may be ‘multiplex,’ consisting of more than one type of tie, such as *both* friendship *and* collaboration.

professional network and therefore the pattern of change over time. As we saw earlier, some ties are common, while others (e.g., funding and employment) are rare.

Friendship, information, and scientific exchange all decrease dramatically, followed by a recovery plateau. These tie types are responsible for the general pattern, a decrease followed by plateaued increase in extended networks during the digital transition. Yet both scientific and information exchange are arguably subject to the particulars of the type of respondents surveyed—scientists, educators, and researchers.¹⁷ Friendship is at once the most common relation in all four waves of our study and the relationship of most general interest. The decline in friendship was unanticipated, but we find this evidence both convincing and consistent with current arguments that express skepticism towards the expanding use of digital communications media (Turkle, 2011, 2015).

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¹⁷ Both information and material exchange characterize most networks—our item wording simply specified the professional/scientific basis of the pattern for our respondents.