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Social and Cognitive Factors Influencing the
International Transfer of Scientific Knowledge:
a report on work in progress

by

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International knowledge transfer: a viewpoint. Not

too long ago in a land not that far away, officials responsible
for economic development concluded that American science and
technology was the answer to all their country's problems.
And so they took steps to transfer that science and technology
to their own shores.

First they sent all their scribes to the United States.
For years and years, these dutiful civil servants transcribed
the scientific and technical books found in America's most
renowned universities. The carefully printed manuscripts
were returned to the homeland and laid to rest in a magnificent
archive specially constructed for this purpose. In time all
of America's scientific and technical knowledge was transferred,
or so it was thought.

And nothing happened.

Then they prevailed upon American corporations to build plants in their homeland and to employ the unruly hill tribesmen who had encamped in the plain surrounding the capital city. And American corporations built plants utilizing the most sophisticated, the most advanced, production techniques then known. The hill tribesmen were taught to punch timeclocks, push buttons and pull levers.

Years passed and the corporations waxed rich, reaping a goodly profit due, in no small measure, to the very generous tax laws originally designed to encourage the "transfer of advanced technology." But the native workers still punched time clocks, pushed buttons, and pulled levers.

What is science and technology transfer? Our little fable illustrates what international science and technology transfer decidedly is not. "Science and technology transfer" implies more than the physical transfer of documents, whether in printed form or in magnetic tapes or whatever. Neither does the term if properly used, refer to the mere physical transfer of technique or knowledge embodied in an artifact or procedure. Yet, so often in the literature one finds the term used in just that way.

Knowledge and technology might have been truly "transferred" to our mythical land if it had scientists and engineers who could

learn--and learn to use--what was written in all those books.

Furthermore, a country profits from foreign science and technology only when that science and technology is wed to economic opportunity. The mere presence of advanced technology in a country does not mean that the country is advanced, economically, technologically, or scientifically.

We maintain that the issue of the science and technology transfer ultimately reduces to questions of education and communication. "Communication" means more than updating a stock of knowledge. It means access to specific information which is needed to identify and/or exploit economic opportunities. Knowledge and technology is truly transferred from one society to another (or from one organization to another) only when the receiving society (or organization) has people who can understand the knowledge and technology and can apply it to the solution of problems of their own choosing. What does all this imply for a developing country that wishes to employ science and technology in the service of the nation? Clearly, it implies the need for a trained scientific and technological establishment ("education"). This is well understood and need not be belaboured. But what is not well understood, however, is the equally pressing need for that establishment to be well integrated with its counterpart in other countries, particularly the major research centers ("communication"). No nation today, and certainly no small nation, creates all the knowledge and technology it needs. Old knowledge must be updated, and new knowledge filtered for its usefulness. There is a high degree of international

interdependence in this sphere.

In the contemporary era, an effective science and technology establishment is a valued national asset. We take the position that an "effective" science and technology establishment is one which supports, augments, or otherwise fosters national economic goals. Our hypothetical developing country, therefore, wants its scientists and technologists to be capable of keeping pace with the frontier of knowledge as it advances in the major research centers of the world.

A scientific and technological establishment which keeps abreast of activity abroad is one that much better equipped to tap the pool of the most advanced work, and that much better equipped to apply this work in the service of the nation, should the need arise. Thus, it is in the national interest that the science and technology establishment be well-integrated into the international scientific community.

Anyone trying to foster this integration (say, a science policy official) would do well to consider the social system of science and technology, i.e., the specific mechanisms which encourage or inhibit the creation of professional ties between scientists and technologists on the "periphery" (Ben-David, 1962) and their counterparts abroad (especially in the major centers). Conceivably such mechanisms could account for the entire observed pattern of communication in a national R & D establishment. But how to identify these mechanisms? One possible point of departure might be an examination of the motivational system, the system of inducements

offered to scientists and technologists. More specifically: what social or psychological rewards direct ^{say,} a scientist's attention to foreign activities? What behavioral factors cause him to ignore these activities?

For some insight into this question we turn to the sociologists of science.

The Sociology of Science. There are two main research traditions within the sociology of science. The first, and by far the better known tradition, owes its genesis and a good deal of its subsequent development to Robert Merton. Merton was the first to view science, not as an evolution of ideas, but as a social institution (1968). From this perspective, then, the critical research questions are: (a) what motivates scientists to contribute their energies for the good of science as a whole? and; (b) how is social control exercised and deviance treated?

The Mertonian paradigm rests on twin pillars: a theory of norms and a theory of stratification. For our purposes, the latter is more important. Merton's description of the normative structure of science suggests only possibilities, the range of behaviors found in the system. It is like an idle automobile engine. What fuels the engine, what provides the scientific institution with its dynamic, is its method of allocating rewards. In the Republic of Science, recognition and acclaim by one's peers is the coin of the realm (Merton, 1962). Recognition and acclaim flow to those who make original contributions.

Merton thus explodes the myth of the disinterested scientist working in isolation, finding his satisfaction solely in the pure intellectual joy of discovery. Priority disputes have peppered the history of science and eponymy is one of the highest honors a scientist can win. Both phenomena underscore the great value which scientists place on professional esteem and acknowledgement. Scientific work implies an endless grappling with the unknown. Feedback, especially from one's peers, is a psychological necessity; it serves to buttress the professional role and confirm the scientific discovery. As Storer (1966) noted, the act of scientific creation is not complete until it elicits the "competent response" of those capable of fully appreciating it.

The second major research tradition focuses on the communication system of science. Information is both a principal input to the scientific enterprise and its output. Although this approach has been cultivated by people with some very practical concerns, i.e., research management and science policy, it has produced work of great theoretical interest.

In his seminal study, Derek de Solla Price (1963), gave empirical rigor to what is now a common observation, to wit, the explosive growth of science over the past three hundred years by whatever measure: personnel, journals, articles, abstracts, etc. The "knowledge explosion" threatens to inundate the researcher. How can the communication system of science continue to sustain this rapidly increasing burden?

The sheer proliferation of information in each field exceeds any man's capacity to keep abreast of it all.

Price hypothesized that science, as an institution, has responded by developing special social forms. And these forms, or mechanisms, permit scientists to bypass the literature completely as a source of problem-relevant information. Literature still retains its archival value and functions as a device for establishing priority claims. But, continues Price, the leading figures in each subfield do not exchange information through such formal channels. Thus, a scientific field can be properly thought of as a closely knit social circle embracing the leading workers and their associates. Science, says Price, is reverting back to a modus vivendi first developed in the seventeenth century, that of the "invisible college."

The "invisible college" hypothesis also rejects the view of the scientist as a stratified social organism, a system of patterned interaction and interpersonal communication. Several investigators have substantiated Price's view and provided convincing evidence that the "invisible college" does not indeed exist, at least in those fields which they have examined (Crane, 1969, 1971; Crawford, 1971; Griffith and Mullins, 1972).

The "invisible college" hypothesis also suggests that, since scientific activity spans international boundaries, so will these interpersonal networks. Links with colleagues abroad are sustained through travel, especially during periods

of active collaboration. Thus we observe, continues Price, groups of "affluent commuters," working in several major centers for a period of time, dispersing and then reforming new groups in the same centers again. An individual scientist's career will include periods of work at these international centers, if he is a recognized leader in his field.

The research project reported here draws upon both of these research "traditions." It is an analysis of the entire science establishment in one small country, the Republic of Ireland. The author was particularly eager to determine how a small, and -- relative to the world of science -- somewhat peripheral country manages to maintain professional ties with the major centers abroad and thus "import" current knowledge. What encourages the integration of Ireland's scientists with their foreign colleagues? (Ben-David (1962) provides an interesting discussion of this problem and underscores its importance.)

Ireland is an excellent research site. It is a "developing" country, one making deliberate and self-conscious efforts to wed science and technology to the goal of national development. Although Ireland is European and caucasian it bears the scars of a long, often brutal, colonial experience. The legacy of imperialism includes: uneven economic development, excessive reliance on a narrow range of export products and failure to cultivate markets outside of the United Kingdom.

Thus, Ireland offers an example, a case study, of the underdeveloped society, or at least one in an intermediary stage of development. Very little is truly understood about the contribution R & D activity makes to economic growth, particularly in such societies. Even less is known about how society, the broad social environment, influences the organization, and by inference, the performance of R & D work.

In Ireland, social research at the national level has not proven to be beyond the capability of a handful of workers. Extraordinary resources are not required. We are dealing with a small R & D establishment; the total population of interest hardly exceeds 1500 individuals. Many U.S. organizations are larger.

Project background. As indicated above, the invisible college hypothesis has stimulated a good deal of research on the interpersonal communication of scientific and technical information. To be sure, written courses, i.e., the literature, still retains its value for the research worker as an instrument of continuing education. But in specific, problem solving situations -- situations typically characterized by great uncertainty and severe time pressures -- interpersonal exchange between colleagues has been found to be the most effective and efficient mechanism for information transfer.

Interpersonal exchange is effective because rapid feedback between the information seeker and his sources enables him to narrowly define his specific information needs. It also keeps the door open to the serendipitous discovery, the unsought after approach (Menzel, 1962; Merton, 1962). It is also efficient because the knowledgeable colleague can shift and filter information and protect the enquirer from "information overload." The only information that is transferred is that which bears on the problem in question. Allen's "gatekeeper" (e.g., Allen and Cohen, 1969), about which more will be said below, and at least one of Farris' "catalytic colleagues" serve this filtering function. (See Gerstberger, 1971, Chapter 1, for an excellent literature review).

In his dissertation study of technical communications, Allen (1966) discovered that industrial development engineers underutilize internal consultants, i.e., their own colleagues. Although superior technical performance proved to be associated with the use of internal, personal sources, Allen's subjects tended to prefer consultation with extra-organizational parties. The internal source, though shunned because of status barriers and the natural reluctance to expose one's ignorance before superiors and colleagues, is, withal, more familiar than any outside party with the specifics of the technical problem at hand and with the organization's culture, its jargon, its capabilities, its values, in short, with the whole set of

social constraints which have been placed on problem solutions.

This finding served to raise yet another question. No organization is technically self-sufficient. To perform successfully over along period of time it must "import" knowledge, information, from other organizations. But the problem solvers who tried to seek out this needed information directly turned in a poorer performance than did those who turned to internal sources. How then should technical information enter the organization?

The data strongly suggested the existence of some boundary-spanning role. Perhaps those productive internal sources were also individuals with extensive knowledge of external sources, both written and interpersonal. If so, the argument continues, information flows into the organization via a "two-step" process analogous to that which has been found to facilitate the diffusion of innovations (Katz and Lazarsfeld, 1955; Katz, 1957; Coleman, Katz and Menzel, 1966). In this model, it is the sociometrically central members of the social network, the most sought after discussion partners, who are the cosmopolitan information scanners. They straddle the boundary between the social system (e.g., the organization) and its environment. They collect whatever information the system requires and diffuse it quickly and efficiently through their many interpersonal contacts.

Allen and his associates have, in a series of studies, substantiated this model (Allen, 1967; 1969(a) and (b), Allen

and Cohen, 1969). Allen refers to these sociometrically central cosmopolitans as "technology gatekeepers." The gatekeeping role develops spontaneously, in response to the very real need to surmount certain barriers: barriers created by separate organizational cultures ("coding" barrier; cf. Katz and Kahn, 1966) and barriers erected by the organization in its effort to preserve its proprietary interests.

In 1968, Allen tested the gatekeeper hypothesis on a national level. Data were collected at the Irish Agricultural Institute (An Foras Taluntais), a (Irish) government-sponsored research organization, employing perhaps two hundred professionals, and engaged in all areas of agricultural research of interest in the Republic of Ireland. Again, evidence was found that those scientists most frequently nominated by their organizational associates as discussion partners tended to report more frequent use of foreign information sources. That is, the "communication stars" read more foreign journals, went abroad on sabbaticals more frequently and attended more foreign conferences. Thus, certain individuals were clearly both (1.) well-integrated with organizational colleagues (collaborated with and were frequently consulted by colleagues); and (2.) highly knowledgeable of work performed outside of Ireland. Allen concluded that gatekeepers do, indeed, serve as communication intermediaries for nations as well as for singular organizations

(Allen, Piepmeier, Cooney, 1971). An independent study of projects undertaken at the Irish Agricultural Institute established the link between these "international gatekeepers" and innovative project solutions, i.e., high technical performance (McCarter, 1972). Thus, the gatekeeper role exists and it makes a substantial contribution to problem solving and creativity.

Elaboration of the gatekeeper hypothesis. Another survey was undertaken several years later (1970). This time, data were collected from the entire R & D establishment within the Republic of Ireland. Nearly 1100 respondents returned useable questionnaires, representing about 70% of the subject population. The analysis discussed below made use of this larger data base and the Agricultural Institute data. The investigator elected to consider only respondents working in the scientific disciplines, and to ignore, at least at that time, both engineers and physicians. Scientists, engineers, and physicians are sociologically distinct groups and must be treated separately. Furthermore, as others have noted, scientists and engineers display quite different patterns of information search and information utilization (Allen, 1966; Price, 1970).

Departing somewhat from previous "gatekeeper" studies, this investigation employed the scientific field, rather than the organization, as the unit of analysis. The relevant question is therefore not: does this or that Irish organization make use of gatekeeper roles to tap foreign sources

of information, but rather: does the X-group of scientists (physicists, chemists, etc.) in Ireland keep abreast of the developments abroad by making use of gatekeepers? More specifically, for a given scientific specialty, are those individuals who maintain fairly stable and enduring professional relationships with foreign-based colleagues precisely the people whom other scientists in Ireland consult for problem-relevant information and advice? Are those most advantageously situated in the field's interpersonal communications network, also the very people who have access to foreign interpersonal sources?

The results of our investigation were quite unexpected.

Simply stated, gatekeeping is very much in evidence in certain fields selected as case studies but not at all in others. Specifically, the data indicate that the gatekeeping role exists within the animal sciences and dairying but that it is not found in physics or geology (Table 1).

Each sub-specialty in physics and geology seems to have developed its own information "life line" to the world beyond Ireland; each developed its own interpersonal sources abroad. Consequently, far more physicists and geologists reported foreign contacts than was true of animal scientists or dairying specialists. About 23% of the respondents in the two agricultural fields reported a foreign discussion partner. A significantly higher proportion of those in each of the physical science fields did likewise (Table 2). Why?

The survey data permitted the investigator to develop a visual representation of each field's interpersonal communication network. Both physics and geology emerged as relatively fragmented fields. Animal science and dairying, by contrast, appear to be highly cohesive. Clearly, a subset of scientists cannot function as gatekeepers for their specialty unless that specialty is somewhat integrated. Without a rich network, information will not diffuse quickly, if at all. Conversely, a high degree of internal integration makes it possible for a small number of people to serve effectively as international information-gatherers. Their findings can become common knowledge fairly quickly.

But why should social structure vary so from specialty to specialty? Hagstrom (1965) posits three conditions which contribute to competitiveness within a scientific field. First, there must be a high degree of paradigm development, enough so that workers in the field can reach a consensus about the next important problem to be attacked. In this case, proportionately large numbers of scientists will work on the same problem. Secondly, success in solving a problem should be fairly unambiguous; research results must be universally accepted. Thus all the glory and recognition flow to the relatively few. And finally, there should be a large number of workers in the field.

Fields characterized by a high degree of competitiveness may also display a high level of collegial communication. There is more reason to communicate with colleagues if a common research

problem is shared (Lodahl and Gordon, 1972); it really doesn't matter for our purpose whether the intent is collaboration or competitive surveillance. Further, a good deal of precious time could be lost working on a problem which has already been solved to everyone's satisfaction. Better to keep close tabs on what others are doing; if they seem to be nearing a breakthrough, this may be the signal to "bail out" and get a running start on the next problem.

Clearly a higher degree of paradigm development exists in the physical sciences than in the life sciences. Experimental results are less ambiguous and more widely accepted. Have we found an explanation for our pattern? Do physical scientists communicate more with foreign colleagues because they share common research interests, because there is greater need to keep abreast of developments? The life scientists may not share research interests with as many colleagues, within or outside Ireland. Their findings, particularly with regard to agriculture, are not of universal interest.*

What, then, may be the key is the existence of a highly visible foreign reference group, a collegial network spanning

*Agricultural problems, it may be argued, are usually peculiar to specific geographical locations. This alone may account for relatively lower volume of transnational communication among agricultural scientists. However, the conclusions drawn in the study retain their plausability even when the analysis treated only agricultural fields which consider problems of international interest, e.g., veterinary medicine (cf Herzog, 1975, ch. 5).

international borders but concentrated in the major research centers. Diana Crane's analysis of collegial networks in two scientific fields provides empirical support for our speculations (1972). Mathematicians concerned with the theory of finite groups (high paradigm) developed an international communication network. However, sociologists in the field of agricultural innovation diffusion (low paradigm) were overwhelmingly American. The implication is clear: low paradigm fields tend to give rise to distinctive, national research traditions with little international cooperation.

The economic relevance hypothesis. But there may be yet another reason why physical scientists and mathematicians seek a foreign reference group to a greater extent than do life scientists.

From the point of view of the small country's policymakers, it is desirable to have a scientific establishment well-integrated with professional colleagues abroad, as long as this scientific establishment continued to choose research problems that are relevant to the home country. Now, clearly, not every discipline is equally relevant to the home country's economy. Ireland's principal exports are agricultural products. The potential contribution of the physical sciences is a good deal less than that of the biological and agricultural sciences. Even within each discipline, projects in progress will vary along this dimension of practical potential, or as we prefer to designate it, economic relevance.

If then, all scientists in the sample can, in principle, be ranked along this dimension, how might this ranking correlate with some hypothetical measure of integration with foreign colleagues? The hypothesis we wish to suggest is that

In small countries, the less relevant a scientist's work to the economic problems of his own country, the more highly integrated he is likely to be with foreign colleagues.

The reader may find this hypothesis running counter to his own intuition. Will not a scientist working on applied, practical problems have a greater incentive to seek helpful information from diverse sources? Will not his efforts be more focused, and the promise of rewarding feedback from his environment so much greater?

Let us address these two issues together. The aim of basic science is not necessarily useful knowledge, much less useful artifacts or productive technologies. The goal of basic science is knowledge per se, empirically verified theory. The direction of scientific activity is established when a theoretical paradigm is widely accepted within the scientific community. What Kuhn (1970) has called "normal" science consists of activities intended to develop, verify and elaborate the paradigm. The efforts of these "paradigm elaborating" scientists is every bit as focused as those of scientists working on applied problems or problems with an immediate, practical import. The real issue is: where does the scientist find his problems, how does he become recruited to a particular research area? If a small-country researcher is in an area which does not lend itself to economically relevant

problems, we would expect him to pay greater heed to foreign reference groups in the major centers and adopt, as his own, problems suggested by these groups, i.e., problems which these groups deemed scientifically important. These groups become sources of both technical support (problem-related information) and professional reward (acclaim, recognition).

Conversely, the small country researcher working in economically relevant fields will find problems, information and recognition at home. Many problems will be cast in a way that does not generate professional interest abroad; they may be unique to the local situation, or may not be seen as currently relevant to the main thrust of research in the major centers.

In short, an individual recruited to the less relevant areas experiences relative difficulty establishing his professional identity. His compatriots may very well pay him great honor; an academic scientist, in particular, may enjoy a favored social status. But, in the Republic of Science, the acclaim of one's peers is the coin of the realm. The act of creation is not complete until it has elicited the "competent response" (Storer, 1966) of others who are qualified to evaluate it. If such response is not forthcoming from parties at home, it will be sought abroad.

Work reported by Aran and Ben-David (1968) provide some support for this argument. They studied 30 Israeli medical researchers (internists) and found that those who undertook their research training abroad were more productive and had more colleague contacts abroad than those who took their research training within Israel. They explain their findings by noting that physicians are trained as clinicians; a physician who elects a research career

must undergo an intense resocialization experience in order to effect the transition from the clinical world to the world of research. The resocialization, the adoption of a new professional identity, will be more successful if the candidate can remove himself from his clinical associations. In a country as small as Israel, this is not possible. Foreign study serves the function of providing the Israeli physician with an opportunity to assimilate a research role, unencumbered by the demands of the clinical role. Those Israeli internists who did not study abroad failed to find the "critical mass" they needed to serve as a resocializing agent; they failed to find a set of effective role models, a reference group.

The current phase. Thus two rival hypotheses could explain the observed differences,* the paradigm hypothesis and the economic relevance hypothesis. Unfortunately, a critical test was not possible in 1970. The critical variables were hopelessly confounded: fields characterized by low paradigm development were economically relevant (i.e., the life sciences), whereas those in the high paradigm group (the physical sciences) were not. The existence or non-existence of foreign reference groups accounts for the dual pattern discussed above but why one group of scientists accepts such groups and the other does not remain an unsolved problem. Is the theoretical physicist more likely to collaborate with foreign

*Several other hypotheses were examined and dismissed. There is no difference in the age distribution of the two groups of scientists. Furthermore, there is no evidence that dependence on apparatus found outside Ireland accounts for the differing rates of foreign contact.

colleagues frequently, and otherwise display an international orientation, because (a) he and other workers in his field (including those abroad) share a common research paradigm and therefore agree on research priorities; or because (b) he needs the feedback and approval of foreign counterparts to help him sustain his professional identity in a local environment which provides little or no "competent response" to his work?

The author is currently engaged in a critical test of the two hypotheses. Additional data has been collected from the Irish geological research community this past summer (1976). Since 1970, geology has shifted dramatically along the economic relevance dimension. The recent discovery of large deposits of zinc and lead in Ireland has fostered a growing extractive industry. This development, and the prospect of off-shore oil deposits, has transformed geology into a highly relevant science within the Irish context.

It has also provided the investigator with what amounts to a natural experiment. An analysis of this new data and comparison with what was collected from the Irish geologists in 1970 should decide the issue between the rival hypotheses. If the economic relevance hypothesis is correct, we will note marked changes in (interpersonal) communication and travel patterns, collaborative arrangements, and so on. Geologists should look more like agricultural scientists and less like physicists. If these changes are not observed, the paradigm hypothesis will emerge as the more satisfactory explanation of the Irish dualism,

for geology has not changed markedly in this respect during the past five years.

The data collection instrument used in 1970 was also used again in 1976. Thus, we have tapped the same variables at two points in time. Note also that many respondents to the 1976 survey were also represented in the 1970 sample. The responses of this sub-group represents true panel data. Panel analysis (Katz and Proctor, 1959; Lazarsfeld and Rosenberg, 1955; Levinson, 1972; Zeisal, 1968) permits us to make statements about causality with greater confidence than would otherwise be the case.

Major findings 1970. For the remainder of this paper we wish to present a few more findings of the original study. All of these findings are compatible with either the economic relevance or the paradigm hypothesis.

For example, both paradigm and economic relevance bear on the observed pattern of domestic, extra-organizational communication (Table 2).

Dairying specialists and animal scientists are motivated to confer with workers in other organizations and other organizational sectors who share their goals, their mission-orientation (economic relevance hypothesis). Consequently, their interpersonal network spans universities, research institutes, government agencies and industrial firms (data not shown). Physicists and geologists are more concentrated in the university sector (they were not, in 1970, employable outside this sector) and tend to limit

their collegial contacts to other academicians.

Alternatively, we can say that the low-paradigm agricultural scientists must conduct a wider, less directed search for problem-relevant information. A highly developed paradigm permits the scientist to isolate his problem from the broader context and to conduct a more restricted, more efficient search for information.

Thus far, we have based our discussion on what has been found to be true of four fields. Does an examination of the entire sample confirm our beliefs?

By and large, it does. Academic scientists in physical science, chemistry and mathematics reported a higher rate of foreign contact than did their counterparts in the life sciences (Table 3). This finding holds true even after controlling for the foreign nationals working in Ireland. There is no such difference in the mission-oriented sector. In the latter case, the organization directs the course of scientific activity and tries to limit extra-organizational contacts to those sources enjoying official approval. The effect we are discussing is not "swamped" in the academic (non-mission) sector. In the absence of an explicit organizational mission and associated rewards, the pull of extra-organizational reference groups is irresistible. As several sociologists of science have argued (e.g., Hagstrom, 1965; Storey, 1966), scientists derive their principal satisfactions from "competent response" of colleagues, the self-confirming approval of the professional reference group. For scientists with relatively few colleagues at home, the reference group in question must necessarily be based abroad.

Additional support for this view was found. Perhaps one-third of the discussion partners reported by Irish academic physical scientists, chemists and mathematicians are foreigners versus about ten percent reported by life scientists (Table 4). Furthermore, this latter group reports that significantly more of its domestic extra-organizational discussion partners are in the mission sector (i.e., research institutes, government agencies, industrial firms). Academic scientists in the economically relevant (low paradigm) fields tend to restrict their contacts to parties in Ireland, but not to fellow academicians exclusively. Relative to their counterparts in the non-relevant (high paradigm) fields, they are well integrated with co-workers outside the university walls (Table 5).

The influence of the foreign reference group was found to manifest itself in several interesting ways. Due to space limitations, we shall confine ourselves to only one issue, that of publication in foreign (i.e., non-Irish) journals.

Transnational scientific communication is an issue for policy makers in small countries; most, if not all, commentators on the subject assume that communication, i.e., access to pertinent information, is positively related to productivity. Information, after all, is a critical input to the entire enterprise. Another widely held belief is that work published in major (read: American and British) journals is of higher quality than work published locally. The major journals are strictly refereed by leading figures in their respective fields and, moreover, have a wider

selection of contributions to choose from.

The foregoing suggests that Irish scientists who have access to international sources will be more productive as a result and that one manifestation of increased productivity is publication in foreign journals. However, the thesis developed here argues that a scientist is more likely to both (i) develop interpersonal sources of information abroad and (ii) publish in foreign journals if he has a foreign reference group. The reference group is obviously a source of colleagues; furthermore, one latent function of publication in foreign journals is to secure a place for oneself in the eyes of this reference group.

The effects of foreign reference groups, foreign job, foreign discussion partners and foreign publications are all mutually reinforcing. We have shown elsewhere (Herzog, 1975) that scientists in the non-relevant, high paradigm fields are more likely to take a job or extended research sabbatical abroad and to form enduring collegial ties with people whom they met in that way. No doubt, exposure to diverse sources of information does enhance their creativity and leads to publication in more prestigious journals. But note: such publication also augments a scientist's visibility and standing, which, in turn, may generate increased opportunity for foreign employment. This visibility and heightened professional stature also makes a scientist a more desirable colleague and discussion partner in the eyes of foreign

colleagues. As Becker (1970) has forcefully demonstrated, in another context, the "cosmopolitan" orientation may be as much a result of sociometric centrality (or high productivity) as its cause.

If the effects of (i) foreign employment experiences (ii) foreign discussion partners and (iii) publication in foreign journals are all mutually re-inforcing (Figure 1), then the relationships between these factors should be amplified among the non-relevant group, i.e., those most responsive to the expectations of foreign reference groups. More specifically, we should

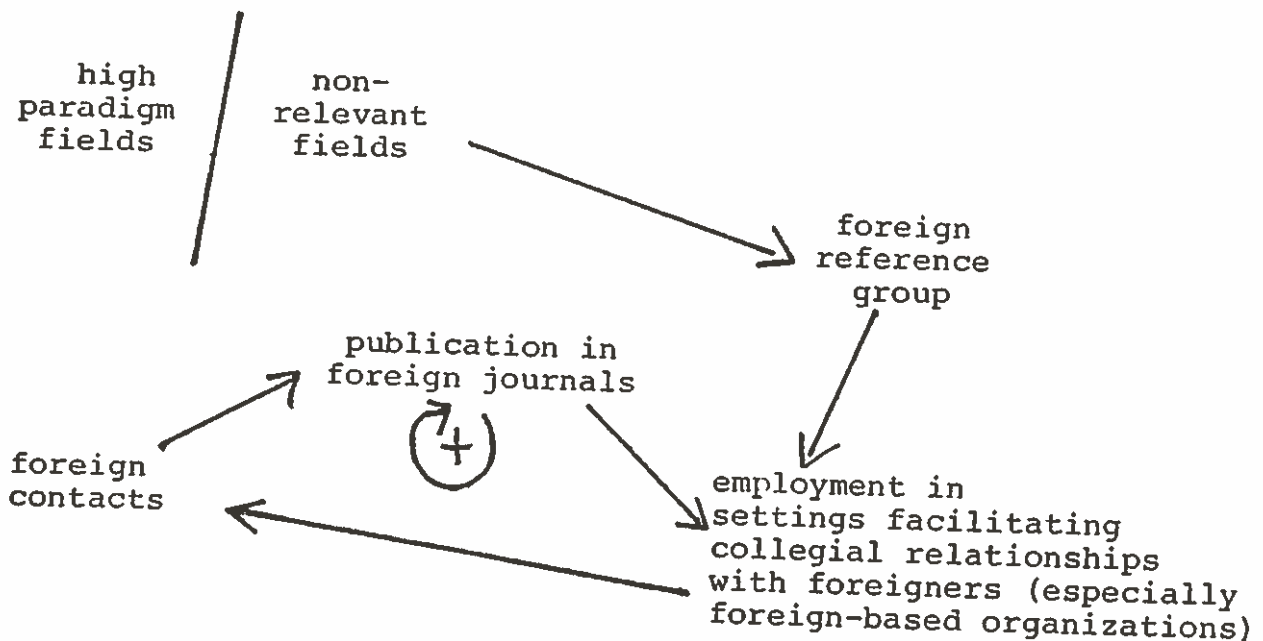


Figure 1. Direct and indirect influences of foreign reference groups on publications in foreign journals.

observe for this latter group a relatively strong correlation between publications in foreign journals and foreign contacts met via work relationships.

This is, in fact, what the data indicate (Table 6). Respondents in this research category (economically non-relevant, high paradigm fields) who report relatively many articles published in foreign journals, do tend to meet their foreign contacts in work settings, whereas those reporting few articles published in foreign journals do not. Respondents in the relevant, low paradigm fields are as likely to meet their contacts in work-related settings as not. And this is true for both the high as well as the low contributors to foreign journals.

It is true that in both research categories, the scientist who reports a foreign contact is quite likely to be a scientist who has published in foreign journals. But an interesting difference emerges if we look at the rate (or likelihood) of foreign contact at various publication levels (Table 7). About 16% of the non-producers reported a foreign contact, and this is true in both research categories. But if a scientist in a less relevant (high paradigm) field orients himself towards the international community, the probability that he will report a foreign contact triples. This seems to be true at all publication levels.

However, there is a monotonic relationship between publication level and incidence of foreign contact among the more relevant (low paradigm) scientists. It is unlikely in the light

of findings reported elsewhere (Herzog, 1975, chapter 6) that publication in foreign journals leads directly to foreign contact.* The reference group notion suggests that a desire to win the approval of foreign colleagues results in more foreign publication.

Among the non-relevant, high paradigm group this desire for approval (or for identification) seems to be an all-or-nothing affair; the non-relevant high paradigm scientist seeks contacts eagerly at whatever publication level once he elects to enter the international arena. But the relevant, low paradigm scientist has a domestic reference group; he can try to split his concern between domestic and foreign colleagues. The more a relevant, low paradigm scientist concerns himself with foreign colleagues, the more he will publish for these colleagues. This is why we observe a monotonic association between publication in foreign journals and rate of foreign sociometric nomination.

A final word. All scientists and technologists everywhere must contend with the "knowledge explosion," the sheer proliferation of information in each field beyond any man's capacity to keep abreast of it all. Several writers have assumed that science, as an institution, has responded by developing special social forms. They postulate a handful of leading workers in each sub-

*Respondents were asked to indicate how they met their extra-organizational discussion partners. A simple tabulation of the responses revealed that employment in a foreign research organization was the single most productive source of foreign contacts. No one reported that he was contacted by a foreign colleague as a result of his (own) published work.

field who identify the problems all in the field of work on, train new workers, develop the field's research paradigms and evaluate research findings (Price, 1963; Crane, 1972). This "invisible college" of leading figures and their associates is a closely knit social circle. Communication is largely interpersonal and outside the formal channels.

While this form of social organization may provide a solution to the "data overload" problem for the field as a whole, it doesn't help researchers who are not in the scientific "metropolis," that is, those who live and work outside the major research centers. It is unlikely that workers in the small countries will ever become part of the "inner circle" unless they spend a good part of their career outside their homeland.

This last point suggests a problem for small-country policy planners. If the "invisible college" hypothesis is correct, a relatively small group of men in the major centers specify which problems in the field are worthy of attention; they decide which problems are important. There is no guarantee that the problems so identified are relevant to the economic development of small nations (or of large, developed nations, for that matter).

The problem arises because developing nations want their scientists and technologists well integrated with colleagues abroad. Countries with relatively few workers in each subfield cannot develop all the knowledge they need, nor can they develop an effective peer review system.

Let us develop this last point. Why is it difficult for the national establishment to maintain high standards without reference to foreign activities, i.e., to what is acceptable abroad? Typically, in smaller communities, a handful of organizations employ the great majority of workers in each field. These workers will all be acquainted with each other's professional activities certainly, and most probably choose many social intimates from this group as well. People engaged in common tasks will interact with each other. Interaction leads to social relationships and yet more intensive interaction. Small, cohesive groups will develop norms, standards of acceptable behavior, which may not agree with the norms and standards of others. The point is that research scientists in small countries may adopt standards of professional performance a good deal lower than those maintained in the major scientific centers.

In order for researchers in the smaller centers to maintain the highest international standards they must submit their work for review by peers abroad. This means publishing in foreign journals. But to publish in foreign journals, to elicit the professional acclaim of foreign colleagues, they must work on problems of interest to those colleagues. And what kind of problem is of concern to foreign counterparts? Typically it is a problem selected by the key figures in the field, one deemed

important because its solution promises to contribute substantially to -- what is, after all, the principal objective of science -- the development of theory. In those fields characterized by highly developed theoretical paradigms, problems suggest themselves in a logical sequence. The higher the state of paradigm development, the easier it is for key scientists to reach a consensus regarding the research priorities.

Quice obviously, there need be no congruence between (i) that set of problems the solution of which promises short, or intermediate, term benefits to the small, developing economy and (ii) that set of problems which is of great theoretical interest. Such congruence would be highly fortuitous but quite improbable. Thus, the mechanism which insures against mediocrity (i.e. peer review) also tends to wean scientists away from work which has great economic potential locally; it diverts manpower into channels designed by leaders of the "invisible college," men who may have no practical, real-world referent. We hypothesize that such tendencies are particularly pronounced in non-mission oriented organizations such as universities. The university typically does not direct its faculty to specific research areas. Academic scientists derive their principal satisfactions from the "competent response" of colleagues, the self-confirming approval of the professional reference group. In the absence of an organizational mission and associated rewards, the pull of extraorganizational reference groups must be irresistible. For scientists with relatively

few colleagues in the home country, the reference group in question must necessarily be based abroad.

This explains why the Irish physical scientist will publish in foreign journals. But for whom should an Irish life scientist write? If he writes for Irish journals and speaks to an Irish audience about Irish problems, he denies himself the criticism and corrective feedback of leading figures abroad. If he writes for foreign journals, there is the danger that he will be, subtly, led away from locally relevant problems. One way out of the impasse is to encourage publication in Irish journals which have engaged an international panel of referees. The editorial policy of the journals will remain in Irish hands and should favor work which is in the national interest. The board of referees, if selected with care, will lend prestige to the journal and subject Irish research to the highest international technical standards. The comments of foreign referees can be expected to inform Irish researchers of foreigners working on similar problems, new techniques, etc. Because the referees will be reviewing specific projects their comments and suggestions will be equally specific.

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TABLE 1

Representation of "Stars" Among Those Respondents Reporting at Least One Foreign Discussion Partner by Research Field

	Physics		Geology		Dairying		Animal Science	
	total No.	with foreign partner	total No.	with foreign partner	total No.	with foreign partner	total No.	with foreign partner
stars	13	3	10	5	11	4	13	6
non stars	52	21	29	17	21	3	71	12
Fisher's exact test	$p(n \geq 3) = 0.93$		$p(n \geq 5) = 0.83$		$p(n \geq 4) = 0.16$		$p(n \geq 6) = 0.03$	
					$p(n \geq 4) = 0.03$		$p(n \geq 6) = 0.01$	

TABLE 2

Percentage of Scientists

- (i) who reported a foreign discussion partner;
- (ii) who reported a domestic extraorganizational discussion partner

Research Field	Percent of respondents reporting	
	at least one foreign discussion partner	at least one domestic extraorganizational discussion partner
Dairying	22	62
Animal Science	23	67
Geology	58	53
Physics	37	52

TABLE 3

Statistical Significance of the Research Field and Citizenship Effects, Non-Mission Sector
(Method of Average Weighted Differences; cf. Snedecor and Cochran, 1967)

Field	n	a	Irish (1) p = a/n	v = pq/n	n	a	Non Irish (2) p = a/n	v = pq/n	Citizenship Effect
Physical Science, Chemistry and Mathematics (1)	106	39	0.367925	0.002194	44	25	0.568182	0.005576	D = 0.200257 V = 0.007770 W = 128.7001 WD = 25.77314
Biological and Agricultural Sciences (2)	150	39	0.260000	0.001283	36	12	0.3333333	0.006173	D = 0.073333 V = 0.007455 W = 134.1310 WD = 9.836266
Research Effect			D = 0.107925 V = 0.003477 W = 287.6456 WD = 31.04401				D = 0.234849 V = 0.011749 W = 85.11435 WD = 19.98898		

Main effects:

- (a) research field
 $(\Sigma WD/\Sigma W) = 0.1369057$, s.e. = $1/(\Sigma W)^{1/2} = \pm 0.0517946$
 $z = (\Sigma WD/\Sigma W) \div \text{s.e.} = 2.64$, $p = 0.004$
- (b) citizenship
 $(\Sigma WD/\Sigma W) = 0.1354839$, s.e. = $1/(\Sigma W)^{1/2} = 0.0616827$
 $z = (\Sigma WD/\Sigma W) \div \text{s.e.} = 2.20$, $p = 0.01$

TABLE 4

Distribution of Extraorganizational Discussion Partners Reported by Academicians

Research Field	Percentage of discussion partners located within Ireland			
	Irish respondents	n	All respondents	n
1. Physical Science and Mathematics	62	63	66	100
2. Chemistry	68	43	50	50
3. Biological Sciences	87	84	82	108
4. Agricultural Sciences	90	66	91	78

Research Field	Percent of discussion partners located within the academic sector			
	Irish respondents	n	All respondents	n
1. Physical Science and Mathematics	69	63	78	100
2. Chemistry	82	43	83	50
3. Biological Sciences	43	84	48	108
4. Agricultural Sciences	27	66	32	78

TABLE 6

How Irish Academic Scientists First Met Their Foreign Discussion Partners, By Research Category and Publication in Foreign Journals

No. Articles Published in Foreign Journals	No. of foreign discussion partners reported by respondents in:			
	Non-relevant fields		Relevant fields	
	Met thru work rel'n.	Other	Met thru work rel'n.	Other
0-3	9	16	15	18
3+	37	7	26	19
Chi-square	16.59, $p < 0.001$		1.16, $p > 0.25$	

TABLE 7

Relationship Between Articles Published in Foreign Journals and Foreign Discussion Partners, By Research Category (Irish Academic Scientists)

No. of articles	Percentage of respondents with at least one foreign discussion partner			
	Non-relevant fields	n	Relevant fields	n
-0-	17%	30	16%	58
1-3	46%	22	26%	43
4-10	46%	26	38%	21
10+	42%	26	48%	23