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Are Scientists in Developing Countries Isolated?*

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Are Scientists in Developing Countries Isolated?

Abstract

Most scholars and development experts assume that scientists in developing countries are isolated, although some posit that they are part of a global scientific community. This paper seeks to determine the size of professional networks for scientists in LDCs as well as the distribution of their ties across organizational contexts and locations. Professional contact networks of scientists in Africa and Asia were determined in personal interviews with 293 researchers in universities, government laboratories, and non-governmental organisations. Contrary to expectations, researchers in the least developed countries do not have the smallest networks. Results indicate that (1) international and domestic networks are inversely related, (2) education abroad increases contact with the developed world for scientists in state institutes and NGOs but not for academics, and (3) there are reduced returns to education for researchers in the least developed research systems. Our primary conclusion is that the characterization of LDC scientists as 'isolated' is misleading when their professional networks are concentrated in local arenas.

It is widely assumed, both by development specialists and students of science and technology, that scientists[i] in less developed countries (LDCs) are 'isolated'. As Stevan Dedijer wrote in 1963, they "suffer isolation" from each other and from the international scientific community. Dedijer's view still dominates, taking two main forms. In its empirical form the assumption of isolation implies that LDC scientists have very few professional contacts. In its normative form the assumption implies that LDC scientists should have greater contact with scientists in developed countries. This essay addresses only the empirical form of the assumption, but the two are not unrelated.[ii]

The isolation assumption is relatively pervasive. As recent compilations and review articles make clear, both scholars and policy makers generally take for granted a key feature of science and technology in the developing world: research takes place under conditions of isolation and, further, this isolation is a problem (Arvanitis and Gaillard 1992; Salomon et al. 1994; Shrum and Shenhav 1995; Gaillard et al. 1997). There are two primary aspects, based on formal and informal aspects of communication that have long been recognized as critical for science in the developed countries (Merton 1973; Mullins 1972).

Formal communication practices have been widely studied owing to the ease of obtaining data from bibliographic sources (Blickenstaff and Moravcsik 1982; Braun et al. 1988; Davis 1983; Davis and Eisemon 1989; Frame 1980; Frame, Narin, and Carpenter 1977; Gibbs 1995; Konrad and Wahl 1990; Sen and Lakshmi 1992). They are useful for the analysis of issues such as collaboration between scientists, accessibility of scientific publications, and influence patterns as reflected in citation practices. Problems with the use of such data involve the lack of inclusion of most LDC journals in internationally accessible databases (Frame 1985; Sancho

1992; Whitney 1992) and the unrepresentative sample of LDC scientists who are visible in such sources (Shrum 1997).

However, the central problem with the use of bibliometric methods such as coauthorship and citation analysis is that they do not measure the informal communication patterns generally deemed crucial for research. That is, they do not address the dominant interpretation of isolation in terms of communication or connectivity. When Abdus Salam wrote on the 'isolation of the scientist in developing countries' in an article by that name in 1966, he did not emphasize accessibility of publications, but the fact the individual scientists in LDCs pursue their research activities alone, cut off from contacts with other scientists.

Of course, those who assume isolation do not mean that individual scientists have no professional contacts whatsoever. The difficulty in examining such an assumption is that it cannot be assessed directly, except by inquiring about the extent to which LDC researchers ever communicate with other scientists. For instance, where contacts with the developed world are at issue, since many LDC scientists receive training abroad, an affirmative answer to this question would be trivial. Moreover, the question of connectedness is always a matter of degree. Many scientists are isolated in the sense that they are not part of active research fronts.[iii] Indeed, variability in levels of connectedness is one of the key features of scientific and technical organisation in developed countries (Shrum and Mullins 1988).

Two problems confront an investigation of the integration of scientists in LDCs. One is to develop an interpretation of the kinds of professional contacts that are relevant to the conduct of particular kinds of research. But the crucial problem is to provide a standard of comparison for levels of connectedness. It is misleading to compare the networks of LDC scientists directly

with those of DC scientists. If scientists in developed countries are viewed as working within a global scientific 'center,' connections to the center are not the same as connections within it. It is probable that scientists outside of any locale have fewer connections to those within it, than those within it have with each other. Little significance could be attached to such a finding.

Therefore, even if such data were available, it would not be appropriate to compare the networks of those who are members of the center with those who are not.[iv] Instead, a more illuminating comparison is within LDCs themselves. The notion of isolation implies that scientists from the least developed countries are the most isolated--that there is an association between the level of scientific development and the professional networks of scientists. In what follows, we address the question: Are researchers from LDCs at higher levels of scientific development more connected than those who are not?

As in the developed world, nearly all research is performed in organisational contexts. Salaried individuals in universities and research institutes pursue research questions suggested by some combination of personal interest and organisational objectives.[v] In these immediate organisational contexts, communication is direct and personal, in formal meetings and chance encounters. It is interorganisational contact that is problematic. We interpret the empirical assumption of isolation as a question of variability in network connectedness between scientists in different organisations.

This interpretation of the isolation hypothesis--emphasizing variation in professional networks across organisational contexts-- is consistent with scholarly studies by Gaillard (1991: 765-81) and Schott (1993) that treat the integration of LDC scientists as an empirical question and rely on some version of a center-periphery model of communication. This model holds that

for researchers in the developing world, communication with researchers in developed countries is in some respects more significant than communication within their own countries, since scientific influence flows from developed to developing countries. Gaillard, for example, finds that LDC scientists communicated more frequently with researchers abroad than they did with scientists in their own country who were not at their home institution.[vi] He concludes that communication is generally problematic, but emphasizes this within the national context, since contact across organisational boundaries is rare (1991, p. 147).

Schott describes science in theoretical terms as an institution characterized by participation in individual, national, and global communal formations (1993). At the individual level, each scientist is characterized by a personal network ('collegial circle') that serves both as a reference group and a source of support, reward, and resources. The personal network may be local or global in scope, characterized by properties that are now well established in the social network literature (Wasserman and Faust 1994). A circle of local colleagues, for instance, is hypothesized to have low spatial range, but high degrees of homophily, homogeneity, density, and multiplexity. Cross-nationally, Schott found that scientists, although they deferred primarily toward scientific work in North America and Western Europe, were mainly influenced by local work.[vii]

While the studies by Schott and Gaillard are not directly comparable, they imply different professional networks among LDC scientists. Schott views local contact as significant, yet sees the scientific community in the developed world as the primary source of influence. Gaillard views scientists--especially those educated in the developed world--as lacking contact with scientists in their own country. Both agree that the professional linkages are critical to the

scientific enterprise in LDCs, and that their distribution across locales is critical to the flow of information and influence.

Neither Schott or Gaillard interviewed a representative group of LDC scientists. Because their samples were based on receipt of IFS grants or appearance in the Science Citation Index, they constitute an elite group. Moreover, because such criteria typically select for university scientists over those in other sectors, at least three institutional locations are underrepresented. In the developing world, research in key fields such as agriculture and health is often performed in institutes sponsored by state and international donors. Recently, the emergence of nongovernmental organisations in the 1980s and 1990s as significant development organisations has led to an emergent, if still small, research presence in this sector (Farrington and Bebbington 1993). Finally, a few developing countries host international research centers that employ large numbers of researchers, many of whom are nationals.

This paper seeks to shed light on the assumption of isolation by providing basic descriptive information on the professional contact networks of researchers in LDCs. Evidence is drawn from a survey of researchers in Ghana, Kenya, and the state of Kerala in southwestern India. By examining locations that represent different levels of development we can ask whether researchers in more developed locations have more professional ties than those in less developed locations. The analysis first seeks to determine the degree to which LDC scientists have professional ties with various types of organisations and the distribution of these ties across locations in developed and developing countries. Next, we address the question of whether education in developed countries is related to the distribution of ties. Finally, we assess the correlates of extensive networks.[viii]

Methodology

A survey of scientists in the developing world presents special problems, including sampling, communication, and transportation. These difficulties say much about the conditions under which professional networks develop. The problem of sampling has traditionally been approached by starting with a population of cases, or sampling frame. The logistical issues of reaching particular individuals are less significant than the methods by which they are selected and their cooperation when contacted. In the developing world different issues arise, since phone and postal communication is often unavailable or slow. In brief, the sampling strategy used in the present study was based on organisational affiliation, combined with both bibliometric and nomination methods to identify the final group of researchers.

The central issue of integration implies two corollary questions, as suggested already. The developing world is not a unity, nor is all research conducted under the same organisational circumstances. To what degree does the level of development of a country make a difference to the level of professional contact? Second, does the size of professional networks vary for the primary sectors in which research is conducted: universities, state research institutes, international organisations, and nongovernmental organisations?

Data on the individual professional networks of LDC scientists is drawn from personal interviews conducted in 1994 with scientists in three locations, selected to represent low (Ghana), medium (Kenya), and high (India) levels of development in Africa and Asia. One commonly-used indicator of scientific development is publication productivity. Both self-reported counts of productivity and counts based on international bibliographies support a

ranking of Kerala, followed by Kenya, and then Ghana.[ix] India, with one of the oldest and largest national research systems, is in the first rank of developing countries (Eisemon 1982; Krishna 1997). Kenya possessing one of the largest scientific communities in Africa, experienced a rapid expansion of its university system in the 1970s and an increase in scientific output that continued despite the economic downturn of the 1980s (Eisemon and Davis 1992). Ghana inherited academic and state research facilities from the colonial period, but economic and political difficulties throughout the 1980s led to scientific out-migration and a significant decline in scientific output.[x]

The individuals interviewed were all involved in some aspect of research on agricultural, environmental, and natural resource issues. First, a preliminary search of 79 databases was carried out using the DIALOG system. After discarding sources in irrelevant fields and those with few hits, seventeen international databases were searched for the 1992-1993 period.[xi] This allowed the preliminary identification of a group of organisations and scientists before fieldwork began.

Next, a team of three interviewers spent approximately five weeks in each location. The sample was stratified by sector to include the most, but not all, of the primary sectors where research activities are performed in the developing world. The private sector is small in each of these countries, apart from multinationals that perform most of their research in the developed world. There are from three to five comprehensive universities in each location. We sampled from those university departments that appeared most often in the bibliographic search and from most of the national research institutes involved in agriculture and natural resources. A group of nongovernmental organisations was identified in each location with varying degrees of research

involvement. Finally, international research organisations were represented in Kenya, since a significant number of Kenyan nationals are employed there.[xii] In all, interviews were conducted in 53 national research institutes, 48 academic departments, 31 NGOs, and 5 international organisations.

At each organisation, discussions with the director, assistant director, or head of department were held to explain the purposes of the study and identify appropriate individuals, generally those at the mid-career stage. For universities, state institutes, and international organisations we began with the set of names culled from the bibliographic sources. Since prior studies suggested these scientists might not be representative, we sought to interview approximately equal numbers of researchers whose names did not appear in the international databases.[xiii] Although we were successful in all but one case in interviewing at the targeted organisations, the final selection of respondents depended on the exigencies of travel and timing. It was sometimes impossible to contact the organisation in advance of arrival, and occasionally these were in remote locations that were difficult to reach. Often, organisations are small, with only a handful of researchers, some of whom would be 'off station'--in the field or away on training. Since the daily schedule did not permit return visits, it was necessary to interview those who were available at that time.

The survey instrument included both structured and unstructured sections tapping the respondent's professional network, major dimensions of professional research activities, 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. In all, a total of 293 structured interviews were conducted.

Three types of indicators were collected that might be used for addressing the issue of integration. First, there are communication items that measured the frequency of discussions with various categories of individuals. The problem with these measures is their lack of specificity. A response to a question such as 'On the average, how frequently during the past two years did you have professional discussions with people in the following groups' does not indicate particular individuals and is difficult to interpret. Moreover, it requires the respondent to perform the operation of mentally averaging diverse patterns of contact with many persons. Such measures are useful, but are not ideal for this purpose.

Second, network measurements can be derived from a roster technique. The respondent was presented with an extensive list of international and national organisations, asked to indicate with whom s/he has had contact, the nature of that contact, and an assessment of each organisation. To the extent that rosters reduce concerns of memory, this method is relatively comprehensive and provides the best overview of the entire network of relations within a particular social system. However, because the contacts are identified at the organisational level, it does not provide the essential information about the individual professional linkages.[xiv]

In this analysis, we use responses to the following question to measure the core interpersonal networks of scientists in LDCs:

> Now I'd like to ask about a few specific people, the people who <u>have similar interests or do work on the same kinds of things that you do</u>. I only want to exclude other people in <u>this</u> specific organisation. Here include anyone you talk to, anyone you go to for advice, or anyone who comes to you for advice. In other words, just tell me those that are the most important for your own work.

Respondents were asked to provide the first names of these individuals as well as the organisations in which they were located. Particular means of contact were not specified--the

contact might be through correspondence, fax, phone, in person, or e-mail.[xv]

Usable professional contact data was obtained from 281 individuals.[xvi] These responses were entered into a data matrix of relationships where each case represented one reported tie between a respondent and one of his professional associates. In all, 1321 professional relationships were reported with people in 590 distinct organisations, for an average of 4.7 contacts per respondent.[xvii] Basic information about the social location of the contacts themselves was obtained from their organisational affiliation, allowing us to address the question of geographical and sectoral distribution.

[Table 1 about here.]

These professional ties themselves constitute a population of relationships. Table 1 shows their distribution by sector for 1232 reported links where sector could be determined. Universities are the most common institutional locus of contacts, but still represent less than half (44%) of the total, with government-sponsored research institutes the next most common sector (29%). NGOs contacts represent nearly 10% of the population, while links with ministries (generally, these are departments associated with agricultural extension or production) represent 7%. Private firms are not significant sources of professional ties (about 2%) for this sample of scientists.

[Table 2 about here.]

To what degree are these professional ties to actors outside of the local research system? To answer this question, 'internal' and 'external' loci of communication are distinguished in Table 2. Since Kerala is a state of India rather than a country, it is not strictly comparable to Ghana and Kenya. Here, as in much of the analysis that follows, we consider India part of the external

environment for Keralan scientists rather than part of the system itself.[xviii]

Table 2 shows that, in all, over half of all reported professional contacts are internal to the research systems themselves.[xix] For each sector, the proportion of internal ties is larger than proportion of external ties. However, in some cases this difference is relatively large, while in others it is relatively small. External university ties are nearly as common as internal university ties, but ties to government research institutes and NGOs are more than twice as likely to be internal. Ties with international research centers, are also quite common. At 8% of the total, they occur nearly as often as ties with external institutes. Combining these two, ties with international and external research institutes represent about one fifth of the total. As a rough approximation, we may say that universities (internal, external), national research centers, and external research centers constitute approximately equivalent loci of professional contacts, with NGOs making up most of the remainder.

The Distribution of Professional Contacts

While the frequency distribution of relations gives a general indication of the way professional contacts are distributed among sectors, it is highly dependent on the particular sample under study. For example, our decision to include respondents from NGOs but not private firms may be the reason NGO contacts outnumber private contacts by a substantial margin. In the analysis that follows, we examine the professional contact networks of individual researchers. The file of contacts was sorted and aggregated by respondent to indicate the extensiveness of professional contact, as measured by the number of ties reported with various countries and sectors.

The first part of this analysis examines the degree to which LDC scientists have professional ties with different types of organisations and the distribution of these ties across geographic locations. We then turn to education in developed countries as a possible source of variation in professional networks. In the third section we examine the factors associated with participation in extensive internal and external professional networks.

[Table 3 about here.]

Table 3 shows the average number of reported ties for each sector in each of the three survey locations. The clear finding from this table is that conventional wisdom regarding the sectors and countries that should have the most extensive professional networks does not hold. Relative to the sample average of 4.7 ties per respondent, Keralan researchers report fewer professional ties than researchers in either Ghana or Kenya. First, respondents in the African systems, which are less developed than the research system in India, report over five contacts per researcher, as compared with fewer than four in the state of Kerala. Second, academic respondents report *fewer* professional ties than respondents in any other sector. NGO respondents report an average of six ties, followed by researchers in international centers (5.25), and those in national institutes (4.61).[xx]

Table 3 also shows that sectoral variation in extensiveness of professional contact networks is largely, but not completely, consistent within locations.[xxi] University researchers report the fewest professional ties in each location, while NGOs report the most. The exception is Kenya, where NGOs respondents reported fewer contacts than those in national research centers, a difference that is not statistically significant.

While Table 3 contravenes expectations in terms the locations and sectors that report

extensive linkages, it says nothing about the nature and location of these linkages. A scientist may report many ties, but all within his own country, or all within his own sector. Another scientist might report fewer ties, but these few ties might be widely distributed in terms of sector and location, indicating greater 'reach' of the network and greater likelihood of accessing alternative sources of information and resources. This possibility is addressed in Tables 4 and 5 for professional contacts within each location.

[Table 4 about here.]

Table 4 classifies the number of reported ties by respondents in the column sectors to their contacts in the row sectors.[xxii] The last column of Table 4 shows that professional contacts with academics are more common than those with state research institutes, followed by NGOs and international institutes.[xxiii] That is, while academics have the fewest contacts, contacts of LDC scientists are most likely to be with academics. The values in the diagonal cells of the table show the extent to which professional networks are 'intra-sectoral' while off-diagonal cell values show 'inter-sectoral' linkages. While university and NGO respondents report more contacts within their own sector than with other sectors, both national institutes and international research centers rely more on intersectoral contacts. For the latter, the primary intersectoral contact is with universities. Researchers in national and international centers report more contact with academics than academics themselves. Put another way, scientists in universities, national research institutes, and international centers all look to universities as their main source of professional relations, while the primary relations of NGOs are with other NGOs.

[Table 5 about here.]

Table 5 shows these relationships for each location separately. Consistent with Table 4,

universities and national research institutes are the most frequent sources of professional linkages, with NGOs and international research centers less common. Intersectoral patterns are similar to those in Table 4 as well, with universities and NGOs generally displaying within-sector tie preferences, while researchers in national institutes report more professional contacts with academics than within their own sector.

Distinctive patterns pertain to NGOs and international centers, which are relatively more important in Ghana and Kenya (as indicated in Table 3). In both African locations, NGO respondents report more linkages with NGOs than with other sectors, while in Kerala, they are more likely to report ties with universities and national research institutes. Although Nairobi is home of several prominent international centers, respondents in Kenya have only slightly higher levels of contact with international centers than those in Ghana. In Kerala few academic researchers report professional links with anyone in nongovernmental or international organisations.

We turn now to the question of geographical distribution. Table 2 showed that significant numbers of important professional contacts were external to the three study sites. Where are these external relations located? Table 6 displays the average number of reported ties to the major continents.[xxiv] Since English is not only the scientific language but also the primary governmental and professional language owing to the colonial heritage of all three sites, contacts with the US and UK were coded separately.

[Table 6 about here.]

Table 6 shows that European professional contacts exceed all other locations, and Asian contacts are very few. Yet significant differences exist in the overall pattern of contact between

countries. The pattern of contacts for Ghana and Kenya is relatively similar (differences are not statistically significant), with ties to the European region most extensive, followed by ties to the US. For Ghanaians, ties to other African countries are proportionately greater than ties to other locations, while they are less common for Kenyans. The location with the highest level of scientific development, Kerala, reports relatively few contacts with any location other than Indian states. Researchers at international centers are most highly connected to Europe, but US and UK ties are strong, as well as African ties, since our international respondents were all located in Nairobi.

The last three rows combine external ties in general indicators of professional linkages to the developed and developing world. Scientists in Kerala have fewer ties to developed countries. However, they have significantly more ties to the developing world when ties to India (outside Kerala) are included. Researchers in Ghana and Kenya report very few links to others in less developed countries, but those in Kenya have a significant proportion of their ties to the developed world. So although Keralans do not have many connections with researchers in either the US or Europe, they maintain scientific networks with others in India, which constitutes the external context for their research.

The Impact of Education in Developed Research Systems

We have seen the extent to which scientists in three LDCs are tied to professionals in developed countries. Table 7 addresses the most common explanation for the existence of these ties, the experience of training abroad. Receiving part or all of one's education in the developed countries is often thought to explain why scientists in the developing world have connections to

scientists there. Of course, there are many other reasons why such links develop, including workshops, international conferences, scientific travel, and visits by DC scientists to the developing countries. However, higher education, because of its duration, and because of the strong bonds that often develop between professor and student, is viewed as more likely to contribute to ongoing professional ties.

[Table 7 about here.]

Table 7 shows the total number of professional ties and, more importantly, the number of ties to developed countries by education in developed countries. What is consistent about both indicators is that while education in DCs is associated with a larger number of ties for the entire sample of researchers, it is *not associated with a larger number of ties for academics*. The first panel in Table 7 reveals that education abroad nearly doubles the number of contacts with DCs overall. But for university researchers, education in developed countries makes virtually no difference to their contact with professionals in developed countries.[xxv]

The difference in education abroad is particularly apparent for NGO respondents. The number of ties to developed countries increases from less than one to nearly two, while the overall number of professional contacts increases from 5.5 to more than eight. NGO respondents educated in developed countries have more extensive professional networks than any other group in the sample.

Correlates of Network Size

In the final section, we turn to the question of why some scientists have more extensive professional networks than others. A study designed to answer this question would, ideally, follow a sample of researchers throughout their careers, collecting data at several points in time. Since the present data are cross-sectional rather than longitudinal, claims about the direction of causality can only be inferential. What we can do, however, is examine the association of a wide variety of dimensions with the reported size of scientist's networks, rule out several possible explanations, and provide some direction for future research on professional contacts. We can, for example, examine whether social characteristics and organisational contexts distinguish those with more or less extensive professional networks.

Because the preceding analysis suggested differences in internal and external professional ties, the overall measure of network size was disaggregated into ties to developed countries and ties within the locations themselves. The association between internal ties and ties to developed countries is negative for the entire sample, and negative for every organisational context except NGOs.[xxvi] Put simply, those who have more ties to developed countries have fewer ties within their own countries. Therefore, separate models were estimated for the number of 'internal' professional contacts and professional contacts in the developed world.

Before selecting the final models in Table 8, we examined the relationships of network size with six general structural dimensions:[xxvii] individual background characteristics (gender, age); career (receipt of awards, membership on committees, professional experience); education (highest degree, years spent in developed countries); productivity indices (papers at conferences, articles in national journals); organisational position (weekly time spent on research, number of professionals and technicians supervised), and access to technology (telephone, email, personal

computer). For each of the six general dimensions, the factors that correlated most highly with network size were selected.

Next, multiple regression analyses were performed separately for network size, using the preferred variables from these six dimensions as predictors.[xxviii] Controls for location and sector were added. Finally, interaction terms were employed where mean differences in the tables above showed that the effects of certain factors (e.g., education in developed countries) might depend on the location or sector of the respondents. All models were estimated using respondents from national research institutes, universities, and nongovernmental organisations.[xxix]

[Table 8 about here.]

Table 8 presents the results of the multivariate analysis, after eliminating factors that were not statistically significant at the .10 level.[xxx] Both models are statistically significant at conservative levels. Adjusted R-square values show that 21% of the variance in contacts with developed countries and 17% of the variance in internal contacts is explained by the selected variables. However, the most important finding in Table 8 is that <u>different factors are correlated with internal and external professional contact</u>. The only factors consistently important for both models are location and sector.

The first panel of Table 8 exhibits the results of regressing the number of ties to professionals in developed countries on thirteen independent variables. The effect of location is shown in the positive coefficients for Ghana and Kenya, relative to Kerala.[xxxi] Researchers in the two African locations have more ties than those in India, even controlling for a variety of other factors related to network size, though Kenyan respondents do not have significantly more

internal contacts than Keralans. The effect of sector is shown in the coefficients for national research institutes and NGOs relative to the comparison category of universities. For links with the developed world, sectors are not significantly different, but for internal professional linkages, NGO respondents have more extensive networks, holding other factors constant.

For links to professionals in developed countries, the main effect of sector is not significant, but is important because of its interactions with education and resources, as indicated in the last rows of Table 8. Note first that the main effect of education in the developed countries has no impact in either model.[xxxii] However, significant coefficients for the last two interaction terms show that education in developed countries has a positive effect on ties to professionals in developed countries for researchers in government institutes and NGOs. That is, relative to academics (the comparison category), state and NGO scientists are more strongly connected to researchers abroad when they are educated abroad. This finding confirms the result in Table 7, controlling for a variety of other factors.[xxxiii]

The impact of education on scientific networks abroad is more apparent in the extent of education than through its location. The indicator of an advanced degree is positively related to developed country contacts. Researchers with either a Master's degree or Ph.D. have more linkages, raising the average by nearly one contact over those who do not.

An important sectoral effect is also evident in the first interaction term in Table 8, for the interaction of sector with an indicator of resource availability--the presence of a personal computer in the room where the interview was held. After each interview was completed, the interviewers made notes on the condition of the building and office, the presence of telephones, fax machines, and so forth.[xxxiv] Personal computers are associated with higher levels of

developed country contact for researchers in national institutes.

The first model in Table 8 also reveals an important aspect of development in the negative coefficients for international visibility and education in the developed world. Our indicator of visibility is based on whether the respondent's name appeared within a two year period in lists of books, articles, and conference papers in standard, bibliographic sources.[xxxv] International visibility is positively related to international linkages, as we would expect, but much less for Ghana than for Kerala (the comparison category). That is, for researchers at the lower levels of development, publication in international outlets entails fewer contacts to developed countries than for researchers in more developed locations.

The final coefficient tells a similar story for education in the developed world. The third interaction term in the first panel of table 8 shows a statistically significant interaction between education abroad and location on the number of professional ties. The coefficient of -.96 indicates a negative effect of education abroad on network size for researchers in Ghana. Relative to researchers in the most developed location (Kerala, the comparison category), Ghanaians are less strongly connected to researchers abroad when they are educated abroad.

The second panel of Table 8 exhibits coefficients for the model predicting the size of networks within Ghana, Kenya, and Kerala. Except for the positive main effect of location in Ghana, no single regressor is significant in both models. The model for internal ties is simpler than that for developed country ties. Respondents in NGOs report large local networks, the strongest effect in the model. Indeed, members of NGOs mention an average of 1.3 more ties to professionals within their location than academics (the comparison category). Older scientists also have more ties.

Neither education abroad, nor visibility is associated with internal contacts. However, there is an interaction between visibility and organisational context, as shown in the last row of the second panel. For researchers in state institutes, international visibility is negatively associated with the size of the local network (-1.02). Those whose publications appear in international databases are less likely to have extensive local networks. Finally, structural position and receipt of awards also reduce local ties. Although the effect of the latter is not strong (statistically significant only at .07), the presence of postdoctoral students is worth noting. The presence of such students may require lengthy supervision and reduce local contact.

Discussion

These results allow us to draw some preliminary conclusions about the ways in which the professional networks of scientists in developing countries are structured. The main findings are summarized, followed by a discussion of integration of local and Western science, the local context of research, the importance of organisational context for understanding professional networks, and the role of education.

(1) Most professional contacts of LDC researchers are internal to the research systems themselves. There is an inverse relationship between local ties and ties to developed countries for every sector but NGOs.

(2) Kenyans and Ghanaians have larger professional networks than Keralan researchers.

(3) Academics have the smallest professional networks, while NGOs have the largest, particularly in terms of local ties. However, more professional contacts are reported <u>to</u> universities, both internal and external, than any other sector.

(4) Higher education is associated with increased ties to developed countries. But education abroad is associated with stronger links to developed countries <u>only</u> for state research institutes and NGOs. Academics who

have been educated in developed countries do not have more ties abroad than those who are not.

(5) For researchers in national institutes, immediate access to a personal computer is associated with larger developed country networks, but international visibility is associated with smaller local networks.

(6) International publication and education abroad are related to international linkages but the payoff is smaller for Ghanaians than Keralans

(7) Local networks are larger for older scientists. They are smaller for those who supervise postdoctoral students and have received awards.

We began by noting received wisdom on the professional networks of scientists in developing countries:

> It is now generally recognized that an endogenous scientific community can only develop in a peripheral position if its members have sustained relations with the center. One of the best ways to establish such relationships is through interpersonal contacts between scientists...[including] studying at foreign universities, often in a country in the center...and publishing articles in journals of international repute. (Gaillard 1991, p.3)

This view is rendered problematic in light of the results summarized above. We emphasize that these findings are not based on a longitudinal study and, hence, do not meet the temporal conditions necessary to establish stronger claims. Too, we **, four general points are worth noting.

First, though our initial interest was in examining the structural conditions underlying the size of professional networks for LDC scientists, it is misleading to speak of these networks as if they were simply larger or smaller, as if scientists in developing countries are 'more or less' isolated or integrated. The principal reason is that local networks and ties to the developed world operate in distinctive, and perhaps even opposing, fashion. For this sample of scientists, (a) different factors are associated with the size of local and external professional networks; and

(b) those with more ties to the developed world have fewer local ties. Of course, we have also seen that most professional contacts of LDC researchers are internal to the research systems themselves. If those who have more ties to developed countries have fewer ties within their own countries, it behooves us to learn more about the social processes involved in establishing and maintaining ties before establishing policies and programs to increase ties to DCs.

This relationship between local ties and ties to developed countries applies to all organisations studied here except NGOs. The strong negative relationship for researchers in international laboratories is probably not surprising. After all, these centers are established as general, international sources of programmatic and technical expertise rather than local centers with strong ties to the national research systems where they are located.[xxxvi] More important is that in both universities and national research institutes, researchers have fewer local ties when they have more external ties.

An alternative perspective on links with developed countries, found in the literature on indigenous knowledge and only rarely in policy analysis, views Western science as a mechanism of domination. In this account, Western science produces the technological means of subjugation, is a deleterious ideological force, and an inappropriate developmental model. The creation and maintenance of scientific institutions absorb scarce personnel and capital and constitute an irrelevant ideological diversion for countries without the resources or connections to pursue Western, specialty-oriented science (Shahidullah 1991). From this perspective, researchers in LDCs who have links to the 'scientific core' produce knowledge in collaboration with foreign colleagues and research centers that fails to take LDC needs into account.

While we do not subscribe to the view that Western science is an iniquitous influence, a

related and less extreme version of this view is that scientists in LDCs tend to be either 'internally' or 'externally' oriented. An 'internal' orientation implies that research with a local orientation takes precedence over research addressed to global or developed country problems. An external orientation implies membership in the global scientific community conceptualized by Schott (1993). Insofar as local and external linkages are signals of such orientation, or more likely, operate to shape it, a tradeoff such as that reported here tends to support such a view.

Not only do researchers with more external ties have fewer internal ties, the divergent factors associated with these ties indicate that they are generated through different processes. For researchers in national institutes, access to resources increases contact with the developed world. Such a finding would not itself be of concern, except that international visibility is associated with smaller local networks. Independent of organisational context, those who have received awards for their research also tend to have fewer internal ties. Some prior studies indicate that for the least developed countries there is a weak or negative association between international and domestic productivity (Shrum 1997). This pattern suggests that as scientists become more prominent, they are pulled away from the local research system, resulting in fewer linkages to other professionals in the national research system and fewer articles in national publication outlets.[xxxvii]

The background assumptions for the present study are that location indicates the level of development of the social and scientific system, while sector indicates the organisational context in which research is conducted. Our expectation that scientists in more developed locations and in academic contexts would have the most extensive professional networks did not hold. The second general point is that local context--the historical and social background of the research

system--is more important than the general level of development of the country or the scientific system in structuring the opportunities for professional contacts. The work of V.V. Krishna (1993, 1997) shows that India is a special case in the developing world, owing to both the sheer number of researchers there and the early development of its educational and scientific infrastructure. With the world's third largest scientific community and the largest university system outside the US, it is common to receive scientific training, employment opportunities, and career development completely within the Indian context. Movement is often from state to state, and training 'abroad' in the Indian context may simply involve travel from a southern to a northern state. As a established professional, contexts may be extensive outside the state, but not outside of the India. This pattern is shown for Keralan researchers, who often have many ties to neighboring Tamil Nadhu or the network of institutes involved in an All India Coordinated Research Program (AICRP). The fact that these scientists have fewer ties to the US and Europe does not mean they are isolated, but that their 'external' context is Indian rather than with researchers in developed countries.

Africans, who operate within systems that are less developed than those in India, have larger professional networks. Ghanaian researchers, who operate within a national research system that is relatively undeveloped, do not have particularly few ties, and they have more ties to locations in the developed world than Keralans. However, if we view ties to the developed world as an asset, or form of social capital to be valued, the above findings are disconcerting. Education and publication have negative effects on contacts with the developed world for Ghanaians. For researchers at lower levels of development, this implies that the visibility that might be provided by widely available publications or education abroad does not result in

professional ties with researchers in developed countries.[xxxviii] It is possible that professionals in the developed world find ties with scientists in the least developed locations difficult to maintain, or that scientists in these locations do not have the resources to maintain them. Further research is needed to determine the most likely interpretation.

Third, organisational context shapes the professional networks of researchers. NGOs, though their research functions are limited, are distinctive in this regard. As we have seen, NGO respondents have the largest professional networks and are the only group for which internal and external ties are positively associated. This finding makes it unnecessary to suppose that an increase in contacts with developed countries necessarily results in a decrease in local ties, so the reasons for this are important to determine in future studies. One reason may be that NGOs typically have fewer staff members. When intraorganisational resources are limited in terms of personnel, the motivation to seek interorganisational linkages is greater. In the case of NGOs that have only a handful of staff, an individual wishing to pursue any kind of research activity will look for advice and assistance outside the organisation. These resources are found in collaboration with universities and, less often, with state research institutes, but generally with other NGOs.[xxxix] In Ghana, which has the most developed system of NGOs, NGO to NGO contact is greater than any contact between sectors in all three locations. When links are established to those outside the national research system, they do not decrease the number of local ties.[xl]

The provision of interpersonal, research resources is the most likely reason for the paradox that makes universities a special organisational context. Academics have the smallest professional networks, but more professional contacts are reported to university researchers

(both internal and external) than any other sector. Indeed, respondents in both national and international centers reported more contact with academics than academics themselves. Of course, there is never symmetry in reported contact, even when respondents are given a list of possible contacts.[xli] Asymmetric naming tends to reveal relations of influence and information flow, and can be an indicator of status (Wasserman and Faust 1994). Hence, the fact that academic researchers are named most frequently supports the idea that universities are a resource for other sectors. It may also be that academic departments are more self-reliant, which explains their lower contact. Scientists in universities, national research institutes, and international centers all look to universities as their main source of professional relations.[xlii]

Finally, we have seen that higher education is associated with increased ties to developed countries, but the role of education abroad is more complex than scholars and policy analysts have previously assumed. Stronger links to developed countries are formed for government research institutes and NGOs, but for academics, those who are educated in developed countries do not have larger international networks than those who are not. Ties with major professors and graduate school colleagues are more difficult to maintain as distances are great and research interests diverge over time. The contexts leading to broader international networks for academics are based not so much in the educational experience as in the opportunities (meetings, workshops, international conferences) they are more likely to experience <u>after</u> entering the academic profession.

At the outset we noted a relationship between the empirical and normative aspects of 'isolation'. The assumption that scientists in developing countries have few ties, and few ties to developed countries, is readily interpreted as a deficit to be remedied. More contact is assumed

to be better than less contact. Improved ties to the developed world will lead to improvements in research performance. Although we have not examined this latter proposition, we have cast doubt on the former. The short answer to the question 'are scientists in developing countries isolated?' is 'No'. But the reality is more complex. Scientists in the developing world have professional networks that are more local than international in character--just as most scientists in the developed world--and that does not warrant an ascription of 'isolation'. Scientists in more advanced developing countries do not have more ties to the developed world than scientists in those that are less advanced, so there is no simple relationship between level of development and ties to the Western scientific community.

These results suggest that as scientists become more prominent they are pulled away from the local research system. Whether they do more good by connecting with a global network is impossible to address with our data, but the significant aspect is that 'brain drain' may not require the physical emigration of a body. If scientists who become prominent by publishing internationally and increasing their international contacts also reduce their local ties, they may become less valuable to the national research system even as they gain stature in the global community. The example of NGOs shows us that ties to the local environment are not mutually exclusive with international linkages.

What is certain is that the environment for international scientific communication is changing. It may well be true that Dedijer and Salam were correct to speak of isolation in the 1960s and 1970s. Precisely because of their efforts, as well as the efforts of the national and international groups that supported them, science in developing countries takes place in far different, if still precarious, conditions in the 1990s. It will change further with the advent of the

internet. We found that for researchers in national institutes, immediate access to a personal computer is associated with larger developed country networks. It seems possible that the low costs of using internet technology makes it a candidate for increasing international ties without decreasing local ties.[xliii] What will be the effect of the diffusion of electronic communication technology on the professional networks of scientists in the developing world? The academics in our study were more likely than others to perceive electronic communication as an important means of keeping in touch with colleagues. However, researchers at international centers who were, at the time of the study, the only ones to have regular access to such technology, often said that it was not so important.[xliv] Future studies to examine the effects of this new communications medium are absolutely critical.

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Table 1: Sectoral Distribution of Reported Contacts

SECTOR	Frequency	Percent
International Research Center	103	8.4
Ministry	88	7.1
Non-Governmental Organization	113	9.2
National Research Institute	360	29.2
Private Company	30	2.4
University	538	43.7
Total	1232	100.0

Table 2: Distribution of Reported Contacts by Sector and Location

	SECTOR	Frequency	Percent
Internal	University	279	22.6
	NRI[a]	246	20
	NGO[b]	78	6.3
	Ministry	58	4.7
	Private	19	1.5
Total Internal Contacts		680	55.1
International Research Center		103	8.4
External	University	259	21
	NRI	114	9.3
	NGO	35	2.8
	Ministry	30	2.4
	Private	11	0.9
Total External Contacts		449	36.4
Total Contacts		1232	99.9[c]

[a] NRI=National Research Institute.
[b] NGO=Non-Governmental Organization.
[c] Total not equal to 100.0, due to rounding error.

Table 3: Size of Core Professional Networks by Sector and Location

SECTOR	LOCATION				Mean
	Ghana	Kenya	Kerala	Int.Res.Cen t	
University	4.29	4.40	3.47		4.00
Nat.Res.Cent.	4.72	5.38	3.88		4.61
NGO	7.30	5.22	5.18		6.25[a]
Internat. Res. Cen.				5.25	5.25
Mean	5.14	5.10	3.90[b]	5.25	4.70**

(N = 281) ** p<.01

[a] Mean for NGOs is significantly higher than for universities and NRIs (p<.05).

[b] Mean of respondents from Kerala is significantly lower than the mean for Kenya and Ghana (p<.05).

Table 4: Size of Core Professional Networks by Sector of Respondent and Contact

SECTOR of REPORTED CONTACT		SECTOR of RESPONDENT				
		University	NRI	NGO	Internat. Res.Cen.	Mean for Contact Sector
Internal	University	0.82	1.16	0.77	1.00	1.00
	NRI	1.01	0.83	0.87	0.82	0.88
	NGO	0.04	0.07	1.62	0.18	0.28***
	Ministry	0.13	0.16	0.54	0.27	0.21**
	Private	0.03	0.08	0.13	0.00	0.07
Internat.Res.Cen.		0.29	0.40	0.21	1.18	0.37**
External	University	0.79	0.72	0.31	1.27	0.70+
	NRI	0.04	0.30	0.03	0.18	0.18***
	NGO	0.04	0.05	0.51	0.09	0.11***
	Ministry	0.06	0.09	0.08	0.27	0.09
	Private	0.03	0.03	0.03	0.00	0.03
Mean for Respondent Sector		4.00	4.61	6.25	5.25	4.70

(N = 278)
Levels of significance: + p<.10, * p<.05, ** p<.01, *** p<.001

Table 5: Size of Core Professional Network by Sector of Respondent, Sector of Contact, and Location

	Sector of Contact								
	Internal						External[a]		
Sector of Respondent	University	NRI	NGO	Ministry	Private	Int.ResCent.	University	NRI	NGO
Ghana (N=94)	1.29	1.21	0.04	0.18	0.04	0.32	1.00	0.00	0.11
	1.35	1.13	0.07	0.33	0.11	0.48	0.70	0.37	0.00
University	0.85	0.65	2.50	0.70	0.15	0.25	0.40	0.05	0.85
NRI	1.22	1.05	0.57***	0.36+	0.10	0.38	0.72	0.19**	0.21***
NGO									
Mean									
Kenya (N=76)	0.70	1.10	0.10	0.25	0.05	0.55	1.10	0.00	0.00
	1.06	0.63	0.10	0.15	0.15	0.63	1.23	0.40	0.15
University	0.75	1.25	1.13	0.63	0.25	0.25	0.50	0.00	0.38
NRI	0.93	0.82	0.21***	0.22	0.13	0.57	1.12	0.25*	0.13+
NGO									
Mean									
Kerala (N=97)	0.45	0.76	0.00	0.00	0.00	0.07	0.38	0.10	0.00
	1.09	0.75	0.04	0.04	0.00	0.14	0.30	0.16	0.00
University	0.64	1.00	0.36	0.18	0.00	0.09	0.00	0.00	0.00
NRI	0.85*	0.78	0.06***	0.04	0.00	0.11	0.29	0.12	0.00
NGO									
Mean									

Level of significance: + p<.10, * p<.05, ** p<.01, *** p<.001

[a] For Keralan respondents this does not include contacts in India outside Kerala.

Table 6: Location of Contacts by Country of Respondent[a]

LOCATION OF CONTACT	LOCATION OF RESPONDENT				Mean
	Ghana	Kenya	Kerala	Inter.Res.Cen.	
Internal	3.20	2.32	1.72	2.78[b]	2.43***
Europe	0.50	0.68	0.20	0.72	0.45**
UK	0.29	0.45	0.10	0.45	0.27*
North America	0.32	0.56	0.20	0.45	0.35**
US	0.23	0.43	0.18	0.45	0.28*
Africa	0.22	0.15	0.00	0.55	0.14**
Asia (excluding India)	0.03	0.09	0.04	0.09	0.05
India (excluding Kerala)	0.00	0.01	1.42	0.00	0.50***
Developed Countries	1.07	1.53	0.45	1.56	1.00***
LDCs[c]	0.22	0.16	0.01	0.67	0.15***
All LDCs [d]	3.43	2.46	3.15	2.82	3.04*

Level of significance: * p<.05, ** p<.01, *** p<.001

[a] Contact organizations are included when it was possible to identify their location. Therefore, the number of cases is smaller than in previous tables.

[b] Since all respondents for international research centers are located in Kenya, "internal" contacts represent ties with professionals in Kenya.

[c] Includes contacts in less developed countries but not Ghana, Kenya, or India.

[d] Includes India, Ghana and Kenya as well as other contacts in less developed countries.

Table 7: Influence of Location of Education on Network Size

	SIZE OF DC NETWORK (N = 266)		OVERALL NETWORK SIZE (N = 269)	
SECTOR	Educated in DCs	Educated in LDCs	Educated in DCs	Educated in LDCs
University	0.76	0.69	4.26	3.69
NRI	1.59***[a]	0.71	5.03	4.25
NGO	1.82**[a]	0.61	8.09	5.55
Mean[b]	1.34***	0.69	5.04*	4.37

Level of significance: * p<.05, ** p<.01, *** p<.001

[a] Interaction effects show that education in developed countries increases the size of the DC network for those in NRI's and NGO's but not universities.

[b] One-way ANOVA contrasting those with educated in DCs with those educated in LDCs.

Table 8: OLS Regression Models of Internal and DC Network Size

	Number of contacts with DCs		Number of internal contacts	
	b	SE	b	SE
Location of respondent				
Kerala	---		---	
Ghana	1.34***	(0.31)	0.85*	(0.35)
Kenya	0.62*	(0.28)	0.49	(0.37)
Sector				
University	---		---	
NRI	-0.03	(0.26)	0.34	(0.35)
NGO	0.16	(0.35)	1.31**	(0.44)
Personal Computer	-0.06	(0.31)	---	
Graduate degree	0.92**	(0.32)	---	
International Visibility[a]	0.56**	(0.21)	0.18	(0.44)
Education in DCs	0.04	(0.37)	0.17	(0.30)
Age	---		0.03*	(0.02)
Award	---		-0.70+	(0.39)
Post graduate students	---		-0.17**	(0.06)
Interaction terms				
PC*NRI	0.91*	(0.42)	---	
Visibility*Ghana	-1.13**	(0.41)	---	
Education*Ghana	-0.96*	(0.41)	---	
Education*NRI	0.69+	(0.36)	---	
Education*NGO	1.33*	(0.54)	---	
Visibility*NRI	---		-1.02+	(0.54)

+ p <.10 * p <.05 **p <.01 *** p<.001

[a] No NGO respondent was found in international bibliographic databases. This variable only contrasts university and NRI respondents

Appendix 1: Matrix of correlations (Pearson's coefficient) for the variables in the regression models

	Number of contacts with DCs	Number of internal contacts
Presence of a PC	0.22***	-0.04
Graduate degree	0.03	-0.19**
Citation in international bibliographic databases	0.09	-0.21***
Education in DCs	0.23***	0.09
Age	-0.07	0.01
Reception of an award	-0.02	-0.21***
Supervision of post graduate students	0.05	-0.24***

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

Note about the GLM procedure

Because the different categories of the independent variables have unequal numbers of cases, their effect was tested with a one-way or two-way ANOVA (PROC GLM in SAS) and Tukey's HSD (Honestly Significant Difference) test, at the .05 level of significance. Tukey's test compares means by pairs and identifies the groups whose means are significantly different from each other. When an independent variable has a significant effect on the dependent variable, and its interaction with other independent variables is not significant, the independent variable displays a significant main effect. In this case, the mean score of the dependent variable is different for at least two categories of this variable. On the other hand, if the interaction between two independent variables is significant, the effect of one has to be examined at each level of the other, because the influence of one predictor on the dependent variable will be different at different levels of the other predictor. For instance, the sector of the respondent may have an effect on the number of professional contacts in Ghana, but not in Kenya. We conclude that there is a simple effect when one independent variable presents a significant effect at a given level of the other (in the example, there would be a simple effect of sector in Ghana, but not in Kenya).

NOTES

i.In this essay the term 'scientist' refers to individuals who spend at least a portion of their time in research activities. This is narrower than the usage in some LDCs, where 'scientist' may refer to any individual with technical training, but broader than that usage which assigns the label of 'scientist' only to academic researchers with Ph.D.s. The term 'researcher' is, in general, more descriptive of the activities most debates over science involve.

ii. For instance, in 1995 the International Council of Scientific Unions formed a Committee for Capacity Building in Science, which adopted the 'isolation of scientists' as one of three principal problems for capacity building. The empirical assumption that scientists in LDCs had few connections to scientists in DCs was combined with the normative assumption that more extensive ties would be better.

iii. Most scientists are not part of a 'core set' that makes up an active research front and will never be part of one throughout their careers as scientists (Collins 1983).

iv. A 1980s survey of US scientists included respondents from the same organizational contexts as the present study, with the addition of private firms. A roster rather than a nominations method was used for estimating linkages, so the size of networks cannot be compared directly. However, several items tapped the frequency of discussions with those in different sectors. More frequent contact (about once a month) was reported by US researchers with government (63% to 20%) and business (44% to 18%), but more frequent contact was reported by our respondents with universities (58% to 31%) and national research institutes (61% to 46%). Comparing reports of formal communication, slightly more US scientists had been a member of a government committee or advisory group (45% to 40%) and given advice to NGOs (45% to 34%), but more of those in LDCs had served as a consultant (64% to 47%) and attended project or program review meetings (87% to 83%). Finally, the average number of annual meetings attended (government or professional society) was about five per year for US respondents, compared to about three per year for those in LDCs (Shrum 1985: 154-55, 159). Given that the US sample was selected to represent a relatively elite group of researchers, while the present sample was not, there is no evidence here for any general hypothesis of "isolation" among LDC scientists relative to those in the developed world.

v. Interestingly, the 'modernisation' hypothesis of a series of developmental stages experienced by LDCs has never been applied to the institution of science and technology--otherwise, an 'independent inventor' or 'gentleman scientist' model might be viewed as appropriate to some LDCs. Science and technology, even in the modernisation literature, are assumed to transfer directly.

vi. Gaillard surveyed 489 scientists who received grants from the International Foundation for Science between 1974 and 1984. This result is based on reported frequency of communication

with different categories of scientists at the rate of once a year (1991, p. 77-8). However, without information on specific ties and their organisational locus, it is impossible to draw further conclusions about the distribution of professional contacts.

vii. Schott surveyed 616 scientists in 13 countries, including India, Nepal, Bangladesh, Indonesia, Brazil, Chile, and Uruguay (1994). His questionnaire asked each respondent to name the scientists who had performed the best scientific work in the field and those whose work had influenced the respondent's own research. However, the scientists were selected by a geographical index of authors in the Science Citation Index and is not representative of LDC researchers.

viii. "Extensiveness" is, in this context, another term for network size. Network size is a direct indicator of range since the similarity of attributes of a respondent's contacts tends to decline as the number of individuals in the network increases (Campbell et al. 1987). Size is also an indicator of social integration (Marsden 1987; Smith-Lovin and McPherson 1993).

ix.This applies to both foreign and domestic publications for the sample in this study and for the nation as a whole using publication counts compiled from the Science Citation Index (Eisemon and Davis 1992).Publication counts in Eisemon and Davis were for India as a whole.)

x. The trend began to reverse itself in the 1990s, largely through Ghana's implementation of the structural adjustment programs and an associated increase in donor interest.

xi. The Corporate Source field, containing the organisational affiliation and address of authors of entries in these data bases, indicates that the entry (publication, report, conference paper) originates in a particular location. In the present case, the subject matter of interest--agricultural and environmental research--encompasses a large proportion of the total research profile of most developing countries.

xii. NGOs are impossible to identify using bibliographic methods since they do not generally publish the results of their work. The number of interviews per organisation ranged from one to five and was proportional to the size of each organisation (Shrum and Beggs 1997).

xiii. A special effort was made to interview women researchers, who constitute about one quarter of the sample. 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, and at all university departments with significant agricultural or environmental research and failed in only one case, where an NGO had recently incurred the theft of their computer equipment.

xiv. The ideal method of measuring professional contacts would be a roster method using individuals instead of organisations. However, such a list would be impossibly long.

xv. One dozen spaces were provided for these names. In three cases all spaces were used, and in

only one case was the space exceeded.

xvi. Network data was obtained from 78 academics, 151 researchers in state institutes, 40 in non-governmental organisations, and 12 in international research centers.

xvii. The debate over a fixed or open-ended number of nominations has been largely resolved in favor of the latter. Most question wordings ("name generators") yield relatively small numbers of nominations. For example, the most systematic national study of personal networks in the US, based on a module in the General Social Survey that asked respondents to name all those people with whom they discussed important matters within the past six months, produced a mean and mode of three (Marsden 1987, p. 125). Other studies using a combination of questions to generate a respondent's 'core network' have yielded an average size of less than four (Beggs et al. 1996).

xviii. Research systems in India are organised by state. National institutions such as the Indian Council on Agricultural Research are part of the external institutional environment because even external aid must generally be channeled through them. More than many other states, Kerala has a distinct identity and a distinct social environment that has often been identified as a 'Kerala Model' of development (Parayil 1996).

xix. If multilateral are excluded, then the proportion of internal ties, from Table 1, is 680/1232=.55. However, to the extent that many of these ties to multilateral organisations are internal to Kenya, the total is closer to 60%.

xx. The tables here, except where noted, are based on analysis using a general linear model (PROC GLM in SAS) that contrasts mean differences (e.g., in the size of the network) between categories on one or more independent variables. Because different categories of the independent variables have unequal numbers of cases, their effects were tested with a one-way or two-way analysis of variance, together with Tukey's HSD (Honestly Significant Difference) test at the .05 level of significance. Tukey's test compares means by pairs and identifies the groups whose means are significantly different from each other. When an independent variable has a significant effect on the dependent variable, and its interaction with other independent variables is not significant, the independent variable displays a significant main effect. (In this case, the mean score on the dependent variable is different for at least two categories of the independent variable.) However, if the interaction between two independent variables is significant, the effect of one has to be examined at each level of the other, because the influence of one predictor on the dependent variable will be different at different levels of the other predictor. (For instance, the sector of the respondent may have an effect on the number of contacts in Ghana, but not Kenya.) We conclude that there is an interaction effect when one independent variable presents a significant effect at a given level of the other.

xxi. As indicated above, international research centers are not, strictly speaking, part of the internal research system of an LDC. All of our respondents affiliated with such centers were

located in Kenya. In terms of overall connectedness, these respondents are more similar to those in Kenyan national research institutes than to those in Ghanaian or Keralan institutes.

xxii. Overall means for each 'sending' sector are the same as those in the last column of Table 3. In Table 4 they are disaggregated by 'receiving' sector.

xxiii. This pattern is consistent with Table 1, as we would expect, since the latter provided a dyadic view of the same phenomenon.

xxiv. Only one reported link in the survey was to an individual in Latin America.

xxv. For academics, DC education increases the total number of professional contacts slightly, from 3.69 to 4.26. Education in developed countries increases the number of contacts with DCs from .69 to .76, but the difference is not statistically significant.

xxvi. Spearman (rank-order) correlations were used to establish these negative association between internal ties and DC ties (confirmed by Pearson correlation coefficients): -.20 for universities; -.29 for national institutes; -.70 international institutes. Only for NGO respondents is there a positive association between internal and external ties (.35).

xxvii. A total of 43 structural variables were examined. The variables listed here are illustrative of the measures that fall under each of the six major categories.

xxviii. Since network size is skewed, we also estimated models using a logarithmic transformation, but this affects the results only minimally, so we present the models in Table 8 using the integer values.

xxix. Researchers from international research institutes are excluded from this analysis because they are not typical of researchers in developing countries. Moreover, owing to the small number of such individuals interviewed, the models were generally impossible to estimate when they were included.

xxx. Effects of sector and location are included in both models, as well as the main effect of any factor that is included in a significant interaction effect. In addition we estimated the effect of education in the developed world, and the effects of international publication, which are mentioned in nearly all discussions of LDC science.

xxxi. Since the effect of location and sector must be estimated using dummy variable analysis, we use Keralan respondents and university researchers as comparison categories. Hence, a positive coefficient of .79 for Ghana in the model for internal contacts means that, relative to Keralan researchers, Ghanaians have nearly one more internal professional tie, controlling for other variables in the model.

xxxii. The effect of education in developed countries on <u>overall</u> levels of professional contact is

also insignificant when controlling for other factors.

xxxiii. We also tested for a duration effect, that is, using the number of years spent in developed countries, but this has no impact, holding other factors constant.

xxxiv. We also posed these questions to the respondents directly (e.g., whether they had access to a personal computer). These survey items were generally unrelated to the professional contact indicators analyzed here. The interviewer's observation of a personal computer appears to be a better indicator for these purposes than the survey item itself.

xxxv. Seventeen databases were employed, including the Science Citation Index, the most common source for bibliometric measures. CABAbstracts, AGRIS International, and AGRICOLA were included for agricultural topics. Other nonspecialized databases were searched for all records pertaining to agriculture, the environment, and natural resource management.

xxxvi. However, the international centers studied here have stronger links to the Kenyan scientific community, where they are located, than other African national communities. Location does make a difference for international centers as well.

xxxvii. Contrary to Gaillard, as indicated above, education abroad does not itself reduce local contacts (1991). However, our finding that international visibility reduces local contact is consistent with his view.

xxxviii. The interpretation offered here is analogous to that commonly employed in studies of 'returns to education' that find women receive fewer rewards for each additional year of education than men.

xxxix. In Kerala, where the NGO system is least developed, they are more likely to report ties with universities and research institutes.

xl. One other finding is related to the possibility of a tradeoff in ties. Those who supervise postdoctoral students tend to have fewer local linkages, which may mean that the intraorganisational contacts (represented by collaborations with students) substitute for contacts to the local research network.

xli. Contacts in this study were not pre-specified, making even more likely that respondents would name a variety of contacts in different sectors and countries.

xlii. This finding is consistent with Shrum's study of US researchers, which shows that the academic sector has a higher ratio of ties received to ties sent than do national laboratories, the private sector, or public interest groups (1985, p. 177).

xliii. While the costs in time and energy of using operational systems may be low, the financial

and personnel costs of installing and maintaining such systems is not.

xliv. Paraphrasing what one researcher said, 'it'll be another white elephant. The donors will come in and try to establish electronic links, then leave and not support the system'.