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Is Internet Use Associated With Reporting Fewer Problems in Collaboration? Evidence From the Scientific Community in Chile

Ricardo B. Duque[1], B. Paige Miller[2], Omar Barriga Jr.[3], Wesley Shrum[4], and Guillermo Henríquez[3]

Abstract

In the developing world, many advocate the benefits of collaboration as the primary driver of research productivity. One of the crucial conditions that support, and help overcome problems in, distributed work is consistent access and use of Internet technologies. But it is argued that the collaborative benefits of Internet technologies are not symmetrically distributed worldwide, perhaps a result of neo-dependency relationships between the South and the North. To evaluate this, in this article, the authors consider the association between "e-mail use and diversity," "reported problems in web surfing," and "problems in research collaboration" for a population of scientists outside the mainstream, in the South American nation of Chile. They surveyed 337 scientists over three regions asking them to report on their collaborative behavior, Internet use, and research challenges. While they find that Chileans on the whole report fewer problems compared with

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other less developed nations studied in this way, they do report problems when reporting more collaborators and when their professional network is geographically heterogeneous. E-mail use, though, has no association with less frequent reports of research challenges, while reporting that "the Internet has made them more connected" and reporting (more intensely) "problems encountered while surfing the web" are significantly associated with reporting more problems in research, when controlling for background, professional activities, institutional and field context, and the number and location of collaborators.

Keywords

Chile, collaboration, development, e-mail, Internet, networks, science, web

Science and technology policy makers expect Internet technologies[1] to expand the collaborative reach and productivity of scientists worldwide. This is based on numerous studies conducted in advanced nations that support the positive relationship between Internet use and knowledge work (Finholt & Olson, 1997; Lee & Bozeman, 2005; G. M. Olson, Zimmerman, & Bos, 2008; Sproull & Kiesler, 1991; Walsh & Maloney, 2007). There exists, however, a strong suggestion that being overly digitally connected can sometimes lead to a saturation of communication, information security concerns, and even unintended conflicts (Bawden, 2001; Friedman & Currall, 2003; Mano & Mesch, 2010; O'Kane & Hargie, 2007; Sproull & Kiesler, 1991; Whitman, 2003). Also, even though there are reports demonstrating how shared work does NOT always lead to positive outcomes (Duque et al., 2005), in the modern era, collaboration is often seen as inevitable, a policy end in itself, which is seemingly dislocated from any measurable benefit it may have on knowledge production (Wagner & Leydesdorff, 2005).

Despite these cautionary contradictions, the collaborative potentials of Internet-mediated distributed work suggest a new frontier for global science. Rapid innovations in the form of "collaboratories" (Finholt & Olson, 1997; G. M. Olson et al., 2008) and "grid networking" (Hey & Trefethen, 2008; Hine, 2006) facilitate data management and networking at a distance and across disciplines, sectors, and regions (Sproull & Kiesler, 1991). These digital benefits promise to diffuse among knowledge professionals located in less developed nations as well, given that the technology can be successfully sustained in that context (Castells, 2000; Fuchs & Horak, 2008). The developing world, though, poses a host of challenges to this Modernization assumption. Science communities there are quite different from those located in advanced regions that can support Big Science (Drori, Meyer, Ramirez, & Shafer, 2003; Sagasti, 2004).

While there is very little research to date that tests the benefits of Internet technologies on professional outcomes in developing nations, there do exist ongoing theoretical debates leading to various interpretations. Technological deterministic and modernization perspectives would generally contend that since Internet technologies have led to increased scientific activity in the North (Castellls, 2000; Hine, 2006), they should lead to the same benefits in all regions regardless of developmental level. Where there are no immediate improvements, it is a result not of the technology itself but of the lack of consistent and sustained access to it. And there is support for these positive evaluations as findings suggest that during the global diffusion of the Internet, international collaboration among developing world scientists has resulted in more visibility and productivity (Hill, 2004) of this historically isolated population (Gaillard, 1992; Sagasti, 2004). However, other studies from sub-Saharan Africa conclude that the same sociotechnical obstacles that inhibit the consistent access to it also pose problems for this complex technology's effective employment even if it were widely available (Duque et al., 2005; Ehikhamenor, 2003; Fuchs & Horak, 2008). Studies like these support the plethora of neo-dependency scholarship on the "digital divide," arguing that Internet technologies will benefit advanced regions, which produce them, at the expense of less developed nations, which are often not involved in their design, implementation, and innovation (Ganesh & Barber, 2009).

To evaluate further if Internet technologies are associated with progress or dependency, in the following we consider the association between "e-mail use," "reported problems in web surfing," and "problems in research collaboration" for a population of scientists outside the mainstream, in the South American nation of Chile. While heralded in the region for its economic robustness, highly developed digital infrastructure (dating from the late 1980s), and growing scientific presence through international collaboration (Hill, 2004), Chile's economy continues to depend on primary goods exports. Subsequently, its science policy generally promotes agricultural and mining science over technology innovation and basic research (Holm-Nielsen & Agapitova, 2002). Moreover, its universities do not provide doctoral degrees across all fields; thus, many scholars seek training in advanced nations only to return to few jobs and limited research resources. In a qualitative study of how they employ Internet technologies in their work, many Chilean scientists reported using the Internet to circumvent local constraints that limited their access to up-to-date literature and research funds (Duque, 2007). International collaborators located in non–Spanish-speaking countries often mediated these needed resources. This is also supported by a quantitative study conducted in Chile that links larger international networks with more frequent Internet use (Duque, Shrum, Barriga, & Henríquez, 2009). In addition, Chilean scientists often reported the mass of irrelevant information available on the web. Location of training, distance, language, and the web's relevance are expected to shape the kinds of problems Chilean scientists encounter when collaborating with local or global partners. Thus, by choosing Chile for our study, we (a) contribute to the dearth of studies on science and communication technology in developing regions, especially the few conducted in non–English-speaking areas while (b) effectively canceling out the usual arguments that inconsistent and expensive access disqualifies any meaningful assessment of the Internet's potential impact in less developed countries.

To guide our study, we hypothesize that Chilean scientists who make greater use and diversity of Internet applications also report fewer problems in collaboration. In addressing this hypothesis, we first review the pertinent literature that best frames this investigation. Then we outline the study's sample and methods and offer cross-sectional results. The present study enjoys a distinct advantage, since the instrument on which the data are based is the same one employed in other less developed regions, where the relationships between collaboration, productivity, and Internet use has been evaluated. Where relevant, we compare our findings with those of previous studies conducted in other less developed regions.[2]

Literature Review

In the following, we review the literature on science collaboration and global stratification of science and then review the Internet's challenging role in facilitating distributed work in less developed regions. We conclude with a literature synthesis that introduced our hypothesis.

Science Collaboration and Global Stratification of Science

Collaborative behavior is considered the foundation of human social organization (Hinds & Kiesler, 2002; King & Frost, 2002). Moreover, shared work is theoretically linked to structural cohesion arguments, describing one mechanism by which science paradigms historically developed and reproduced over generations (Kuhn, 1996; Moody, 2004).[3] Throughout the past half century, meanwhile, coauthored publications and multi-investigator grant proposals have increased at a dramatic rate (Gaillard, 1992; G. M. Olson et al., 2008; Price, 1963). Among other things, this rise of scientific collaboration is credited to the increasing specialization within fields, the complexity of research problems, and the high cost of new technology.[4]

But collaboration itself poses problems in communicating and coordinating along a variety of continuums—for example, in terms of size, diversity of fields, the distance between collaborators, and the technology used to communicate (Duque et al. 2005; Monteiro & Keating, 2009; J. S. Olson et al., 2008; Walsh & Maloney, 2007). For example, Sonderegger (2009) suggests that "trust" is a factor in predicting positive collaborative outcomes that tend to benefit face-to-face collaborative structures over mediated distant ones. Meanwhile, cultural differences may arise when replacing face-to-face with the virtual during shared knowledge and organizing work (Keating & Jarvenpaa, 2011). Even the use of e-mail in collaboration reveals new risks for collaborative teams, such as security of information (Whitman, 2003) and miscommunication (Cummings & Kiesler, 2005; Sproull & Kiesler, 1991).

In addition, contextual factors can affect collaborative profiles and frequency. Comparing research universities with historically Black universities (where teaching responsibilities are stressed), the amount of time, resources, and support conducive to collaboration simply does not exist in the latter setting (Sonnenwald, 2007). This mirrors somewhat the conditions that scientists encounter while working in the developing world context, where salaries are often low, while social obligations are high. As a result, this population tends to take on more teaching responsibilities to make ends meet, leaving less time to focus on original research (Duque et al., 2005). Moreover, scientists across fields display variations in terms of their collaborative behavior (Lee & Bozeman, 2005). For example, distributed work in the physical sciences often involves a number of individual and group contributors compared with those in the social sciences. This could result from the need to divide work in quantitative investigations, but not qualitative ones, more generally associated with the social sciences (Laband & Tollison, 2000; Moody, 2004). Collaborative behavior may also vary with the level of competition and cooperation in a given field and time—for example, the lack of collaboration among AIDS postdocs competing for limited university positions (J. S. Olson et al., 2008). In addition, the rise of international collaboration has been connected to the growth of basic research, which is more international in nature than applied research. It is also due in part to the historical desire of scientists in smaller nations to find funding opportunities in the exterior (Frame & Carpenter, 1979). This is particularly relevant to understanding the collaborative behavior of scientists in developing regions, where local research capacity and resources are limited (Drori et al., 2003; Sagasti, 2004).[5]

The historical and present-day dimensions explaining the rise and variations in collaborative behavior can be applied and elaborated on when considering the resource-poor conditions reflected in many developing nations. First, research emphases in these regions tend toward the agriculture and medical sciences and to the applied sciences over basic science (Drori et al., 2003; Gaillard, 1992). This is credited to the initial importance of solving immediate problems facing less developed regions following World War II. As a result, today few universities located there offer advanced degrees across a wide variety of disciplines, motivating many less developed world scholars to seek training in the advanced nations of the North (Sagasti, 2004). Training abroad naturally promotes an outward orientation of many of their returning scholars in terms of theories, methods, research practices, and professional network profiles, reflecting the structural cohesion arguments mentioned earlier. As a result, expatriated scholars often return to home countries with intellectual tools that are considered relevant in advanced nations but perhaps not so relevant in less developed ones (Sagasti, 2004). This may also explain some portion of the "decoupled" or "disarticulated" science profile that many less developed regions experience (Drori et al., 2003; Sagasti, 2004; Vessuri, 1987). More evidence of this can be gleaned from the geographical imbalance that often characterizes the professional networks of scientists working in the South. An inverse relationship exists between global and local contacts. A scientist is connected either almost exclusively to global contacts or almost exclusively to local ones (Davidson, Sooryamoorthy, & Shrum, 2003; Duque et al., 2009).[6] This suggests that one segment is isolated from the global scientific community, while another segment may be dislocated from local relevance. Exasperating this asymmetry is the high competition for limited research resources among scientists within developing nations, whether locally or globally trained, which has also promoted an outward orientation in collaborative behavior. Nevertheless, it is often assumed that by reducing the transaction costs to communicating and sharing information with contacts, Internet technologies are expected to help balance this asymmetrical distribution of local and global linkages that create this "dislocated" structure. The following subsection addresses more closely how Internet technologies may or may not help integrate scientists working in different developmental spheres.

Limits to Internet-Mediated Collaboration in the Developing World

Just as international collaboration has been emphasized, policy initiatives have often promoted Internet technologies as a panacea for productivity, especially in driving research activities in less developed regions (Drake, Ludden, Nzongola-Ntalaja, Patel, & Shevtsova, 2000; Wagner & Leydesdorff, 2005). In the developed world, there is a clear historical basis for the positive evaluation of scientific collaboration. Harnessing of the technological resources and combined knowledge power of multiple laboratories, often across regions, accelerated the phenomenon of "Big Science" like the Manhattan Project (Drake et al., 2000) and, more recently, the Genome Project and CERN's (Conseil Européen pour la Recherche Nucléaire [European Organization for Nuclear Research]) particle physics consortium (Vermeulen, 2009). These large-scale collaboratories were first facilitated by computer technologies to address scalability issues (Meyer, 2009). They were expanded further by the ubiquitous nature of Internet technologies, which reduced the archiving, computation, and communication transaction costs associated with large-scale and shared work at a distance. Regardless of region, most scholars agree that Internet use has the potential to impulse greater scientific productivity by digitally streamlining geographically distributed and transnational knowledge work (Cohen, 1996; Hesse, Sproull, Kiesler, & Walsh, 1993).[7] But while developing world scientific communities might experience some residual benefit from access to Internet technologies, neo-dependency scholars argue that the knowledge and economic divide might actually increase in the digital age as a result of this asymmetrical structure of research credit, resources, and application (Escobar, 1995; Sagasti, 2004).[8] And this bears greatly on whether Internet technologies can support collaboration in less developed regions.

As intimated earlier, collaboration is traditionally seen as a benefit to projects that employ an intellectual division of labor (Beaver & Rosen, 1978; Cohen, 2000; Hinds & Kiesler, 2002; Melin, 2000). The benefits, in terms of publications for example, are greater than the costs involved in coordination. Recent studies, though, contend that collaboration translates into higher publication rates in some regions, but not in others. For example, collaboration had substantial and consistent association with publication levels in Lee and Bozeman's (2005) sample of U.S. scientists. A recent study conducted in Chile reflects U.S. findings. Collaboration is positively associated with domestic publication across sectors in Chile (Duque, 2012). Moreover, one interpretation from an investigation comparing African and Indian scientists suggests that collaboration actually depresses total publications for scientists in research institutes (Duque et al., 2005). In the Kenyan context especially, the costs seem to outweigh the benefits. These African researchers collaborate most but publish the least. Although distinct, the Malayali

(Kerala, India) context also supports the argument of a “collaboration paradox” (Duque et al., 2005). These Indian researchers on average collaborate less than their African counterparts, while publishing more frequently, thus putting into question the notion that collaboration alone is the driving force of productivity across all regions.

Our research so far has concluded that the challenges of communicating and coordinating are magnified for researchers located outside advanced regions, explaining the variations in findings across Africa and India. This is generally attributed to less developed world’s “cultural and technological assembles” that are often “decoupled” and uncoordinated at best and at worst operating at crosscurrents (Bijker, 2002; Drori et al., 2003; Duque et al., 2005; Sagasti, 2004).[9] As a result, in many resource-poor regions, monetary, transportation, communication, and security infrastructures are limited and often inconsistent. These disadvantages are then exacerbated by the low wages and inconsistent access to research materials available to many developing world scientists compared with those available to their highly resourced counterparts in the North. Adverse conditions like these tend to slow the pace of research in some regions. This was our experience working on transnational collaborations with colleagues located in six less developed nations. And it seemed to be the case when collaborators were in the same city, whether in Santiago, Nairobi, Accra, Durban, Manila, or Thiruvananthapuram. We concluded that where the costs of coordinating a project are high, the benefits of collaboration are limited (Duque et al., 2005). The Internet, though, promised to be a technology that could circumvent local problems by reducing the cost of communication, while streamlining the access to and dissemination of project information using online data storage and e-sharing platforms.

Scholars have argued that in the West, the primary technology of collaboration has been the Internet and, in particular, communication using e-mail (Finholt & Olson, 1997; Hine, 2006; Walsh & Roselle, 1999). While these technologies are available globally, local variation in access and use is great. But countless innovations and unending, costly upgrades have left, in the words of one of our African collaborators, “a very rough technological terrain” in many sub-Saharan regions. In contrast, most scientists in advanced nations enjoy consistent connections, seamless upgrades, and high bandwidth, with few exceptions. Not surprisingly, a study by Walsh and Maloney (2007) found that for a sample of 230 U.S. scientists stratified by field, the number of e-mails per day was associated with less intense reports of problems for coordinating collaborative projects.[10] Even though Internet access varies widely, the positive impacts of e-mail use are nominally supported by a similar study conducted on a sample of 918 African and Indian scientists with important caveats (Duque et al., 2005). Considering the association of 10 problems in collaboration[11] and access to e-mail, the Indian scientists reported the most consistent access to e-mail, while reporting problems less intensely in collaboration (although this did not necessarily translate into more collaboration). Conversely, African scientists have the least consistent access to e-mail and report more intense problems in collaboration. Paradoxically, this did not limit the Africans, especially the Kenyans, in their high collaborative behavior. Some have argued that these seeming inconsistencies may be an indication of neo-dependency with regard to the impact of Internet technologies in less developed countries (Davidson et al., 2002; Duque et al., 2009; Sooryamoorthy, Duque, Ynalvez, & Shrum, 2007). Where resources are few and inconvenience high, new technologies like the Internet may actually increase the global development gap in terms of knowledge production.

Literature Synthesis

The previous literature review lays out a clear path for better understanding the impact of Internet-mediated collaboration on scientific communities located in less developed regions. At best, collaboration is seen as a “good” that can help boost scientific output. However, collaboration involves a host of coordination and security problems that working in solitude does not entail. Research challenges, though, can be exacerbated when distributed work crosses geographical and cultural boundaries. Also, some fields require more shared work than others. This suggests three conditions that can magnify the problems associated with collaboration:

1. When there are more collaborators involved, there will be more problems reported.
2. Where collaborations extend beyond geographical borders, more problems will be reported.
3. In fields that necessitate collaboration, there will be more problems reported.

Internet technologies are considered the state-of-the-art media that can successfully overcome these contextual obstacles to collaborative research. This has been the general finding of U.S.-based studies. The developing world, though, represents a prism of technological, science, and social settings that often refract the intended impacts of collaboration and new technologies that support it. In very resource-poor regions, like, for example, sub-Saharan Africa, the few studies conducted there suggest that combining collaborative behavior with inconsistent Internet technologies is not leading to positive outcomes and in some cases may be retarding scientific output.

In contrast to African scientists, Chileans scientists have enjoyed relatively consistent access to the Internet since the late 1980s. This is credited to over 25 years of digital infrastructure investments begun during the Pinochet dictatorship (Duque et al., 2009; Mullin, Adam, Halliwell, & Milligen, 2000). And since the global diffusion of the Internet, Chilean science has experienced dramatic growth. This has been credited mainly to the rise of international collaboration over the past two decades (Hill, 2004). Still, many of Chile's top universities do not offer doctoral programs across all fields. Thus, the road to professionalization and promotion often passes through institutions located in advanced nations, perhaps imprinting an international orientation toward the research process among those who return. Chilean scientists also report that there are few local resources for research. As a result, they readily seek collaborations abroad to access up-to-date literature and financial support. To this end, the Internet has proven an invaluable tool to circumvent local limitations. The question is whether Internet use is helping overcome or magnify the challenges of distance that can inhibit the benefits of collaboration. Chile's advanced Internet infrastructure suggests that this region may avoid the research setbacks experienced in other developing regions. Therefore, to evaluate if Internet use is associated with fewer research challenges in the Chilean context, we hypothesize the following:

Hypothesis 1: When controlling for the number and geographical distribution of collaborators, Chilean scientists by field who make greater use and diversity of Internet applications also report fewer problems in collaboration than do Chilean scientists who use these technologies less frequently and diversely.

In the following, we describe the sample and method of this investigation and then test our hypothesis through bivariate and multivariate analyses of our data.

Sample and Method

This article's research focus concerns the relationship between problems in collaboration and Internet use. This is addressed through face-to-face survey questionnaire interviews administered in 2005-2006 to Chilean scientists in both academic and research institute settings.[12] Local collaborators in Concepcion and Puerto Montt helped assemble and direct a team of 14 postgraduate student interviewers. These research assistants conducted survey questionnaires with 337 scientists—approximately 4% of the national workforce of 8,500. Face-to face questionnaire interviews were stratified (a) by research sector—university departments and national research institutes,[13] and (b) across three regions—Santiago, Concepcion/Chillan, and Puerto Montt/Osorno.[14]

We relied on a communication network survey already employed in five other research settings (Kenya, Ghana, South Africa, Kerala in India, and the Philippines). The questionnaire included sections on background, professional activities (projects directed, collaboration, attending conferences), outcomes (publications and awards), organizational affiliations (academic or research institute), professional networks (interorganizational/intraorganizational and domestic/foreign), and Internet access and use patterns. This instrument is unique in that it is able to tap both individual and organizational professional contacts and can distinguish various network dimensions. Most relevant, the survey accounts for the critical factor of geographical location. This is necessary in order to assess the relationship(s) between the number of domestic and foreign collaborator(s), Internet use and diversity, and reported problems in research. Finally, since this survey instrument was adapted to a Spanish-speaking nation, and global science and the World Wide Web are generally mediated in the English language, we also included a section on English communication proficiency.

Measures

In the following, we outline the pertinent measures of this study, while including references to additional supporting literature.

Problems in collaboration. For comparison with other less developed regions, we employ the same "problems index" used in a previous investigation conducted in Africa and India (Duque et al., 2005).[15] That study, like this present one, measured the same 10 problematic dimensions associated with a respondent's collaborative projects: problems with (a) "contacting people," (b) "coordinating schedules," (c) "getting others to see your point," (d) "security of information," (e) "resolving conflicts," (f) "coordinating schedules," (g) "length of time to get things done," (h) "transmitting information," (i) "dividing work," and (j) "keeping others informed of progress." Coded 1 to 3, respondents self-reported whether these dimensions were a *major problem* = 1, *minor problem* = 2, or *no problem at all* = 3. For comparison purposes with the past study conducted in India and Africa, we maintain this counterintuitive intensity direction for these "problem" measures. We highlight this in the tables and analyses that follow.

We then created a diversity measure of "problems in research" that includes both major and minor problems to indicate the variety of problems reported per each respondent. On this dichotomous additive scale, if a respondent reported a "1" (*major problem*) or "2" (*minor problem*) for a given dimension of the 10 described above, they were assigned a "1" for that problem, while a "3" (*not a problem*) produced a "0" for that problem dimension. Ranging from 0 to 10, higher figures on this additive scale represent more problems dimensions reported in research collaboration.

Measures of collaboration. Work group size is a factor that increases both coordination cost and security concerns (Baker & Faulkner, 1993). In science, the number of collaborators associated in the work often represents the size of a work group. In this present study, collaboration is measured in three general ways. First, the "degree of collaboration" is an additive scale that measures the number of collaborations out of three possible current projects.[16] Respondents were then asked to report the location of collaborators in up to six regions per each of three possible current projects—"local city," "outside local city but within Chile," "outside Chile but within Latin America," "Europe," "United States," and "Other." From this aggregate count of collaborators by region (over a possible three reported main projects), we derived a total number of collaborators, a continuous variable ranging from 0 to 18 (three projects times the possibility of collaborators being located in six regions relative to the respondent's geographical location). Since this variable is positively skewed, it is expressed in a natural logarithmic transformation in the analyses.

Diverse networks, based on disciplinary or geographical dimensions, often provide access to new information and resources that may lead to increased productivity (Burt, 1983; Lin, 2001; Popielarz, 1999). However, they also may result in coordination difficulties that could inhibit productivity (Rothschild-Whitt, 1979; Sirianni, 1993). To account for this additional dimension, a dummy variable (0, 1) was computed from a respondent's total number of collaborators to indicate the "homogeneity of a collaboration network." A value of 1 indicates only Chilean collaborators, while the reference group indicates collaborators within and outside Chile.

Finally, in order to control for their respective assessment of how collaborative their field was, respondents were asked to what degree they agreed or disagreed with the following statement: "People in my field work mostly by themselves," based on a Likert-type scale in which *agree strongly* = 1, *agree somewhat* = 2, *disagree somewhat* = 3, *disagree strongly* = 4. To clarify the interpretation of this measure, for the analysis we reversed the coding so that 1 = *disagree strongly* and 4 = *agree strongly*.

Internet use. Since we are interested in how Internet use is associated with collaborative behaviors, attitudes, and outcomes, we account for two dimensions of e-mail practice,[17] one dimension of Internet attitudes, and three dimensions of web experiences. In its first decade, global Internet research considered only e-mail access. This is in large part due to the novelty of the technology in the early stages of its worldwide diffusion. Studies conducted in its second decade, though, have argued for the inclusion of frequency and diversity of use and the speed of connection (Lenhart & Horrigan, 2003; Robinson, 2003; Ynalvez et al., 2005). In a previous study looking at "problems in collaboration" and "Internet use" that was conducted in the less developed world (Duque et al., 2005), "e-mail access" was the only variable considered, indicating the great disparity at this time among scientists in Africa and India in terms of this basic dimension. In Chile, though, access is not a problem. However, there is variation in the weekly intensity in which scholars rely on e-mail. Therefore, in this present study, "e-mail use" was accounted for by asking respondents to report their "hours using e-mail in a typical week," an ordinal variable measured as 1 = *less than 1 hour*, 2 = *1 to 5 hours*, 3 = *5 to 10 hours*, 4 = *10 to 20 hours*, 5 = *20 hours or more*.[18]

Ynalvez et al. (2005) considered "e-mail diversity" for a sample of African and Indian scientists to identify distinct research practices and technology access across developmental context. They concluded that e-mail diversity was significantly and positively associated with the number of foreign publications reported by this group of developing world scholars. Moreover, Ynalvez and Shrum (2006) considered nine[19] dimensions of e-mail use in a sample of Filipino scientists to identify similarities and differences within the research cultures where these scientists were trained (Japan, Australia, the United States, and the Philippines). Their findings suggest that Filipino scientists trained abroad demonstrate more diverse e-mail use. For comparison purposes, we employ the same diversity index used in the two previous investigations conducted in other developing regions as our second e-mail dimension. This index captures a breadth of topics motivating e-mail communication by scientists working in less developed regions and is based on personal conversations with local collaborators in the regions we conduct our research. E-mail diversity is measured using an additive scale, ranging from 0 to 6. It is constructed from the sum of six dichotomous (1 = *yes*, 0 = *no*) variables that measure whether or not a respondent: (a) "has been a member of science and technology discussion group," (b) "has sent a message to such a discussion group," (c) "discussed research with someone in a developed country," (d) "started a professional relationship with someone met on the Internet," (e) "discussed a research proposal with funding agencies," and (f) "submitted or reviewed manuscripts for journals."

Internet attitudes meanwhile are accounted for by the following statement: "The Internet has made me more connected," which respondents were asked to agree or disagree with based on a Likert-type scale in which *agree strongly* = 1, *agree somewhat* = 2, *disagree somewhat* = 3, *disagree strongly* = 4. To clarify the interpretation of this measure, for the analyses that follow we reversed the coding so that 1 = *disagree strongly* and 4 = *agree strongly*. In addition, respondents were asked to report the intensity of problems for each of the following three web experiences: (a) "unable to find information on the web," (b) "getting disconnected from the web," and (c) "too many junk sites on the web." Coded 1 to 3, respondents self-reported whether these dimensions were a *major problem* = 1, *minor problem* = 2, or *no problem at all* = 3. To clarify the interpretation of these measures, during the analyses that follow we reversed the coding so that 1 = *no problem at all* and 3 = *major problem*.

Contextual factors. Control variables for the analyses that follow are derived from previous research on scientific collaboration. For example, studies have shown the effect of contextual factors on collaboration (Duque et al., 2005; Garg & Padhi, 2000; Lee & Bozeman, 2005). Distance from the core (capital city) is suggested to limit resource flows (Bradshaw, 1987) and to be associated with collaborative patterns that place the periphery at a disadvantage (Cole & Cole, 1973; Merton, 1968; Moody, 2004). Moreover, there are institutional variations in the reward criteria in assessing academic and research institute scientists (Raina, 1999). Different fields also have been known to reflect varying collaborative patterns (Lee & Bozeman, 2005; Moody, 2004; Stephan & Levin, 1992). There is a high frequency of collaboration in the physical sciences and a low frequency in the social sciences. Therefore, this present study controls for the following contextual factors: "Region"[20] is measured as *Santiago* (core) = 1, *Concepcion/Chillan* (semiperiphery) = 2, *Puerto Montt/Osorno* (periphery) = 3, while "Sector" is measured as 1 = research, 0 = academic, and "Field" is measured by a series of dummy (0, 1) variables for agricultural, physical, natural, engineering, and social sciences.[21]

Demographical factors. Internet adoption and collaborative behavior have been known to vary across social characteristics. In the developed world, men were early adopters of Internet technologies (Castells, 2000). But since then, women have not only caught up, in some cases they have surpassed males in access and use (Wellman & Haythornthwaite, 2003). In contrast, findings vary with regard to how female and male scientists collaborate. Some authors have found gender differences in distributed work, which generally favors males (Campion & Shrum, 2003; Prpic, 2002), while others found no significant difference (Gupta, Kumarm, & Aggarwal, 1999). Duque et al. (2009) found a relatively equitable gender distribution of international collaborative contacts among Chilean scientists, while Palackal, Anderson, Miller, & Shrum (2006) concluded that while access to the Internet may be easing differences, female scientists in Kerala, India, are still rather globally isolated. Finally, a recent cross-regional study of Indian and African scientists based on longitudinal data by Miller, Duque, and Shrum (2010) suggests a gender convergence over time in access to technologies and higher education, yet female scientists still lag behind international publications. To account for the gender dimension, the present study measured the sex of a respondent as 1 = *male*, 0 = *female*.

Previous research has also determined a clear age effect on adoption and use of Internet technologies that favors younger cohorts (Castells, 2000; Wellman & Haythornthwaite, 2003). Moreover, scientific activity as well has been influenced by the age factor, suggesting a curvilinear relationship—low productivity in the beginning of careers, peaking at midcareer, and then declining at the end of careers (Cole & Cole, 1973; Stephan & Levin, 1992). In this present study, respondents were asked to report their year of birth. This continuous variable was then recoded into "age" in years.

Education and professional activities. Additional controls measure educational attainment and professional activities since these are expected to shape Internet use and collaborative behavior as well. To measure educational attainment, respondents were asked to report their highest degree. This ordinal variable was then recoded into as dichotomous variable "acquired a PhD" (1 = *yes*, 0 = *no*). Variables used to measure professional activities include a self-reported count of respondent's "number of projects" and the "number of students supervised." Both these measures are continuous variables that are expected to affect (a) the number of collaborations respondents report, (b) their productivity, and (c) to what extent they report the intensity of problems in conducting research. Since "number of students supervised" is positively skewed, it is expressed in a natural logarithmic transformation in the analyses. In addition, respondents were asked to report the "percentage of time they spent on research." The relative portion of a respondent's research commitment is expected to influence the reporting of problems in collaboration.

Language. Finally, since Chilean researchers are encouraged to publish in high-impact Institute for Scientific Information journals (Duque, 2007), many of which result from international collaborations mediated in the English language, we control for the language dimension. This factor is expected to affect the reporting of problems in collaboration as well as the facility to use the Internet, which continues to be dominated by English language content. Respondents were asked to report to what extent they feel comfortable writing and reading in English (1 = *very comfortable*, 2 = *comfortable*, 3 = *not so comfortable*, 4 = *uncomfortable*). To clarify the interpretation of these measures, during the analyses that follow we reversed the coding so that 1 = *uncomfortable* and 4 = *very comfortable*.

Describing the Sample

Table 1 indicates that the sample is distributed across three regions of Chile (Santiago [the core], Concepcion/Chillan [the semiperiphery], and Puerto Montt/Osorno [the periphery]; Items 1-3) and two types of knowledge sectors: academic departments and research institutes. Sixty-two percent of the sample works in academic departments, while 38% are in research institutes (Items 4-5). By field (Items 6-10), the sample broke down as follows: agricultural science, 35%; physical sciences, 11%; natural sciences, 29%; engineering sciences, 15%; and social sciences, 10%.

Only 23% of the Chilean sample represents women (Item 11). This low figure is relatively on par with most of the developing and developed world, where for cultural and structural reasons, women are less likely to pursue advanced training and careers in science (Xie & Shauman, 2003). The average age of our respondents, meanwhile, is 48 years (Item 12) with a range from 27 to 76 years.

Table 1 also indicates the location and level of training for the Chilean sample. Forty-five percent received their high degree from an institution located in a developed country (Item 13), while 58% of the Chilean sample reported that they held a PhD (Item 14). During the qualitative phase of the Chilean study (Duque, 2007), we identified that few universities offered doctoral programs across all fields. This is generally supported in the literature as well (Mullin et al., 2000). The local limitation is augmented by the prestige that accompanies those who train abroad and return. Whether or not successful in their attempts, most pursue training in the exterior. As a result, many Chilean scholars learn and even master a second language. For example, 75% of our sample reported feeling comfortable writing and reading in English (Item 15).

Table 1. Mean/Percentage of Contextual Background, Education, and Internet Factors

	Mean/%	*N*
Region of the country		
1. Santiago (Core)	10.4%	35
2. Concepcion/Chillan (semiperiphery)	77.2%	260
3. Puerto Montt/Osorno (periphery)	12.5%	42
Sector		
4. Academic department	62%	208
5. Research institute	38%	129
Field		
6. Agricultural sciences	35%	114
7. Physical sciences	11%	38
8. Natural sciences	29%	99
9. Engineering sciences	15%	52
10. Social sciences	10%	34
Background and education		
11. Gender (% male)	77%	337
12. Age of respondent (years)	48	336
13. High degree from developed country	45%	337
14. Doctoral degree	58%	337
15. Comfortable reading and writing in English	75%	337
Professional activities, collaborators, and attitudes		
16. Percentage of time spent on research	42%	337
17. Number of students supervised	13.36	337
18. Number of projects	3.44	336
19. Average number of collaborators over three main projects	3.44	337
20. All collaborators located in Chile	45.4%	337
21. People in my field mostly work by themselves (% agree)	84%	337
Internet attitudes, use, and experiences		
22. Personal computer in their office with ready access to e-mail	99%	337
23. The Internet has made me more connected (% agree)	89.3%	337
24. Year first used e-mail	1994	336
25. Five or more hours using e-mail in typical week	22%	337
26. E-mail use diversity (out of six possible uses)	4.2	338
27. Getting disconnected from the web (% problem)	28.9%	337
28. Unable to find information on the web (% problem)	60.2%	337
29. Too many junk sites on the web (% problem)	77.9%	337

Concerning professional activities, the scientists sampled reported on average that they spent 42% of their time conducting research (Item 16), while supervising on average 13.36 undergraduate and graduate students (Item 17). On average, the sample reported working on 3.44 projects (Item 18). Moreover, with regard to collaboration, the sample reported on average 3.44 collaborators over three main projects (Item 19), while 45.4% of the sample reported that all their collaborators were located in Chile (Item 20). Meanwhile, 84% of the sample counterintuitively agreed with the statement "People in my field mostly work by themselves" (Item 21). This somewhat supports the "dislocation" phenomenon documented by past researchers (Sagasti, 2004) suggesting that local scientists often look for collaborators in the exterior to gain access to resources and prestige. This behavior can often pit local scientists in same field against each other in competition over global contacts.

Regarding technology use, 99% of the respondents report having a personal computer in their office with ready e-mail access (Item 22). This is twice the access generally reported by a study on African scientists (Duque et al., 2005). Not surprisingly, 89.3% of the Chilean sample agreed with the statement "The Internet has made me more connected" (Item 23). The Chilean respondents on average report first using e-mail in 1994 (Item 24), 2 years earlier than African and Indian scientists in a similar study on Internet use by Ynalvez et al. (2005). Also, 22% of scientists report using e-mail over 5 hours a week (Item 25). Meanwhile, their e-mail diversity index on average is 4.2 out of a possible six categories (Item 26). These figures are substantially greater than other developing regions studied (Ynalvez et al., 2005).[22] The sample, though, did report that they experienced problems during web surfing. While only 28.9% reported that "getting disconnected from the web" was a problem (Item 27), the large majority (60%) reported that being "unable to find information on the web" was a problem (Item 28), and over two third (77.9%) reported that "too many junk sites on the web" was a problem (Item 29). Even though the Internet may be readily accessible to this group of scientists, and is having a meaningful impact on their professional lives, there seem to be some drawbacks to depending on the technology.

Next, we turn our attention to variations within the Chilean scientific community with respect to reporting problems in collaboration and Internet use.

Findings

In the following, we offer a cross-sectional means comparison of "problems in collaboration." Next, we run a variety of regression models to identify

Table 2. Mean of Problems and Number of Collaborators

	Number of Collaborators[b]			
	1	2	3	4
Research Problems[a]	None ($N = 26$)	1-3 ($N = 177$)	4-7 ($N = 108$)	8 or more ($N = 23$)
1. Coordinating schedules	2.38[c]	2.28[c]	2.07[d]*	2.13
2. Time to get things done	2.08[c]	1.90[c]	1.71[d]*	1.96
3. Transmitting information	2.73[c]	2.50[c]	2.28[d]***	2.30
4. Resolving conflicts	2.69[a]***	2.31[d]	2.20[d]	2.17[d]
5. Dividing work	2.42	2.48[c]	2.25	2.39[d]*
6. Too much information	2.19[c]	2.13[c]	2.01[c]	1.57[d]***

a. Problems coded as 1 = *major problem*, 2 = *minor problem*, and 3 = *no problem*. Lower mean figures indicate more intense reports of problems.
b. Means that do not share the same subscript letters (c, d) significantly differ at the ***$p < .01$, **$p < .05$, and *$p < .1$ level, respectively, in a one-way analysis of variance least significant difference post hoc multiple-means comparison test.

what factors (including Internet variables) are most associated with a dichotomous additive scale measure of "problems in collaboration."

Comparing Problems in Collaboration in the Chilean Context

Table 2 provides the results of a one-way analysis of variance, Fisher's least significant difference post hoc multiple-means comparison tests for these six dimensions of research problems in the Chilean context that were found to be significantly variable. When comparing among Chilean scientists with various collaborative profiles, there is a significant increase in mean intensity of reported problems as scientists indicate a greater number of collaborators. Chilean scientists with four to seven collaborators report significantly more problems than those with one to three collaborators or no collaborators (Items 1-3) for the following problems dimensions: "coordinating schedules": $F(3, 330) = 2.528$, $p = .056$; "length of time to get things done": $F(3, 330) = 2.597$, $p = .052$; and "transmitting information": $F(3, 330) = 4.536$, $p = .004$. Having no collaborators meanwhile, is significantly related with less intense reports of problems for "resolving conflicts" (Item 4): $F(3, 328) = 4.219$, $p = .006$. Those with one to three collaborators report problems sig-

Table 3. Mean of Problems and Location of Collaborators

Research Problems[a]	Network Homogeneity[b] 1 All in Chile (N = 153)	2 Mixed (N = 55)	3 Difference
1. Coordinating schedules	2.30	2.14	0.16**
2. Time to get things done	1.93	1.80	0.13
3. Transmitting information	2.49	2.38	0.11
4. Resolving conflicts	2.34	2.26	0.08
5. Dividing work	2.48	2.32	0.16**
6. Too much information	2.11	2.01	0.09

a. Problems coded as 1 = *major problem*, 2 = *minor problem*, and 3 = *no problem*. Lower mean figures indicate more intense reports of problems.
b. Column 3 reflects the mean difference of columns 5 and 6 in a one-way analysis of variance means comparison test.
**$p < .05$.

nificantly less intensely than those with eight or more collaborators for "dividing work" (Item 5): $F(3, 329) = 2.544$, $p = .056$. Finally, those with eight or more collaborators report problems significantly more intensely than all other categories for "too much information" (Item 6): $F(3, 328) = 3.958$, $p = .009$. Yet the total group number of collaborators is not the only dimension that complicates research. As indicated in the literature, the geographical distribution of collaborators can magnify research difficulties as well.

Table 3, column 3, distinguishes mean differences between the homogeneity of a Chilean scientist's collaborative network. In every category of problem, those with exclusively Chilean collaborators report problems less intensely. However, only two of six dimensions reveal significant mean differences. A one-way analysis of variance test indicates a significant difference in the mean intensity of reporting problems along these dimensions. Having exclusively Chilean collaborators significantly reduces by .16 the intensity of reported problems for both "coordinating schedules" (Item 1): $F(1, 332) = 4.285$, $p = .039$; and "dividing work" (Item 5): $F(1, 332) = 4.709$, $p = .031$. These general findings can be attributed to the benefits of culture, language, and geographical proximity that domestic collaborative relationships enjoy. This confirms to a certain extent the negative results of heterogeneous networks suggested in the literature (Huang, 2007; Rothschild-Whitt, 1979; Sirianni, 1993).

The issue remains whether these reported indices of problems in collaboration are purely associated with the number and location of collaborators with which Chilean scientists work with the intensity and diversity with which they employ Internet technologies in their work. Therefore, next we evaluate the hypothesis of this article: *Chilean scientists who make greater use and diversity of Internet applications report problems less intensely in collaboration than do Chilean scientists that use these technologies less frequently and diversely*.

The Impact of Internet Use and Collaboration on a Scale of Problems in Collaboration

The Chilean scientists in our study report Internet access at close to 100%. This is by far the highest compared with the other developing nations studied in this way (Ynalvez et al., 2005). Connection in Chile is high generally due to a concerted effort to upgrade the digital network among the top research institutes and universities during the Chilean dictatorship of the mid to late 1980s. So unlike the previous study in Africa and India, the question is moot as to whether Chilean scientists with Internet access report fewer problems in collaboration, controlling for other factors; Chileans universally report ready access.[23] Therefore, to identify differences across an additive scale of reporting problems in collaboration, in the following regression analyses we employ two independent e-mail dimensions that distinguish Chilean scientists—"hours using e-mail" and "e-mail use diversity"—while controlling for important contextual, background, and collaboration factors. We also evaluate how Internet attitudes and web experiences vary with an additive scale of problems in collaboration, when controlling for important factors.

Table 4 demonstrates three regression models that reflect the significant association among the various factors that influence reporting more problems on an additive scale of problems in collaboration out of 10 possible. Model 1 considers contextual and background factors and produces a coefficient of determination (R^2) of .111 (Item 15) or explains only 10% of the variance in reporting problems. In this simple model, the "number of total projects" ($\beta = .245$, Item 5) and "number of students supervised" ($\beta = .405$, Item 6) are most significantly associated (at the $p < .01$ level) with reporting more problems in collaboration. These are rather intuitive findings that confirm the prevailing organization constraints associated with knowledge work. Also significantly associated (at the $p < .05$ level) with reporting more problems are working in a research institute ($\beta = 686$, Item 2) and being of younger "age" ($\beta = -.34$, Item 6). These findings as well seem reasonable, given that

Table 4. Regression of Problems[a] on Context, Background, Collaborators, and Internet Use

	Model 1	Model 2	Model 3
Contextual factors			
1. Region	−.170	−.206	.024
2. Sector (research institute)	.686**	.572	.454
3. Field (physical sciences)	−.326	−.195	−.360
4. Percentage of time spent on research	−.012	−.016**	−.013
5. Total projects	.245***	.138	.143
6. Number of students supervised[b]	.405***	.377***	.425***
Background			
7. PhD	−.301	−.414	−.473
8. Gender (male)	−.201	−.139	−.137
9. Age	−.034**	−.032**	−.027
10. English proficiency[c]	−.210	−.187	−.216
Collaborators and collaboration			
11. Total collaborators[b]		.763***	.576***
12. Homogeneity of collaborator network		−.259	−.217
13. People in my field work mostly by themselves[d]		.464***	.428**
Internet factors			
14. Internet has made me more connected[d]			.440**
15. Hours using e-mail			.168
16. E-mail use diversity			.066
17. Unable to find information on the web[e]			.499***
18. Getting disconnected from the web[e]			.197
19. Too many junk sites on the web[e]			.449***
20. R^2	.111	.179	.248
21. N	335	335	332

a. "Problems in collaboration" is an ordinal variable that ranges from 0 to 10, with higher values indicating more problems reported out of 10 possible.
b. Independent variable "Total Collaborators" is expressed in a natural logarithmic transformation.
c. Respondents were asked to report their experience reading and writing in English, so that 1 = *not comfortable at all*, 2 = *not so comfortable*, 3 = *comfortable*, and 4 = *very comfortable*.
d. Respondents were asked to 1 = *disagree strongly*, 2 = *disagree somewhat*, 3 = *agree somewhat*, or 4 = *agree strongly*.
e. Respondents were asked to report if this was 1 = *not a problem at all*, 2 = *minor problem*, or 3 = *major problem*.
**$p < .05$. ***$p < .01$.

research institute scientists often work interdependently with others and thus rely on each other more than academic scientists. In addition, they are often part of a larger transregional hierarchy that can also pose communication and coordination challenges. Though slight, the beta coefficient for “age” indicates a negative relationship with reporting problems, intuitively suggesting that experience may result in some advantages to circumventing research challenges.

Model 2 includes collaboration factors and produces a coefficient of determination ($R^2 = .179$) that is substantially greater than that produced by Model 1. Controlling for the “number of collaborators” over three main projects, “homogeneity of collaborative network,” and the degree to which a respondent agreed with the statement “People in my field work mostly by themselves” eliminates the significance of “research sector” (Item 2) and the “number of total projects” (Item 5), while elevating the significance (at the $p < .05$ level) of the reported “percentage of time spent on research,” which was not significantly related in Model 1. Although the beta coefficient for this factor is quite small and negative ($\beta = -.016$, Item 4), it counterintuitively reflects that as scientists report they dedicate a larger percentage of their time to research, they also are less likely to report more problems in research. This suggests that there might be an economy of scale to being more actively involved in research. The reported “number of students supervised” though continues to be highly significant (at the $p < .01$ level) in Model 2, with only a slight reduction in the beta coefficient ($\beta = .377$, Item 6). “Age” continues to be negative and significantly associated (at the $p < .05$ level) and with only a slight reduction in the beta coefficient ($\beta = -.032$, Item 9).

As with the bivariate analysis that preceded this regression analysis, the reported number of “total collaborators,” over three main projects ($\beta = .763$, Model 2, Item 11), is positive and significantly associated (at the $p < .01$ level) with reporting more problems in collaboration, even when controlling for context, background, and the “homogeneity of collaborative network.” “Homogeneity of collaborative network,” though, was no longer significant when controlling for other factors. Somewhat intuitively, agreeing to a greater degree that “people in my field work mostly by themselves” is significantly associated (at the $p < .01$ level) with reporting more problems in collaboration ($\beta = -.464$, Model 2, Item 13). Perhaps this is why people work by themselves, to avoid problems in collaboration or because they assume that others are more likely to work on their own.

When loading in our Internet factors alongside context, background, and collaboration factors in Model 3, the coefficient of determination again increases substantially ($R^2 = .248$) over the preceding model, indicating that this model explains close to a quarter of the variance of the dependent variable—the total reported number of problems in collaboration out of 10 possible. And when controlling for Internet factors in this final model, the significances of the reported “percentage of time spent on research” (Item 4) and “age” (Item 9) are both eliminated. The number of “total collaborators” ($\beta = .576$, Item 11) and the “number of students supervised” ($\beta = .425$, Item 6), though, continue to be significantly associated (at the $p < .01$ level). In addition when including Internet factors in Model 3, disagreeing to a greater degree that “people in my field work mostly by themselves” ($\beta = .428$, Item 13) also continues to be significantly associated with reporting more problems, although at a reduced significances (at the $p < .05$ level).

Three of six Internet factors emerge as significant in the more elaborated Model 3. Agreeing to a greater degree that the “Internet has made me more connected” is significantly associated (at the $p < .05$ level) with reporting more problems in collaboration ($\beta = .440$, Model 3, Item 14). This reflects, to a certain extent, a different dimension to the “Collaboration Paradox” (Duque et al., 2005). Just like more collaboration did not necessarily translate into more productivity in the African context, Internet use does not necessarily translate into fewer reported problems in collaboration in the Chilean context. Also somewhat supporting this is the result of two out of the three problem dimensions associated with web surfing. “Unable to find information” ($\beta = .499$, Item 17) and “too many junk sites” ($\beta = .449$, Item 19) were both highly significant (at the $p < .05$ level) in Model 3, indicating that as respondents reported more intensely these two problems dimensions of web surfing, they were more likely to report more problems in collaboration as well.

Finally, neither e-mail dimension (time of use or diversity of use) in Model 3 was significantly associated with reporting problems in collaboration, although the beta coefficients for both are positive (Items 15 and 16). While not significant, the direction of the relationship leans toward suggesting that more intense and diverse e-mail use is associated with reporting more problems.

Discussion

Taking a lead from previous studies that have investigated the relationship between reporting problems in research, collaboration frequency, and Internet use, this investigation evaluated how scientists, located in a developing nation (Chile) that enjoys consistent Internet connection, are faring in the digital age. Our results *do not* support our guiding hypothesis that Chilean scientists who employ Internet technologies more also report fewer problems in collaboration, when controlling for other factors. Moreover, across some dimensions, the Internet is actually associated with reporting more problems. This suggests caution in assessing how e-mail communication and web access may facilitate the research process outside the advanced nations of the North.

Since simple access is widespread in Chile, the "hours using e-mail" and "e-mail use diversity" were employed in the analysis. The results demonstrated that the time using e-mail and the diversity of use *were not* significantly associated with reporting fewer problems in research, contrasting with some extent findings from the United States, Africa, and India (Duque et al., 2005; Walsh & Maloney, 2007). Agreeing more intensely that the "Internet has made me more connected" and reporting more intense problems in "finding information" and dealing with "too many junk sites" on the web, though, *were* significantly associated with reporting more problems. While our analysis is only cross-sectional and thus does not support a causal mechanism, these findings nonetheless indicate that Internet use may actually be associated with more problems in research and not less. Perhaps, in the Chilean context this is due to information overload and the miscommunication that can occur when collaborators replace face-to-face discussion with e-mail messages. These are two digital risks that have been considered in past studies (Bawden, 2001; Cummings & Kiesler, 2005; Keating & Jarvenpaa, 2011; Monteiro & Keating, 2009; O'Kane & Hargie, 2007; Sproull & Kiesler, 1991; Whitman, 2003).

Another interpretation is that it may not be that Internet use alone is associated with more problems but also collaborating more, especially over large distances, with collaborators who may not speak Spanish. While Chilean scientists on the whole report fewer problems in collaboration compared to their counterparts in Africa and India, they similarly report more intense problems when reporting more total collaborators in a bivariate analysis. Unlike other developing world settings studied, though, collaboration measures in the Chilean context continue to be significantly associated with reporting more problems in research, when controlling for background, context, professional activities, and Internet factors. These findings question the prevailing "inevitability of collaboration" argument espoused by many science policy makers today.

While the bivariate analysis reflected that Chilean scientists report more intense problems when their collaborative network is geographically heterogeneous, this statistically significant relationship did not hold up when (a) controlling for other important factors and (b) considering total problems reported out of 10. Still, the bivariate findings do confirm the suggestion of past research that distant or cross-national contacts hinder the collaborative process (Huang, 2007; J. S. Olson et al., 2008; Sonderegger, 2009). The consequence of this may be magnified in the developing world research context, since one key motivation for collaborating with partners in the exterior is to access resources that are in short supply at home. This has relevance to the Chilean context, since in qualitative interviews, Chilean scientists reported often seeking international collaborators over the Internet in order to circumvent the lack of local research funding and access to up-to-date literature (Duque, 2007). But if international collaboration is associated with increased obstacles to research, the expected benefits of collaboration for this population of scientists may be cancelled out.

Contextualizing this to the present day is a science network study conducted in Chile that confirmed the inverse network relationship between local and global professional contacts: Either the Chilean scientist is more locally connected or she or he is more globally connected (Duque et al., 2009). The mechanism for this may be that so many Chilean scholars travel abroad for advanced training and then more likely than not return with outward orientations toward research. Meanwhile, resource constraints at home create a competitive climate that motivates the Internet search for international contacts to acquire up-to-date literature and research funds not available locally. And this is supported by the previous study evaluating Chilean science networks that concluded a significant and positive relationship between the size of foreign networks and more frequent Internet use. Moreover, during the recent economic crisis, some Chilean scientists attested to the further "balkanization" of their national research community (Duque, 2012). This has motivated many to look more readily for collaborators abroad instead of within their nation. And almost exclusively it is the Internet that is mediating these searches.

Given these recent developments, could it be the case that the Internet is paving the way for increased and more geographically dispersed collaborations among Chilean scientists with partners in the exterior, which in turn is associated with more problems encountered in the research process? If so, this would corroborate neo-dependency arguments suggested in past studies that the Internet may benefit the core and not the peripheral countries by attracting the focus of Chilean research toward global at the expense of local relevance (Escobar, 1995; Davidson et al., 2002; Duque et al., 2009; Sagasti, 2004; Sooryamorthy et al., 2007).

Finally, past research has suggested with regard to Internet access and use that the intensity and perhaps the benefits and negatives tend to level off with experience (Wellman & Haythornthwaite, 2003). In the case of Chile, the benefits of Internet use in reducing difficulties in research have most likely reached a plateau, since it enjoys the most long-standing and complete digital access of the developing regions studied in this way. Perhaps by comparison, Africans scientists have yet to reach that same milestone, given the inconsistency and high expense of digital access in much of the sub-Saharan region. In some cases, recent reports indicate that Internet infrastructure is just as inconsistent for Africans now as 6 years ago. In contrast, it is expected that Internet infrastructure in Chile will have improved when we repeat this study in the next few years. Whether our panel of Chilean scientists report increased international collaboration along with higher intensity levels of problems in research may be a more robust indicator of whether the Internet is leading to technological neo-dependency in the digital age. In the meantime, science and technology policy analysts should evaluate closely the historical and present-day macro and micro causes of network "balkanization" within scientific communities located in less developed regions. Moreover, they should pay particularly close attention to how "well-intended" directives and/or economic conditions that promote (a) doctoral training in advanced nations, (b) international collaboration, and (c) improvements to Internet infrastructures may unwittingly be magnifying a neo-dependency pattern suggested by this present study.

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Notes

1. Internet technologies (Internet) refer to both web-surfing platforms and e-mail communication that enable ubiquitous global access to contacts and to the retrieval and dissemination of information over digital architectures. In this article, we consider both web surfing as well as e-mail communication, which is considered the primary Internet application for science collaboration (Finholt & Olson, 1997; Hine, 2006; Walsh & Roselle, 1999).
2. While there are many differences between less developed regions in terms of culture and postcolonial experience, there are many commonalities that make

cross-comparison fruitful for imagining what combinations of factors best support scientific activity and technology adoption and use. For example, many regions suffer from a lack of coordination among societal sectors (Drori et al., 2003; Sagasti, 2004). Also, there are generally few resources made available for research. And the funds that are made available tend to support innovations in primary goods production and not cutting-edge basic science and new technologies. Moreover, with few exceptions, access to up-to-date Internet technologies is dependent on innovations from abroad.

3. Senior researchers engage graduate students in collaborative networks of colleagues, which in turn propagate certain research questions, methods, and interpretations.
4. In the modern era, scientific collaboration among peers, though, is characterized by specific output—access to equipment, visibility and recognition, increasing productivity, avoiding competition, surmounting intellectual isolation, and confirming research problems (Lee & Bozeman, 2005; Melin, 2000)—and social motivations—enjoying stimulating experiences and even working with old colleagues (Bouas & Arrow, 1995).
5. To further temper the optimism of Modernization advocates, studies on science stratification suggest that a stable asymmetrical structure exists within science that does not benefit those outside advanced nations (Cole & Cole, 1973; Gaillard, 1992; Merton, 1968; Schott, 1993). Merton's (1968) "Matthew effect" explained the reifying nature of science networks by concluding that the accumulative advantage of academic prestige, funding, and citations tends to concentrate toward elite scientists and institutions located in the core at the expense of those in the periphery like Chile. Francisco Sagasti's (2004) work reflects on this. He suggests that there is an historical self-reifying indigenous/exogenous global system of knowledge production, which he argues places an insurmountable "Sisyphus challenge" before scientific communities located in the less developed world. Uncoordinated indigenous societal sectors in the South, along with very strong exogenous sector connections to the global North, tend to attract scientific attention away from local relevance and toward applications that help the developed nations at the expense of the less developed ones. Translated, this means that the global stratification of science may be resistant to change regardless of the cost-effective information transfer and social networking power of Internet technologies.
6. There is even evidence from a cross-sectional study that the Chilean scientific community fits the asymmetrical professional network profile identified in past studies (Duque et al., 2009). Chilean scientists are either very locally connected or they are very globally connected with few that enjoy balanced professional networks. Moreover, recent qualitative interviews with Chilean scientists during the summers of 2010 and 2011 attest to the further "balkanization" of the scientific community

there, especially during the global economic crisis, when local research funds have been even more stretched (Duque, 2012). With more reason, in the words of one Chilean scientists "we are looking abroad instead of to the side" for collaborative opportunities. And this "looking" is almost exclusively mediated over the Internet.

7. This is not the case universally, even from studies conducted in the North. Cummings and Kiesler (2005) concluded that e-mail complicated the collaborative process for their sample of collaborative researchers.
8. The social inequalities, bureaucratic corruption, and occasionally armed conflict often experienced within less developed regions limit the successful saturation of new technologies like the Internet across class and sector boundaries. But also cited is the lack of cultural relevance associated with some new technologies (Fuchs & Horak, 2008) and the often-unfriendly environmental conditions that do not readily support sensitive modern equipment built for more temperate or climate-controlled environments (Akrich, 1993). These social and environmental obstacles experienced in many less developed regions help explain, for example, the historical low penetration rates of television and landline telephony into sub-Saharan Africa (Castells, 2000). One bright spot is that mobile phones have been much more ubiquitously adopted in resource-poor regions and are credited with propelling substantial social networking gains and economic diversification and growth (Donner, 2008; Palackal et al., 2011; Shrum et al., 2011). This is generally credited to the comparatively lower initial and maintenance costs associated with mobile phones, their culturally acquiescent nature (language based more than cognitive physically based), their smaller size, and the positive network externalities of this particular communication and information technology.
9. Additional scholarly evidence questions the smooth diffusion of complex cultural-technical systems into resource-poor regions like work on cross-cultural technology transfers (Akrich, 1993; Cutcliffe & Micham, 2002; Guille-Escuret, 1993; Pfaffenberger, 1993) and readings from social network perspectives (Fukuyama, 2000; Narayan & Cassidy, 2001; Rogers, 1995). For similar reasons, over the past decade, Internet infrastructure projects have met with only marginal success (Ganesh & Barber, 2009).
10. Walsh and Maloney (2007) constructed their coordination problems factor based on the following dimensions: (a) getting others to see your point, (b) reaching decisions, (c) division of labor, and (d) misunderstandings.
11. Duques et al. (2005) measured problems in collaboration over 10 dimensions: (a) problems with contacting people, (b) coordinating schedules, (c) getting others to see your point, (d) security of information, (e) resolving conflicts, (f) coordinating schedules, (g) length of time to get things done, (h) transmitting information, (i) dividing work, and (j) keeping others informed of progress.

12. After the first round of interviews in late spring of 2005, we discovered an imbalance in sampling that favored academic scientists. To address this, we returned in the summer of 2006 and organized interviews with an additional sample of research institute scientists.
13. Separated by approximately 500 miles, these southern regions are known for marine and agricultural research within both academic departments and research institutes.
14. Due to different distribution patterns by sector, the academic scientists were localized in one region, Concepcion/Chillan, and the research institute scientists were distributed across three regions, Santiago, Concepcion/Chillan, and Puerto Montt/Osorno.
15. Walsh and Maloney (2007) and Duque et al. (2005) evaluated "problems in collaboration" for a sample of 230 U.S. scientists and a sample of 918 African and Indian scientists, respectively. Both studies accept that collaboration itself poses problems in coordination along a variety of continuums, for example, in terms of size, diversity, and the distance between members involved in shared work. Nevertheless, Walsh and Maloney (2007) and Duque et al. (2005) found a positive relationship between e-mail use and reporting problems less intensely. For Walsh and Maloney (2007), less intense reporting of "problems in coordination" was associated with more e-mails sent per day. Duque et al. (2005) concluded that reporting e-mail access was associated with reporting problems less intensely in "contacting people," "transmitting information," "security of information," and "keeping people informed of progress."
16. This initial measure of collaboration (number of collaborations out of three possible main projects) replicates the one used in Duque et al. (2005). In the Chilean survey, though, we were able to account for the number and geographical location of collaborators, allowing for a more comprehensive measure of collaborative network size and location of contacts.
17. We also asked respondents to report the hours spent surfing the Internet and their various uses of the web; but these variables were highly correlated with e-mail use and diversity. For parsimony, we include only e-mail time and diversity measures in the analysis that follows.
18. The particular measures of e-mail use (weekly hours) replicates one measured in a survey employed in Africa and India, where the relationship between e-mail use and problems in collaboration has been studied. In the previous study, though, "access to e-mail" was considered in the analysis and was found to be positively associated with reporting less intense problems in collaboration (Duque et al., 2005). Walsh and Maloney (2007) considered a measure of "e-mails per day" for a sample of U.S. scientists and also found a positive relationship with reporting problems less intensely in coordination.

19. Ynalvez and Shrum (2006) considered three additional measures relevant to the Filipino context.
20. In Chile, the scientific core has been established as being located in Santiago, the capital, due to the concentration of top universities, national research institutes, and corporate R&D facilities (Mullin et al., 2000, Organisation for Economic Co-operation and Development/Bío Bío's Regional Steering Committee, 2009). The second-highest ranked university is located in Concepcion, which leads all other national universities in patents produced (Organisation for Economic Co-operation and Development, 2009). This region hosts a variety of highly productive research institutes as well.
21. In the interest of parsimony, the analyses that follow only employ the dichotomous measure for "physical sciences," since in our Chilean sample, this field reported on average the lowest number of collaborators and the fewest reported dimensions of problems in collaboration. This is in stark contrast to findings in the developed world, where these disciplines are normally associated with projects consisting of many collaborators. Echoing the asymmetrical global distribution of science fields (Drori et al., 2003), this indicates how globally isolated some central fields are when crossing borders, even in a rather advanced developing country like Chile.
22. Ynalvez et al. (2005) found that Kenyan scientists averaged 2.47 out of 6 possible e-mail uses measured, while Malayali (Kerela, India) scientists averaged 2.45, and Ghanaian scientists averaged 2.10 out 6 possible e-mail uses measured.
23. Ynalvez et al. (2005) found that scientists in Kerala (India) enjoyed 80% to 93% ready e-mail access depending on what research sector they worked in. Ghanaian scientists reported 64% to 66%, while Kenyans lagged behind at 43% to 57%.

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