Research Program on the Management of Science and Technology

TECHNOLOGY TRANSFER TO DEVELOPING COUNTRIES:

THE INTERNATIONAL TECHNOLOGICAL GATEKEEPER

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August 1970

(Supersedes #467-70)

The research was supported by An Foras Taluntais, the Irish Agricultural Institute. Raymond N. Seakan and William T. McCarter provided assistance in the data analysis. The authors gratefully acknowledge the cooperation of the management and employees of An Foras Taluntais. A major portion of the paper is based upon a Master of Science thesis by J. M. Piepmeier.(1)
ABSTRACT

A questionnaire was developed and administered to the research personnel of An Foras Taluntais, the Irish agricultural research and development organization, to study the operation of communications channels for the international transfer of technological information. The techniques employed are consistent with those used in previous studies of the purely domestic flow of technological information into American research and development laboratories.

Results of the study show that the international transfer, like domestic transfer, takes place in a two-step process operating through intermediary agents called technological gatekeepers. These technological gatekeepers must be well integrated into two information networks, an external network of information sources and an internal network of users to whom the information can be delivered. Possible strategies for gatekeeper development are discussed.
A great deal of attention has been devoted during the past decade both to the problems of economic development and to the implications of the so called "information explosion" in science and technology. Far less consideration, however, has been given specifically to the point at which these two areas intersect.

The problem posed by this intersection can be stated quite simply. A massive body of technical information exists in the world which, theoretically, the developing country should be able to tap and apply in its development programs. The developing country must select and apply this technology efficiently, however, in order to reap the greatest benefits from it. But technology continues to multiply and accumulate at such a rapid pace that it is extremely difficult to keep track of it.

How then does the scientist or engineer working in a developing country with modest resources isolate and identify those pieces of the vast reservoir of the world's accumulated technical knowledge that are relevant to his current work? How, indeed, can he even discover whether his particular problem has already been solved by a researcher in another country? Surely limited R&D budgets can be applied more efficiently if existing solutions to current technical problems and new advances in research techniques can be communicated to those abroad who need them, rather than having to "discover" them over and over again in each separate country.

Of course, as many authors have already pointed out, all R&D suffers from this malady -- however the symptoms are likely to be much more acute in a small country with limited resources. Such a country can ill afford duplication of research.
The question to be addressed, therefore, is -- how do we improve the communications channels that carry information from research groups in one country and deliver it to research groups in another (particularly a developing) country? A prerequisite for answering such a question must be a good understanding of the ways in which scientific and technological information flows between countries. An understanding of the way in which the existing system functions can often, by itself, suggest directions for improvement, and will lessen the likelihood of costly errors in policy formation or system design.

THE PROBLEM OF INTER-ORGANIZATIONAL TRANSFER OF TECHNOLOGY

Before turning directly to an examination of channels used in international technology transfer, it will be useful to look first at an analogous situation. The large, technology-based firm faces a problem very similar to that confronted by the small country. No single organization can be technologically self-sufficient. There will always be relevant technology to be imported into the organization. The means by which large American corporations accomplish this feat has been the subject for much research in recent years. (2)

Most attempts at bringing new technology into the firm have assumed a straightforward model of information flow. According to this model, the interface between technical personnel in the firm and the external technical environment is a simple and direct one. Each and every member of the organization accomplishes this interface in exactly the same way. He both reads the literature and talks with people outside of the firm. To promote technology transfer under the terms of this model, all one must do is increase the degree and ease of contact between organization members and the two external information sources. Although in theory, this is very simple, in practice it often becomes very costly and is frequently ineffective.
Research now shows that neither of these sources has been successful in providing information to the average industrial scientist or engineer. The literature is ineffective because it is not used (3). The average engineer makes very little use of his literature, particularly that contained in professional engineering and scientific journals. Furthermore, increasing the quantity of literature to which he is exposed will do little to alleviate this situation, since he already feels swamped by written material.

Direct contact with people outside of the organization is ineffective for different reasons. Such contact occurs quite a lot, but studies have shown a consistent negative correlation between the use of this information source and the user's performance (4). There are many reasons for this. Suffice it to say at this point that the channel is a "noisy" one, subject to misinterpretation, and is, therefore, an ineffective medium for technology transfer (5).

There is only one information source, in all of these studies, whose use has consistently shown a positive correlation with technical performance. It lies not outside the firm, but within. A colleague of the information seeker within his own organization proves to be the most effective direct source of information. This, however, begs the question of transferring information into the firm, and it isn't until one steps back and looks more carefully at the internal consultant that the most effective connection to the outside world appears. Those who were highly chosen as internal consultants also, on the average, made significantly greater use of the professional and scientific journals and maintained ongoing informal contact with many colleagues in other organizations, particularly university and non-profit laboratories (6). They, thus serve as intermediaries between the average member of the firm and external sources of information. For this reason, they have been given the name "technological gate-keeper".
The technological gatekeeper receives information from a wide variety of sources external to the laboratory and, in turn, acts as an information source for his colleagues in the laboratory. Such a two-step flow seems to be significantly more effective in transferring technology than a simple direct connection from source to receiver. Gatekeepers, in at least some organizations, exist not as solitary intermediaries, but have actually developed a network among themselves (7). The gatekeeper network extends considerably the range of contact between organization members and sources of information in the world at large.

A similar phenomenon has been shown to play an important role in communications over a wide spectrum of human effort including: the adoption of hybrid seed corn by farmers (8); the prescribing of new drugs by doctors (9); and the spread of political opinions among the electorate (10). It is not surprising therefore that the same two-step process is important in technology transfer into R&D labs.

For some time now it has seemed possible to extend the methods used in the study of American R&D laboratories to the problem of the small nation. As a first step in this direction, an empirical analysis has been made of the way in which foreign agricultural information is acquired, by one small country, and then disseminated among its agricultural scientists. This study hypothesizes that communications channels for the international transfer of technical information will also demonstrate a two-step flow process and that "international technological gatekeepers" can be isolated and identified as key intermediaries through which information from abroad is channelled and distributed.

To facilitate comparison, the methods used to identify international gatekeepers are tailored on the pattern of previous studies of American laboratories.
The sample population comprised the native-born personnel (11), of An Foras Taluntais (AFT - the Irish Agricultural Institute) including research personnel and first and second line supervisors but not technicians. Those who reported spending less than 10% of their time on R&D were also removed from the sample.

An Foras Taluntais operates under a charter similar to that of many other government supported research institutes. One of its primary goals is the acquisition of information to promote agricultural innovation as a means toward the economic and social development of the nation. It, therefore, acts in one sense as a gatekeeping institution, mediating between the Irish farmer and agricultural developments occurring both within and outside of the country (12).

AFT is divided into six divisions. Each division is further subdivided into several departments (Glasshouse Crops and Mushrooms, Meat Research, Pig Husbandry, etc.). Each department may be spread over several geographic areas and, furthermore, sections of several separate departments may be lumped into a single research center. The research personnel of AFT are overwhelmingly Irish by nationality (95% are citizens of the Republic of Ireland or Northern Ireland). The sample population of 180 scientists contained 55 Ph.D.'s and most of the remaining held a degree or certification higher than the bachelors level.

METHOD OF INVESTIGATION

The Questionnaire

A brief questionnaire containing 30 questions was administered to all scientists in An Foras Taluntais. In addition to the usual demographic and biographic questions, the respondents were asked to name the people both within and outside of AFT with whom they most frequently communicated on scientific matters, and to
estimate the intensity of their foreign correspondence over the past year. The questionnaire enjoyed an 85% response.

Criteria for Choosing International Gatekeepers

To be an effective gatekeeper in an international sense an individual must be well integrated into two networks: an external network of foreign information sources and an internal network of domestic users to whom the required information can be delivered.

The Internal Network

The structure of the internal communication network can be approximated by examining the responses to the question in which "most frequent" scientific discussion partners are named. Each respondent is thus connected to those whom he names. This can be accomplished in either matrix or diagram format (Figure 1). This allows the computation of the number of entering branches which can be used as an index of the number of people who turn to a given individual for information, or the number of people who can potentially be reached by information held by that person. A person with a large number of entering branches is likely to be a very important source of information for his colleagues in the organization. For purposes of the present study, this person will be called a "communication star" (13). Numbers 14, 15, 20, and 28 are communication stars in the figure.

External Network

For a communication star to also be a technological gatekeeper he would have to be well integrated into an external network of foreign information sources. In choosing a discriminator to identify those who have established and do employ an
external network two factors are important. The discriminator must identify: (a) those who frequently and continually use the network, and (b) those whose network is broad enough to include diversity of foreign information sources.

Two criteria -- the frequency of foreign technical correspondence and the frequency of foreign scientific and professional society attendance -- are used. Each of these channels can be used frequently and each allows contact with a large number of overseas colleagues. The degree to which they are used is therefore judged to be a good measure of integration into the external network.

For the concept of the "technological gatekeeper" to be proved operative, it must be demonstrated that the communication stars described above actually do receive a greater amount of foreign information than do their colleagues. If each individual were to receive most of his foreign technical information directly from its source (direct flow) the gatekeeper concept would be meaningless. Similarly, if the high international communicators were isolates within the country, the gatekeepers would be non-existent. Simply stated, a single individual must be instrumental in both the acquisition and dissemination of foreign information.

In fact, the data show that technical discussion stars actually do receive significantly more international technical information than non-stars as measured by frequency of foreign correspondence and attendance at foreign scientific and professional society conferences (Figure 2). They also read a significantly greater number of foreign journals (14). The gatekeeper hypothesis is quite strongly supported.

The international gatekeeper in addition to his communication activity displays somewhat greater technical competence than his non-gatekeeper colleagues. Technical performance is of course, extremely difficult to measure, but to the extent that publication of scientific and professional papers and the acquisition
Figure 2. Degree of foreign communication by internal communication stars

Mean number of times

Correspondence with foreign research workers in past year

Attendance at foreign conferences

Foreign scientific technical journals read regularly

Mean number read

* t-test

p < 0.05*

Other researcher.
of patents serves as an indicator, the international gatekeeper is a high performer indeed. The technological gatekeepers in AFT are, on the average, significantly superior to their colleagues in both publications and patents and a higher proportion have a Ph.D. degree.

**THE GATEKEEPER NETWORK**

Recent studies (15) have found that in American research laboratories, gatekeepers often develop a tightly connected network of their own within the laboratory's communication network. Such a gatekeeper network provides an effective mechanism for coupling the laboratory to outside events. The average engineer or scientist is now provided with more than just a single intermediary to provide him with outside information; he has instead an entire network to perform the mediating function. Information which enters the organization through one of the members of the network (a gatekeeper) can then be transmitted quite readily to other members of the network as a result of their high level of interaction, and is eventually disseminated to the rest of the laboratory. This final step in the process is possible because nearly everyone in the organization is in direct and frequent contact with one or more of the gatekeepers.

In An Foras Taluntais, there are 26 scientists whose communication activities fit the operational definition for a gatekeeper (16). All but 5 of the 28 are members of a single "strong component" (17) in the organization communication network. A strong component is a subset of the total network in which all members are mutually reachable. In other words, it is a very highly connected portion of the total network, whose members are in close and frequent contact with one another. This strong component is drawn within the dashed line in Figure 3. It can be seen from this figure, that even the five gatekeepers who are not members
of the strong component, are not very far removed from it. For this reason, it can be argued that all 28 gatekeepers have developed for themselves a fairly cohesive network. The formation of the network is still more impressive when one considers the barriers to its formation. We have already mentioned that An Foras Faluntais is divided into six divisions. Worse than this, the scientific activities of the six divisions are conducted at seven major locations within the country. These seven centers are spread over a large geographic area with distances between centers ranging from 15 to more than 150 miles. In Figure 3, each center has been given a letter code, such that all P's are from one location, all G's from another, and so on. The gatekeeper network thus extends over all of the centers. Geographic dispersion therefore is not an insurmountable barrier to communication among gatekeepers.

The gatekeeper network thus formed serves as a vital mechanism for bringing foreign science to bear upon the agricultural problems of Ireland.

THE DEVELOPMENT OF INTERNATIONAL GATEKEEPERS

Given the existence of gatekeepers at an international level and their importance in coupling the country to foreign science and technology, the important problem now becomes how to develop people into this role. There are of course many possibilities, but two would appear most likely. First of all, a scientist might develop contacts through foreign education and maintain these after returning home. If this were the case, a government desiring to stimulate the importation of foreign technical information could do so by supporting the education of its citizens in those countries with which it hoped to promote communication. On the other hand, a more direct attack upon the problem might be to encourage the employment of foreign nationals. The foreigners would presumably retain contacts
in their home countries, thereby establishing themselves as potential gatekeepers for the host country.

At least the first of these potential solutions does not appear worthy of support. The people who are functioning as gatekeepers for the agricultural institute were not predominantly foreign-educated (Figure 4). Proportionately, gatekeepers do not hold foreign degrees any more frequently than do non-gatekeepers. Foreign education does not appear to be an effective strategy for creating gatekeepers (18). Employment in research in another country is, however, quite effective in this regard. A very high proportion of the gatekeepers (89.3 percent) were either employed by a foreign agency or firm or visited another country to work on a sabbatical or research fellowship. This finding seems quite reasonable. Far more enduring relationships can be established during post-graduate research than during the educational process. A government wishing to establish foreign communication channels would, therefore, be well advised to support the graduates of its own universities for short periods of work abroad, rather than to support foreign education.

The effectiveness of foreign visits in promoting communication is, as expected, a decaying function of the time since the last visit (Figure 5). Unless given an opportunity to renew acquaintanceships, a person's level of foreign communication will steadily decline with time. Judging from the present data, scientists, who are to function as gatekeepers, should be encouraged to participate in foreign sabbaticals every five to ten years. International conferences certainly have a potential for offsetting this decline. Just how effective they are in maintaining these communication channels remains to be determined.
Figure 4. Foreign experience of gatekeepers
Figure 5. Correspondence with research workers met during employment, or sabbatical, etc., as a function of time since return from.
THE POSITION OF FOREIGN NATIONALS

There are in the sample ten scientists who are citizens of foreign countries. While this is an admittedly small sample from which to generalize, the importance of the question of foreign nationals' effectiveness in bringing science and technology into a country is so great, that we would be remiss in not considering it.

First of all, it must be pointed out that none of the gatekeepers is a foreigner. Although the ten foreign nationals all exhibit a high degree of communication with scientists outside of the country, none is an internal communication star. They are all well integrated into the domestic communication network, but none to that exceptionally high degree required of a gatekeeper. Does this mean that they are not being fully effective in the technology transfer process? Before attempting to answer this question, it might be profitable to examine just how these ten have fitted themselves into the domestic network.

In Figure 6, we see that six of the ten have attached themselves in a very direct fashion to the gatekeeper network. From these positions, any information which they obtain can be fed directly into the system with a very high probability of reaching the parties who most need it. This is perhaps the best way to fit a foreign national into the organization. Not all foreigners can be expected to become gatekeepers, and none can be expected to accomplish this feat overnight. So the best compromise might be to bring them into direct contact with those members of the organization who have the widest range of domestic contact. In this way, the number of people who have at least indirect contact with the foreigner is maximized. The members of the gatekeeper network are, naturally, in the best position to serve as a buffer stage between the foreigner and the organization. They might also be better equipped to aid the organization in assimilating the foreigner. They have usually been exposed to cultures other than their own and
have perhaps had experience in a specific foreigner's own country. They are therefore better able to understand and communicate with the man and to make his expertise relevant to the problems of the country. The gatekeeper can thus serve an important function in introducing the foreigner and his expertise into the country. In the absence, or unavailability of gatekeepers, however, the next best tactic would be to provide the foreigner with a close associate, who although not a gatekeeper, is integrated into the domestic network to an exceptionally high degree. This is just what happened in the case of the four foreign nationals who were not connected directly to the gatekeeper network (Figure 7). All four associated themselves with two cliques that had formed around three internal communication stars. This is probably not as effective as association with the gatekeeper network, but the two centers, at which these four foreigners were employed, were not heavily represented in that network. Connecting themselves to important communication cliques in the two centers insured at least, that their competence would be well disseminated within their respective centers.

CONCLUSIONS AND IMPLICATIONS

The existence of the international technological gatekeeper as an intermediary in the technology transfer process has now been clearly demonstrated. The international gatekeepers display characteristics which are very similar to those found in American R&D laboratories. They are, on the average, technically more competent and more productive. They regularly read a large number of technical publications and hold a Ph.D. degree significantly more frequently than their colleagues.

The international gatekeeper's ability to keep abreast of foreign technological developments is an important asset for every small country. The gatekeeper mechanism is not only an effective way for a country to import technological information, but it would appear to be a relatively inexpensive way as well. The cost of allowing a gatekeeper to maintain his foreign contacts through
Figure 7. Portions of the communication network showing the position of four of the ten foreign nationals with respect to cliques formed around internal communication stars.

S05, S09, & N08 are internal communication stars.

FOREIGN NATIONALS

OTHERS
periodic travel is quite small, when viewed in light of the benefits to be derived. The gatekeeper phenomenon is certainly not the complete answer to all of the small nation's problems. But an understanding of this process coupled with a willingness to capitalize upon it will certainly be a long step in this direction, with little costs to the nation.

The present evidence indicates that the gatekeeper develops his external contacts most effectively through active research experience in a foreign country. Doing research in another country is more effective in establishing communication with foreign scientists than is university attendance. Much more enduring relationships seem to be established during a year of postgraduate research than are established during several years of education.

The implications of these results are unambiguous. If international transfer of technology is to be fostered, the small nation should seek to open those channels through which information flows most effectively. In order to foster increased information flow a country should assist able, domestically educated research personnel in getting grants to do research abroad. It should encourage researchers to take foreign sabbaticals, fellowships and other forms of extended foreign technical experience. It should not, however, spend money directly on foreign education for its personnel. Foreign research employment and other forms of foreign technical experience greatly increase an individual's ability to fill the role of international technological gatekeeper and thus improve channels for international communications. Foreign education, per se, does not.

In addition, the nation should recognize that gatekeepers are an efficient mechanism for transfer and it should help them to perform their role. This can be done first of all by helping them to maintain existing contacts through foreign travel. A second possibility is suggested from observation that there can develop,
quite spontaneously, a rather extensive and very cohesive network of gatekeepers. These networks may be confined to a single technical specialty, or they may overlap and include members of several specialties in a single network, depending upon circumstances. This clustering of gatekeepers into a network enhances their functioning considerably. Information can now enter through a single gatekeeper, and eventually reach almost any person needing it after being transmitted along the gatekeeper network. The average scientist or technologist now has not a single intermediary functioning between himself and the world-at-large, but an entire network of intermediaries. The probability of closing the path between information source and user is thereby increased by a considerable amount. The level of probability involved is of course a function of how tightly connected the gatekeeper network is and of the proportion of scientists and technologists who have relatively direct access to it. Both of these conditions can be influenced in many ways. A small country could, with little effort, stimulate the formation of tightly connected internal networks among its gatekeepers. This would most certainly enhance its ability to import the needed technology for economic development.

Foreign scientists can be an important resource for the small country. Care, however, should be exerted in integrating them properly into the domestic communication network. Unless they are brought in at points from which their expertise can be widely disseminated by colleagues, their full potential will not be realized.
REFERENCES


2. For reviews of such studies over the past ten years see the chapters on "Information Needs and Uses in C. Cuadra (ed.) Annual Review of Information on Science and Technology, Vols. I through IV. For a theoretical model describing just how the process occurs, see T.J. Allen Managing the Flow of Scientific and Technological Information, report to the Office of Science Information Service, National Science Foundation, 1966.


11. Foreign born scientists are considered specially and treated in a later part of the paper.


13. Communication stars are operationally defined as individuals with a number of branches entering their nodes (communication choices by colleagues) equal to or greater than one standard deviation above the mean number of entering nodes for the sample.

14. They regularly read a greater number of domestic journals as well.


16. Gatekeepers are operationally defined as communication stars who also have either engaged in correspondence with research workers in other countries or have attended foreign conferences to a degree greater than the mean for the sample.


18. That is not to say that foreign education should never be supported. There will always be fields in which the number of people who are needed is not great enough to warrant the development of a training program within the country. Foreign training will therefore be necessary in these fields. The returning student certainly brings home with him knowledge of foreign science. The only point we wish to make here is that he does not maintain contact with the foreign scientists whom he met.