Scientific Collaboration and the Kerala Model:

Does the Internet Make a Difference?

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Abstract

ICTs have become the panacea for development for many developing countries in the modern, knowledge-based world. Kerala, a southwestern state in India widely known for its model of development, has not only joined this bandwagon but has selected ICTs as a means to pull the state out of its present crisis. The current development policies of Kerala offer a red carpet welcome to ICT-based industries. The question is whether the state will be able to reap the benefits of ICTs as envisaged in its IT policy. The present paper examines the institutions of knowledge production in Kerala (academic and scientific), which are generally the forerunner of other sectors in terms of their use of ICTs. Information is drawn from surveys of scientists in educational and governmental institutes in 1994 and 2000. We examine the extent to which ICTs have affected research communication and collaboration, which are crucial factors in developing infrastructure in the LDCs and make them self-sustainable in the long-run. Often it is argued that the availability of and access to ICT resources is a key determinant in domestic and international collaboration, which in turn opens up opportunities for ICT-based development. However, the results of this study show that despite improved use and increased access to resources such as computers, email, and the web, the level of collaboration is extremely low in Kerala.

INTRODUCTION

Contemporary societies are increasingly information-based, reinforcing linkages between global development efforts, the creation, accumulation and dissemination of scientific knowledge,[1] and innovations in new information and communication technologies (ICTs). This has led to a call for new perspectives aimed at understanding emerging social realities that result from new ICTs (Escobar, 1994), and a clear realization that social, economic and political progress in the new information age is intimately intertwined with the capacity to make informed decisions among a growing array of research-based technologies (UN, 1993). Some have suggested that social science should consider the nature and function of scientific knowledge within a developmental perspective, the social characteristics of the producers and transmitters of such knowledge, and the resulting macro changes in social power relations within and among various developed spheres, especially those shaping international scientific communities (Stehr, 2001). With this spirit in mind, our aim is to identify the crossroads at which development, new ICTs, and scientific institutions interact in the context of Kerala, a south Asian region widely believed to be at the forefront of social and educational progress. Will new ICTs be facilitative or detrimental to the process of scientific research in this area? Based on a longitudinal analysis, we seek to address the issue of access and use of ICTs (such as personal computers, email and the web) and their effects on collaboration in the academic and research sectors of Kerala.

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[1] Brown (1988), Escobar (1995) and Sillitoe (1998) emphasize knowledge as key to the analysis and prescription of development alternatives. However, their treatment of the role of knowledge in development predates the advent of the Internet and fails to recognize new social realities emanating from the rapid diffusion of Internet-based communication technologies towards the new millennium. Castells' (2000) and Stehr's (2001) ideas on knowledge and development are cases in point, which are able to account for these inadequacies, especially in the Escobarian framework for social change and development. Castells (2000) speaks of modes of development (agrarian, industrial, and informational) as the technological arrangements through which labour works on matter to generate the product ultimately determining the level and quality of surplus. He views contemporary societies as representing the informational mode of development wherein the source of productivity resides in the technology of knowledge generation, information processing, and symbolic communication; the informational mode is specifically characterized by the 'action of knowledge upon knowledge itself as the main source of productivity.' In order to understand the current socio-economic trends, Castells (1989) argues for the consideration of `informationalism' as a mode of development, and the adoption of information technology as a powerful working instrument. Informationalism and capitalism have converged into a process of techno-economic restructuring of society. In like manner, Stehr (2001) argues that knowledge has always had a major function in society but that contemporary societies are becoming more knowledge-intensive as compared to modern societies conceived mainly in terms of property and labour. What Stehr (2001) posits is that a new mechanism, knowledge, has entered the social relationship of production to the extent that it challenges and transforms property and labour as constitutive mechanisms.

Developmental perspectives evolving over the last half century include modernization, dependency and dependent development views. Although predating the advent of computer-based ICTs and therefore limited in their direct reference to such technologies, these perspectives remain important in interpreting the social phenomena of the 'Internet era'. For example, modernization theory suggests that development could be fuelled by simply adopting the capital intensive, technologically advanced, economic and social structures of the West (Rostow, 1960). Importing ideals, infrastructure, and methods from the developed world was expected to transform nations whose economies were based on subsistence agriculture into modern, capital intensive, manufacturing societies. By contrast, dependency theory (Cardoso, 1972) and world systems theory (Wallerstein, 1979) described the Third World as a 'periphery' to the developed world 'core'. Its role was in primary production for the economic and geo-political benefit of the West at the expense of social, economic, and cultural self-determination.

Dependent development, seemingly a middle road between the two previous perspectives, suggested that development was possible by taking advantage of certain tutorial relationships between developed spheres. The Asian tigers are commonly presented as an example of incremental development (Roberts and Hite, 2000). In the economic sphere, these nations advanced by first allowing Western donor agencies and multi-national corporations partial access, then locally absorbing and mirroring their advanced techniques, and eventually replacing them with domestic structures and institutions. An important caveat here is that the tutorial relationship between the developing and developed world succeeded in some regions but not in others. The Kerala Model, discussed below, is an important example of a developmental idea that combines the notion of uneven social and economic growth.

The central difficulty with these and other classic developmental perspectives is the failure to incorporate the role of 'relational technologies'[2] in development. While the

[2] Relational technologies include innovations in communication and transportation in the last half century, the impacts of which have changed the structures of social relationships within and among those societies that have incorporated them. New ICTs represent a convergence of communication, information production and media technologies. Email, for instance, is the paradigmatic example of the relational component of these new ICTs, providing low cost opportunities to temporally and spatially expand and manage social networks in ways that go beyond previous communication technologies.

pervasive global influence of new ICTs is now widely recognized,[3] with few exceptions the development literature has not considered this emergent phenomenon until recently. Of late, the ICT and development debate has become digitalized, with two of the three aforementioned classical perspectives taking various sides of the 'digital divide' argument, that new ICTs are adding to a growing socio-economic gap between First and Third Worlds. Representing a neo-modernization perspective, Castells (2000) suggests that the digital divide does and will continue to exist, not exclusively between First and Third World nations, but among connected and non-connected networks within discrete regions. The result is a new world communication structure driven by new ICTs, creating what he terms a network of globally connected cities or nodes and their peripheral 'black-holes', that is, peripheral-urban and rural communities outside the communication grids of major global cities.

Representing a neo-dependency perspective, an Escobarian framework (1994, 1995) is less optimistic, suggesting that just as the development effort over the past half century has been a continuation of colonial exploitation by the First World, the digital penetration of the Third World will maintain this status quo. Those that produce and shape these new technologies will enjoy an even greater material and cultural stranglehold over less technologically developed regions. Taken together, neo-modernization and neo-dependency assessments of how ICTs may shape developing regions offer us a modified dependent development argument that there are phases in a technological trajectory, such that effects are not constant over time and across regions. ICTs may benefit some regions, but not others. With rapid innovation in ICTs, the challenge for resource-poor developing regions to maintain the technological pace needed for upgrades, re-training, and maintenance lends credence to the argument for a high degree of indeterminacy. But it also emphasizes that empirical studies are necessary to understand the conditions under which ICTs are associated with constructive or destructive effects.

While contemporary development perspectives begin to paint a clearer portrait of what is occurring as a result of the global diffusion of new ICTs, empirical analysis must

[3] ICTs play a crucial role in most societies' capacities to produce, access, adapt, and apply information, and thereby providing opportunities for facilitating the transfer and acquisition of knowledge (Morales-Gomez and Melesse, 1988: 3).

focus on the role of ICTs in specific sectors and institutional contexts. Since many of the new ICTs, including the Internet itself, were developed in educational and research settings, the relative absence of empirical work on such institutions is noteworthy. Davidson et al. (2003) provide a first step by associating three positions in the recent literature on globalization of science with the classic and contemporary development arguments just reviewed. The first argument, that the Internet is an 'elixir', suggests that the impact of ICTs will be a boost to science in less developed regions, much like the modernization perspective and the Castellian 'global node' view. The second, 'affliction,' view suggests that new ICTs will be debilitating to science in less developed regions, echoing dependency theory and recent 'digital divide' perspectives. The 'teething' argument represents the middle-ground of 'dependent development', focusing on the role of western, donor-driven research, especially programmes aimed at upgrading research institutions after independence. Such initiatives, including recent 'connectivity' programmes, have shaped science in developing areas, but not uniformly. Some Third World scientific communities are growing into relative autonomy, while others still rely heavily on the financial resources and direction of their developed world benefactors. Although they differ in their assessments of outcomes, both development and recent Science and Technology Study (STS) theories suggest that new ICTs will have a major impact on science in less developed regions. The question remains: How?

In the developed world, a number of studies have identified collaboration as an important facet of the changing nature of science over the past 30 years. These studies indicate that the production of scientific knowledge is increasingly collaborative rather than competitive, owing to the benefits of sharing the increasing cost and complexity of modern research, access to expertise, and the time savings of delegated work (Bordons and Gomez, 2000; Katz and Martin, 1997). In other words, collaboration has been increasingly seen as a 'good' by science policy makers, which should result in increased productivity (Lee and Bozeman, 2004; Duque et al. 2004). One way that the relational components of new ICTs may impact science is by lowering the transaction costs associated with scientific collaboration, especially those communication tasks that involve finding collaborators, organizing schedules, delegating work, and resolving problems (Koku and Wellman, 2002; Walsh and Nancy, 2003). This is especially true for collaborations that cross national borders and time zones, where the problems of collaboration can be magnified by cultural differences. A second influence of ICTs is the reduced transaction costs associated with the gathering and dissemination of scientific information in the form of e-publishing, both through personal-professional web-pages, online digitally-archived journals and reference materials, and the emerging e-journals (Grudin, 2004). But while there has been a good deal of attention to science in the developed world and the impacts of ICTs, few studies have investigated the transformations of science through ICTs specifically in academic and scientific contexts in less developed regions.

Two factors are particularly relevant here: remote and local collaboration. Scientific collaboration can be domestic (local) or international (remote). Domestic collaboration is work shared among scientists within the same locale. International collaboration may be classified as either (1) exclusively among scientists in developed nations, (2) exclusively among scientists in developing areas, or (3) between scientists in developed and developing areas. In relation to positive social change and development, we view this third category of inter-regional collaboration—between developed and developing country scientists—as a means to improve and upgrade scientific capacity, much as suggested by dependent development theory and the 'teething' perspective on the globalization of science. While there will be setbacks and difficulties, the teething argument suggests that inter-regional collaborations may result in more international publication and donor funding.

Collaborations between developing areas are equally important, as a means to autonomously diversify scientific personnel and infrastructure, while local collaborations within national borders strengthen and unify national capacity for research and development. While these forms of collaboration echo both modernization and 'elixir' perspectives, increased participation in the second and third types of collaboration are beneficial to the research institutions in developing areas by paving the way for increased domestic productivity. Long term impacts enhance the development and integration of a local research community, which provides the technical and scientific research needed for national development efforts.

Scientific collaboration, then, is particularly important to the question of whether new

ICTs affect the academic and research institutions of the coastal state of Kerala in southwestern India. Our focus will be on the degree of access and use of new ICT 'relational and media' resources—personal computers, email, and the World Wide Web. We examine the extent of diffusion of these resources and the extent to which they have shaped collaborative behaviour and among scientists in the academic and government research sector. The 'elixir' position argues that ICTs are a determinative factor that can lead to an increase in all forms of collaboration, both local and international. The 'teething' argument suggests that ICTs will increase both remote and local collaboration among Malayalis (the people of Kerala), but that such an effect may not be observable for some time. During the 'teething' period, developing areas may experience a tension resulting from the fact that investments in ICTs have not resulted in measurable impacts on the phenomena of interest. The 'affliction' argument suggests that global access and use of new ICTs will retard local collaboration, while promoting international collaboration. Developed world science, along with its local agents in less developed regions, will utilize these new technologies more effectively to structurally displace their exclusively indigenous Third World counterparts.

In the next section, we introduce the special characteristics of Kerala that have led many to believe it represents a unique developmental model. Next, we describe the methodology used in this longitudinal study of Malayali scientists in academic and research institutions (1994-2000). The findings suggest that relatively widespread diffusion of ICTs has occurred but offer little indication of an impact on collaboration.

KERALA CONTEXT

Located just above the equator on the east shores of the Indian ocean, the tropical state of Kerala has received international acclaim owing to its remarkable socio-economic and demographic achievements since it became a separate state in Indian Union in 1956. Its positive development indices have often been compared with that of highly industrialized and developed regions.[4] As a result, the state has inspired an approach to development

[4] For instance, the life expectancy at birth in Kerala was 72 years (1995) when it was 76 years (1993) for the USA. Similarly, Kerala and the US do not differ greatly in aspects such as death rate per 1000 (8.8 and 6 for USA and Kerala respectively), infant mortality rate per 1,000 births (9 and 12), birth rate per 1,000

known throughout international circles as the ‘Kerala Model’.[5] While the general features of this model are well known (Franke and Chasin, 1994; Jeffrey, 1992; Parayil, 1996), the most important dimensions of the model for our purposes are related to infrastructure and human capital. Kerala, unlike many other states in India, has the advantage of well connected road and communication networks, a high density of telephone connections, and a progressive population. The value placed on education, training, and literacy is widespread through the state, from its emphasis in state policy to the pride with which Malayali families describe the degree credentials of both their sons and daughters.

Recent trends in Kerala, however, have raised doubts about the sustainability of this model (Iyer and McPherson, 2000). Academics, policy makers and the public alike share a common view that a crisis is brewing in this Indian state. Primary and secondary sectors of the economy have not shown any improvement to their contribution to the State Domestic Product. Consumerism is rampant at all levels of the society (Sooryamoorthy, 1997). Growing rates of unemployment—even among the highly educated—crime, suicide and mounting fiscal problems have fuelled this crisis. The ongoing debate may not now be how the Kerala Model can be applied globally, but how to overcome the present crisis and place Kerala back on the right developmental track.

If the crisis persists the difficulty for Kerala to maintain its credentials of development will increase. This intractable situation has given rise to attempts to sustain its regional achievements by searching for alternate development opportunities. New ICTs have been identified as a potential area to attract international capital to induce economic growth and maintain its hard won social development. The recent Information Technology (IT) policy endeavours to delineate a strategy for harnessing the opportunities and the resources offered by IT for the comprehensive social and economic development of the state. This strategy has been conceived keeping in view of the fact that IT constitutes the primary instrument for facilitating Kerala’s emergence as a leading

(15.9 and 15), total fertility rate (2.1 and 1.8) and literacy (96 and 93 per cent). See Parameswaran, 2000: 233.

[5] Franke and Chasin define the Kerala Model as a ‘set of high material quality-of-life indicators along with low per capita incomes, both distributed across nearly the entire population; a set of wealth and resource redistribution programmes that have largely brought about the high material quality-of-life indicators; and high levels of political participation and activism among ordinary people along with substantial numbers of dedicated leaders at all levels (2000: 17).

knowledge society in the region (GOK, 2001). The policy affirms that growth will be increasingly driven by the knowledge and service-based sectors, where ease of information transactions will be a key determinant to success.

When IT is the chosen approach to save Kerala from a downslide, the issue is how far it can be utilized within the prevailing poor economic situation. We maintain that an important indicator will be found at the centres of scientific knowledge and research. Are the institutions of Kerala equipped to meet the challenges posed by the new path of development? How far will the existing centres of knowledge production consent to the objective of making use of IT for growth as envisaged in the policy document? In this paper we look at the context of ICTs in the academic and research institutions of Kerala, using the data collected at two time intervals to examine the degree and level of scientific collaboration among knowledge workers. The degree of Internet adoption and collaboration aids in understanding the degree to which the state can benefit from current efforts focused on promoting new ICTs. The central question is whether Kerala can utilize these new relational and media technologies as a major instrument for developing scientific capacity, production and collaboration.

METHODS

We analyze data from two surveys of the educational and scientific community, conducted six years apart in 1994 and 2000. The 1994 sample was originally developed through a bibliometric analysis of the Kerala research system (Shrum, 1996).[6] We stratified our organizational sample by sector, including university departments, national research institutes, nongovernmental organizations (NGOs), and international research organizations. We sought to interview three individuals in each organization, with a preference for mid-career researchers. A special effort was made to interview women, who constitute about one quarter of the sample.[7]

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[6] The field survey of researchers in the original study was conducted in three locations, selected to represent low (Ghana), medium (Kenya), and high (India) levels of development in Africa and Asia. A team of three interviewers spent 4-5 weeks in each location, completing 293 structured interviews altogether. In all, interviews were conducted at 53 national research institutes, 48 academic departments, 31 NGOs, and five international organisations (Parayil and Shrum, 1996; Shrum, 1997). In this paper we use only Kerala data.

The sampling technique was somewhat different for the second set of respondents, who were contacted during the three months beginning from June in 2000. However, as Table 1 shows, the two samples are similar in terms of such basic social characteristics as age, marital status, and educational levels. While the earlier survey sought to be relatively comprehensive in its coverage of agricultural, environmental, and natural resource-related research institutions, relatively few individuals could be interviewed in each because of time and cost constraints. In 2000 we determined to make every effort to increase the sample size and sought comprehensiveness in the number of individual scientists interviewed within each department or institute. Respondents were drawn from the main central and state government research organizations in the capital city, Thiruvananthapuram, as well as scientific departments of the University of Kerala and the College of Agriculture at Vellayani. The focus, as in 1994, was on fields of specialization in agriculture, biology, biochemistry, geology, mathematics, physics and social sciences. The survey instrument included both structured and unstructured sections on the major dimensions of professional research activities, international and national organizational contacts, frequency of discussions with various groups, supervisory roles and local contacts, professional memberships and activities, self-reported productivity, attitudes on agricultural and environmental issues, and the needs of the research system. The 2000 survey included a large number of items specifically devoted to ICTs.

Fifty seven per cent of our 1994-respondents belonged to national institutes, 31 per cent to universities, and 12 per cent to NGOs. In terms of organizations, these individuals represent 49 organizations in three sectors. Seven are NGOs, 22 are national institutes, and 20 are university departments. Several respondents whose primary affiliation was in the university or state sectors were members of NGOs as well. Since we did not cover NGOs in 2000, we omitted 1994 NGO data from the analysis. The same structured interview schedule, with the addition of 34 new questions, was administered to the 2000-respondents at their respective workplaces. The total number of respondents comes to 392 (89 from 1994 and 303 from 2000).

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[7] A standard response rate is difficult to calculate owing to the method used to obtain the interviews. In each location we tried to conduct interviews at every significant organisation in the state and NGO sectors,

FINDINGS

In this section, we will first discuss the social composition of the research system of Kerala by comparing the characteristics of scientists in 1994 and 2000. Next we will discuss improvements in access to relational and media resources—personal computers, email, and the web. Next we will examine their usage and distribution in detail for the recent sample, including information on the frequency and use of email and the web. We then look at the differences between the two main research sectors, academic and governmental. The significant observed difference in Internet access between the two sectors allows us to make some inferences about the degree to which that access has led to any change in internal and external collaboration. Such comparisons are important, given the widespread expectation that Internet use will have a positive impact on the propensity of the research system to interact across organizational boundaries.

Professional Profile of Scientists

Table 1 presents the basic characteristics of our respondents of 1994 and 2000 surveys. Overall, the research system did not undergo any large shift in this time interval. The gender composition has remained constant, while there is an increase in age (lines 1-2). Effectively, this indicates that the research system in Kerala is aging. The human capital of a research system is indicated by the levels of education and experience as well as location of training. Calculating organizational tenure from line 3 of Table 1, we can see that 1994 respondents had been with their organizations an average of 14 years, while 2000 respondents had been with their organizations an average of 18 years. There is not much renewal or inflow of new blood into the stream. Not only have levels of education remained relatively constant, the percentage of PhDs has gone down slightly (line 4). Degrees from developed countries and years spent outside the country for higher education are lower in the second time period, though not statistically significant.

[Table 1 about here.]

Access to Resources

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and at all university departments with significant agricultural or environmental research.

In sum, the data point to a research system that is aging and relatively stable, without improvement in human capital. However, as Table 2 shows, there is a highly significant shift in access to some of the backbone technologies for the production of knowledge, particularly new ICTs such as fax, computers, printers and email. Access to computers—the fundamental condition of modern ICTs, has improved from 61 per cent to 86 per cent (line 4). But the largest shift is the exponential increase in access to email from six per cent to 86 per cent (line 6). In terms of current scientific practice, across all disciplines and institutions, email is the sine qua non of collaboration—both within and between organizations. In six years, from the mid-1990s to the turn of the millennium, basic access to the core backbone technology of scientific work has increased from a handful of researchers to the vast majority of the knowledge workers of Kerala.

Improved access to ICTs does not imply improved access to all backbone technologies. In fact, evidence from Table 2 is that access is zero sum rather than across the board. While access to modern ICTs has improved, access to telephones has not shown any significant change (line 2) and access to typewriters and secretarial assistance has decreased. These older technologies—in their time critical to the process of knowledge production—are no longer necessary. But access to email is not usage. Does this increased access have a direct bearing on technology utilization and the collaborative efforts of scientists? The following sections look for evidence in this regard.

[Table 2 about here.]

Computers and Connectivity

Our first survey in 1994 coincided with the advent of Internet in Kerala. Therefore, we did not ask any detailed questions on email and Internet use—like many others, we simply did not predict what a massive impact these ICTs would have. For the 2000 survey, a set of new questions related to email, web and Internet use was added. In this section we look at the data separately for the two most important research sectors, academic departments and government research institutes.

[Table 3 about here.]

Table 3 shows that a large majority (85.8 per cent) of the respondents in 2000 have a computer at their workplace (line 1, column 3) and about half of these are connected to the Internet (line 8). While an even larger group has a home computer connected (line 9), this does not necessarily indicate a high level of usage. Many issues of sharing and episodic connectivity intervene between access and use. The location of the computer, an index of better access for individual users, shows that only one quarter of them have it in their personal office. About 40 per cent share with others in an office and another 36 per cent use computers kept in a common room. This situation is problematic, since each work computer is used by nine users including the respondents (line 3, column 3). The result is that considering both work and home use, the average use of computers in a typical week is less than 3 hours (line 7, column 3).

Computer access seems to be significantly higher for scientists in research institutes than academics.[8] More scientists in research institutions have computers at work than their fraternity in academic institutions (Table 3, line 1, columns 4 and 5) and the computer is more likely to reside in their personal office. In academic institutions there are many more users for each single machine (line 3, columns 4 and 5). Consequently computer use, measured by average hours per week, is significantly higher in research institutes (line 7, columns 4 and 5). Scientists in government institutes are more often connected to the Internet (line 8, columns 4 and 5): a difference that disappears when home computers are considered (line 9, columns 4 and 5). Yet overall, scientists in research institutes have a decided advantage over their counterparts in academic institutions.

The evidence presented here shows that computer use is dependent on access to machines (whether available in personal office or shared by many) at work or home. Often our respondents share the machines at work with as many as eight users and this is reflected in usage patterns, fewer than three hours a week. Sectoral differences between academics and government researchers are pronounced.

<u>Email and Web Use</u>

Over 83 per cent of scientists in Kerala had used email by 2000 (Table 4, line 1, column 3). Those who use email report spending 1.49 hours a week on sending and receiving

[8] As noted in the Methods section, the 2000 survey covered two major categories of respondents in the academic and research institutions of Kerala.

(line 4, column 3), mostly from work. About one-third of the respondents are part of an online discussion group and nearly half of them had the opportunity to send a message to a discussion group (line 6). Email is used for contacting local colleagues by about 30 per cent of the respondents. The per centage of respondents using email for contacting professionals outside Kerala but within India (regional contact) is almost double (68%). More than half of our respondents use email when they need to contact their colleagues in a developed country (remote contact). Thus, email is more often used to contact their regional and remote colleagues than local colleagues. While only one-third have used email to start a professional relationship (local, regional or remote) over 70 per cent have used it to maintain a professional relationship.

[Table 4 about here.]

Is there any significant sectoral variation in email use? As in the use of computers, the evidence indicates higher use of email by researchers in government institutes than in universities (line 4, columns 4 and 5). Scientists are not only better connected but are also more frequent users of email. Significant variation between academics and scientists is seen in sending a message to a discussion group, discussing with a colleague in India or in a developed country, and in submitting or reviewing manuscripts. Email use of respondents reinforces the fact that the scientists in research institutes are more avid users of ICTs than academics in Kerala.

Table 5 shows that, on average, our respondents began browsing the web in 1998, two years before we gathered our second set of data. However, one-fourth of them have never browsed the web (line 4, column 3). Currently, those who use the Internet browse an average of 1.63 hours a week (line 2, column 3). About one-third seem to be regular web users as indicated by the fact that they last used the web within the past day. At work, one quarter regularly access the web. Accessing the web from home is less frequent than from work (line 5). Earlier, we have noted that fewer respondents have a computer at home. As for web use, government scientists do more than academics based on total hours of web use per week, frequency of browsing, and accessing the web from work (lines 2-4, columns 4 and 5).

[Table 5 about here.]

Specific web uses reveal a clearer picture. Web use is often related to conducting information searches, finding reference materials, and acquiring or using data (line 6, column 3). There are only a few users for more specialized functions such as accessing electronic journals, collaborating in online projects, obtaining online maps, downloading software, publishing papers, or creating web pages.

In brief, we find significant differentiation between the academics and scientists in the availability of computers and their locations, the number of users per machine, hours of computer use and Internet connectivity. Government scientists are relatively advantaged compared with academic scientists with respect to ICTs. The question remains: Has increased access to these 'relational resources' affected collaboration in Kerala?

Collaboration

Available data allow direct comparisons of internal collaborative practices of researchers (collaboration within the respondent's own organization) in 1994 and 2000. However, given the differences in the items included on the two surveys, we must use indirect evidence to determine shifts in external collaboration, that is, collaboration across organizational boundaries. Our measure of internal collaboration is based on the number of professionals, technicians and non-technicians who 'work closely' with our respondents. Table 6 shows a rather dramatic reduction in professional collaboration. In the early 1990s, scientists collaborated with an average of nine other scientists in their organization, but only three in 2000. Including technicians and non-technicians in an additive scale, the reduction in internal collaboration is even more striking: from nineteen the number of internal collaborators has been reduced to five (line 4).[9]

[Table 6 about here.]

Analysis by sector allows us to determine shifts in external collaboration, across organizational boundaries. We are restricted in our analysis to the data collected at a later time point. Since we observed a relatively high degree of Internet access for scientists who work in government research institutes as compared to the relatively low degree of

[9] This is not owing to any reduction in research activities. Indeed, the total number of research projects reported by our respondents actually increased, from four in 1994 to seven in 2000.

access for scientists who work in universities, we would expect higher degrees of international collaboration for scientists in government institutes.

Table 7 shows the research activity of scientists in institutes and university departments. We asked respondents to describe up to three specific research projects, asked whether they were collaborative, and explored the location of these collaborations. The three items were then (1) summed to indicate the average degree of collaboration (mean number of collaborative projects), (2) dichotomized to indicate whether scientists were involved in any collaboration at all, and (3) coded as 'remote' if the project involved working with an organization outside the country. While academics report engaging in more projects than government scientists (lines 1-2), government scientists are more likely to engage in collaboration (lines 3-4). However, both academics and government scientists are unlikely to be involved in international collaborations.[10] For the entire sample, fewer than one scientist in ten is engaged in an international collaborative research venture.

[Table 7 about here.]

The level of collaboration is such that only three university and six government scientists report involvement in any foreign collaboration. Looking specifically at each of the respondents who reported international collaborative projects, collaboration was with their professional counterparts in counties like the UK, Canada, Germany, New Zealand, the USA, Japan and the Netherlands, which tops the list. Collaborations were reported on nutritional factors in tuber crops, the geochemical significance of laterite, gold deposits in Nilambur-Wayanad gold fields, heavy mineral management, coastal zone management, coastal erosion in Lakshadweep as well as efforts in aquatic microbiology and marine natural products. However, this is a relatively exhaustive list of the collaborations we were able to identify. If internal collaboration since 1994 has notably declined in both the academic and research sectors of Kerala (Table 6), it has not been offset by an increase in external collaborations (Table 7): the number of reported external collaborations is simply insignificant. Given the number of collaborative projects (0.64), and the data on email and Internet connectivity, it is difficult to argue that access is associated with collaborative science.

[10] The difference favours government researchers but is not statistically significant.

DISCUSSION

We have addressed the question of the extent to which ICTs have been incorporated into the Kerala Model, with special attention to the knowledge production sectors, as well as the difference ICTs have made to the process of development through improvements in scientific collaboration. Studies have shown the importance of understanding the nature and function of scientific knowledge in a developmental perspective. Perspectives such as modernization, dependency and dependent development views interpret conditions that have emerged in the recent Internet era. The 'elixir' argument, drawing from the modernization perspective, proposes that the impact of ICTs will boost the production of science in developing areas through opportunities for collaboration, while the 'affliction' argument, which draws inspiration from dependency theory, declares ICTs will be debilitating to these scientific communities as the digital divide widens. The 'teething' argument, compatible with the dependent development perspective, relies on the role of western, donor-driven research in LDCs, suggesting that short term impacts may be minimal, while long term positive effects will be achieved.

We examined how ICT relational and media resources (personal computers, email and the web) are affecting scientific practice in the teaching and research institutions of Kerala. To what degree do scientists have access to new ICTs and do they use them? Do differences exist between university-based researchers and those at government research institutes? Is there any effect on the collaborative patterns of scientists based on their access and use of these new relational and media resources? Data from two time points draw a picture of a stable or aging research system without a significant increase in human capital. The PhD has become a necessary qualification for government scientific positions, particularly since the notification of the University Grants Commission (UGC) in the 1980s.[11] Yet the percentage of scientists with a doctorate and the percentage who received their training abroad are lower now than before.

While there is no evidence of improvement in human capital, the technological means now exist to improve the research system through connections within and among

[11] UGC is a central autonomous body responsible for granting academic approvals and funds to academic and research institutions.

institutions. Our study shows that scientists have much better access to facilities such as computers and email. While the number of respondents with a computer has gone up by a significant amount, the proportion with some form of email access has increased quite dramatically. Yet this access is not evenly distributed. As compared to academics, scientists in research institutions have better access to computers and Internet connections at work. The most frequent users of email are scientists in research institutes, sectoral differences that can be seen in web use as well. We note that very few use the Internet from public terminals, libraries and Internet cafes, the ‘public access’ often touted as important for developing areas. Such uses are determined by the perceived needs of respondents and often these are not high. We believe there is a connection between the finding that knowledge workers rarely use public terminals at all and the finding that Malayali scientists who share computers at work have relatively low levels of Internet use. Shared computers are not ‘personal’ computers.

Simple connectivity is not the lone facilitating factor in email use. Equally important are the nature of work, the desire for career advancement, and the information and collaboration needs of scientists. However, neither the use of email nor web use translates adequately into collaborative research undertakings. Growth in access to computers and the Internet is associated with a decrease in internal collaboration in Kerala. In particular, the respondents in recent years work closely with fewer professional scientists, technicians and non-technicians within their own organizations. The edge of access to relational resources for respondents in 2000 is not reflected in international collaboration. What collaboration exists is mostly local and international collaboration is minimal. So despite great strides in making ICT resources accessible, the degree of scientific collaboration has not been affected.

Each of the theoretical perspectives reviewed above suggests a connection between access to ICTs and collaboration, whether it is domestic or international. The ‘elixir’ position argues that ICTs should increase all forms of collaboration. The ‘affliction’ argument suggests that global access and use of ICTs will retard local collaboration but increase international collaboration. The ‘teething’ argument is that ICTs will increase both local and remote collaboration, but that such an effect may not be evident in the short term. While the evidence presented here does not support any of these arguments completely, it is most consistent with the latter, since the short term effects studied in this paper have been minimal. However, it is important to note that the decrease in internal collaboration is consistent with the 'affliction' perspective. Not just connectivity differentials but sharing and use differentials may maintain and enlarge the digital divide, not only between the First and the Third World countries but also among the connected and non-connected regions (Castells, 2000). In the Escobarian perspective (1994), the digital penetration of the Third World will result in the maintenance of the status quo.

Prior research in the area shows evidence for the relation between email use and collaboration (Kerr and Hiltz, 1982; Walsh and Bayma, 1996a, 1996b; Walsh et al., 2000). Walsh and Bayma (1996a) noted that the biggest effect of computer-mediated communication (CMC) is in collaboration. Walsh and colleagues (2000) have observed consistent and positive relationship between email use and collaboration in their study of American scientists in the fields of experimental biology, mathematics, physics and sociology. However, we have found extremely low levels of collaboration both within and between institutions in Kerala. In normal circumstances, the availability of and access to ICTs is likely to encourage domestic and international collaboration. The evidence for this is not yet forthcoming in the state of Kerala.[12] Other factors may be more important for collaborative research enterprises along with better connectivity.

Unless scientists are motivated to engage in collaborative research in a more meaningful way through benefits such as career advancement, promotion, and recognition, research activities are unlikely to improve. In the present scenario in Kerala, where research and publication profiles are not truly significant for promotion or recognition, the likelihood of increasing the degree of collaborative research is rather poor. No matter whether one is connected or not, collaboration is not bound to grow in the present context of Kerala unless corresponding changes are made in the academic and research systems to encourage the engagement of scientists in research activities made possible by the Internet. Policy changes as envisaged in the IT policy of the state will not be of much relevance if the state is not keen to rope in the advantages of the improvements in ICTs for its own development.

If scientific collaboration is a by-product or an associated advantage of ICTs, then the state is lagging behind. Kerala was quicker than many southern states to recognize ICTs as a panacea for development. Since Kerala Model of development emphasizes human capital, it is reasonable to expect Kerala to benefit more than others from technologies where skill and human resources are at a premium, taking advantage of high levels of literacy and education. In order to match the stated policies and giving material expression to these goals, the state began setting up technological centres called technoparks. Space, buildings, electricity and other basic requirements along with certain tax concessions were offered to global computer and software firms to start their businesses in these organizational niches. These parks have attracted a number of well-known companies which started branch offices, created direct and indirect employment, and produced an inflow of foreign exchange to the exchequer. Attempts have also been made to spread computer literacy among the population of the state for the production of technicians and engineers.

But apart from such sporadic attempts to take advantage of ICTs in growth and development, efforts to spread the benefits of ICTs with appropriate action based on understanding mechanisms of usage are still lacking. Even in the scientific community examined here, the facilities presently available are neither developed nor sufficient to take advantages of ICTs in development. Within the context of a stable, aging research system, it is not personnel shifts that account for behaviour. There has been a shift from 'traditional' backbone technologies such as typewriters, telephones, and secretaries to 'modern' technologies such as email and computers. But these computers tend to be shared, not 'personal' computers. The Internet connections are sporadic and expensive. Many scientists—especially academics—have purchased computers for home use and connected them to the Internet through local phone lines.

In sum, it is a mistake to think that shared and public computing facilities will lead to high levels of collaboration in the production of knowledge without other organizational and personnel policies in place. In research collaboration, as our study shows, scientists and academics have not yet been motivated to establish research links with their

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[12] We did find one possible effect of ICTs. From 1994 to 2000 average number of days spent outside the organization has gone down from 27 to 22 per year. This could be the result of the reduced need for travel

international counterparts, while internal collaboration is declining. Unfortunately, collaborative ventures in Kerala, even in research and developmental projects, invite suspicion. Recently, for instance, there has been a hue and cry about the collaboration in the decentralized planning programme involving a political party, an autonomous research institution, and a reputed NGO that has badly damaged the future of a well-funded collaborative research programme. Such negative attitudes, unfounded controversies and destructive criticisms often serve as a deterrent in collaborative linkages and undermine opportunities to benefit from relations with international partners. Some of our respondents have mentioned their fear of controversies and criticisms emanating from collaborative research ventures. In this scenario, what is missing is the opportunity to capture the benefits ICTs that may help the state to overcome the present crisis of the Kerala Model generated by stagnated growth and ballooning unemployment.

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due to the Internet. However, it is also quite possible that it is due to a decrease in organizational resources.

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Table 1: Profile of Respondents

No.	Variable	1994	2000	Difference between 1994 and 2000	N
1	2	3	4	5	6
1	Male (%)	62.9	62.7	-0.2	392
2	Age***[b]	43.4	46.0	+2.6	392
3	Year first employed by organization [b]	1980	1982	+2.0	390
4	Possession of Ph.D	79.8	77.2	-2.6	305
5	Year obtained highest degree* [b]	1984	1986	+2.0	392
6	Marital status** [a] (%)				392
	Single	6.7	2.0	-4.7	
	Married	93.3	97.4	+4.1	
	Widowed	0	0.7	+0.7	
9	Degree from developed countries [a]	7.9	5.3	-2.6	391
10	Years spent outside India for higher education [b]	0.5	0.3	-0.2	389
11	Years spent in developed country [b]	0.6	0.4	-0.2	391

Notes:*p<.1, **p<.05, ***p<.01; a. In percentage, tested with Chi-square; b. Results of t-test. + sign shows increase over 1994.
Source: Survey data from Kerala 1994 and Kerala 2000.

Table 2: Access to Resources

No.	Resources	1994 (%)	2000 (%)	Change between 1994 and 2000	N
1	2	3	4	5	6
1	Typewriter***	83.9	52.0	-31.9	387
2	Telephone	95.5	95.7	+0.2	391
3	Fax	52.3	60.4	+8.1	391
4	Computer***	61.4	86.5	+25.1	391
5	Printer***	68.2	85.5	+17.3	391
6	Email***	5.7	86.1	+80.4	390
7	Secretarial assistance	64.8	58.1	-6.7	391

Notes: ***p<.01; All Chi-square results; + sign shows increase over 1994.
Source: Survey data from Kerala 1994 and Kerala 2000.

Table 3: Computer Use and Connectivity by Sector in 2000

No.	Computer use	All	Academic Departments	Research Institutes	Difference between sectors	N
1	2	3	4	5	6	7
1	Computer at work***[a] (%)	85.8	78.5	93.8	15.3	260
	In the personal office (%)	25.4	13.7	36.0	22.3	
	In a shared office (%)	38.8	31.5	45.6	14.1	
	In common computer room (%)	35.8	54.8	18.4	36.4	
2	Year in which work computer was available*[b]	1995	1996	1994	2.0	260
3	Mean number of people who use the same computer at work***[b]	9.03	12.68	5.66	7.02	258
4	Computer at home (%)	51.2	55.1	46.9	8.2	303
5	Year of acquisition of home computer	1998	1998	1997	1.0	155
6	Mean number of people who use the computer at home	3.06	3.16	2.94	0.22	155
7	Mean hours of computer use per week***[b]	2.42	1.96	2.91	0.95	296
8	Internet connection on work computer***[a] (%)	45.4	24.2	64.7	40.5	118
9	Internet connection on home computer (%)	74.2	73.6	75	1.4	115

Notes: *p<.1, **p<.05, ***p<.01; a. In percentage, tested with Chi-square; b. Results of t-test;
Source: Kerala 2000 Survey data.

Table 4: Email Use Pattern by Sector in 2000

No.	Email use	All	Academic Departments	Research Institutes	Difference between sectors	N
1	2	3	4	5	6	7
1	Ever used email***[a] (%)	83.5	74.7	93.1	18.4	253
2	Currently using email*[a](%)	94.1	89.8	97.8	8.0	238
3	Year of first email use***[b]	1997	1998	1997	2.0	254
4	Hours spent a week on email use* [b]	1.49	1.35	1.60	0.25	249
5	Means of sending email*[a]					252
	Using connection at home (%)	32.9	41.5	25.4	-16.1	
	Using connection at work (%)	57.1	44.9	67.9	23.0	
	Using a public terminal at libraries/cafés (%)	7.1	11.0	3.7	7.3	
6	Specific email uses					
	Ever a member of a discussion group (%)	30.8	28.0	33.3	5.3	78
	Ever sent a message to discussion group**[a] (%)	46.0	39.0	52.2	13.2	116
	Ever discussed with a colleague locally (%)	30.4	34.7	26.7	8.0	77
	Ever discussed with an Indian colleague*[a] (%)	68.0	59.3	75.6	16.3	172
	Ever discussed with a colleague in developed country***[a] (%)	57.7	45.8	68.1	22.3	146
	Ever discussed proposals via email**[a] (%)	50.6	44.1	56.3	12.2	128
	Ever submitted/reviewed manuscripts***[a] (%)	25.7	15.3	34.8	19.5	65
	Started professional relationship with someone via email (%)	34.9	31.4	38.1	6.7	88
	Ever continued professional relationship*[a] (%)	71.4	62.7	79.1	16.4	180

Notes: *p<.1, **p<.05, ***p<.01; a. In percentage, tested with Chi-square; b. Results of t-test.
Source: Kerala 2000 Survey data.

Table 5: Web Use Pattern by Sector in 2000

No.	Web use	All	Academic Departments	Research Institutes	Difference between sectors	N
1	2	3	4	5	6	7
1	Web first used year	1998	1998	1998	0	199
2	Mean hours of web use a week*[b]	1.63	1.44	1.78	0.34	197
3	Last time web browsed***[a]					199
	Yesterday or today (%)	37.7	22.2	50.5	28.3	
4	Access of web from work***[a] (%)					199
	Daily	26.6	15.6	35.8	20.2	
	Weekly	34.2	26.7	40.4	13.7	
	Never	26.1	40	14.7	25.3	
5	Access of web from home (%)					199
	Daily	17.1	21.1	13.8	7.3	
	Weekly	14.6	17.8	11.9	5.9	
	Never	57.3	52.2	61.5	9.3	
6	Major web uses (%)					
	Conducted an information search	93.5	91.1	95.4	4.3	186
	Found reference material	90.5	92.2	89.0	3.2	180
	Web for acquiring or using data	88.9	85.6	91.7	6.1	177
	Accessed research reports	81.4	76.7	85.3	8.6	162
	Used web for accessing electronic journals	53.8	46.7	59.6	12.9	107
	Web for collaborating on scientific projects	35.2	31.1	38.5	7.4	70
	Ordered product/service on web*[a]	41.2	31.1	49.5	18.4	82
	Used web for online job listings	9.5	11.1	8.3	2.8	19
	Used web for online maps	20.6	15.6	24.8	9.2	41
	Downloaded software*[a]	33.7	23.3	42.2	18.9	67
	Published paper on web	11.6	8.9	13.8	4.9	23
	Chatting on web	18.6	15.6	21.1	5.5	37
	Created web page	24.1	21.1	26.6	5.5	48

Notes: *p<.1, **p<.05, ***p<.01; a. In percentage, tested with Chi-square; b. Results of t-test.
Source: Kerala 2000 Survey data.

Table 6: Internal Collaboration

No.	**Variable**	**1994**	**2000**	**Difference between 1994 and 2000**	**N**
1	2	3	4	5	6
	Internal collaboration***				
1	Number of professional scientists	9.1	3.2	-5.9	390
2	Number of technicians	4.9	1.7	-3.2	390
3	Number of non-technicians	4.9	0.4	-4.6	389
4	Total number of professionals, technicians and non-technicians***	18.9	5.3	-13.6	389

Notes*:* Results of t-test: *p<.1, **p<.05, ***p<.01 + sign shows increase over 1994.
Source*:* Survey data from Kerala 1994 and Kerala 2000.

Table 7: Collaboration and Globalization in 2000

No.	Collaboration	All	Academic Departments	Research Institutes	N
1	2	3	4	5	6
1	Mean number of research projects**[b]	7.2	8.16	6.17	303
2	Mean number of projects directed	3.6	4.1	2.99	303
3	Mean number of collaborative projects***[b]	0.64	0.5	0.8	303
4	Ever collaborated on research (%)*	38.6	33.5	44.1	303
5	Remote collaboration (%)	8.7	5.8	11.1	115

Notes: *p<.1, **p<.05, ***p<.01; a. In percentage, tested with Chi-square; b. Results of t-test.
Source: Kerala 2000 Survey data.