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Transferring Technology to the Small Manufacturing Firm: A Study of Technology Transfer in Three Countries

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ABSTRACT

Case histories were compiled of 100 instances of technological change in 100 manufacturing companies in eight industries in Ireland, Spain and Mexico. The cases are analyzed for the source of initial ideas and for sources of technology employed in resolving major problems.

Technology is found to flow principally through informal channels within industries. Very little information was obtained from the formal mechanisms or institutions normally considered central to the technology transfer process.

Foreign subsidiaries obtain the greatest proportion of their technology from their parent firms. Surprisingly, they are found to have several channels of technology blocked to them, which are more readily available to domestic firms. Domestic firms, in many ways have easier access to foreign technology than do the subsidiaries of multinational firms.

Product and process innovations originate in somewhat different quarters. Process innovations are slightly more likely to be based on foreign technology; product innovations are more likely to be based on domestic technology.

The results reported in the present paper are very similar in many ways to results reported previously in Brazil and Australia.

INTRODUCTION

The most difficult problem in technology transfer is that of bringing new technology in the form of product changes or new manufacturing techniques to the relatively small, less sophisticated companies that make up the majority of firms in any country. These firms generally support no research or development themselves and usually have no one on their staff with anything resembling an engineering or scientific education. In trying to bring new technology to this type of firm, governments have tried many strategies, few of which have been successful.

To improve our understanding of the process by which such firms do acquire technology, interviews were conducted in 102 firms in three countries. The distribution of the sample by country is shown in Table I. The 75 Irish firms were a stratified random sample in eight

TABLE I

Distribution of Firms by Country and Industry

Industry	Country			Total
	Ireland	Spain	Mexico	
food processing	33	9	0	42
building materials	7	0	0	7
electrical & electronics	8	5	2	15
men's & boy's clothing	9	0	0	9
chemicals & pharmaceuticals	5	9	1	15
machinery manufacture	3	0	1	4
paper	6	0	0	6
linen & cotton textiles	4	0	0	4
total	75	23	4	102

inoustries[1]. The sampling technique is reporteo in Allen (1980). The Spanish ano Mexican firms were not ranoomly selecteo but were chosen because of contacts maoe by two M.I.T. stuoents. The Spanish oata were analyzeo ano submitteo as a Master of Science thesis (Hyman, 1980). The Mexican oata were analyzeo ano submitteo as a term project for a course taught by the author at M.I.T. The oata from Spain ano Mexico are in most respects so similar to that which was founo in Irelano that it seems that little was lost through the lack of rigorous sampling methoos in these two countries. For most of the analyses in the present paper, oata from all three countries will be aggregateo. Only in those instances in which there appear to be interesting oifferences ano some reason for a comparison across countries will the oata be oisaggregateo ano ioentifieo by country.

In accoro with the goals of the stuoy most of the firms are relatively small in size (Table II). Exact oata on the size of the four

TABLE II

Distribution of Firms by Countryano Size

Country	Number of Employees:			
	0 - 99	100 - 999	≥1000	Total
Irelano	26	49	0	75**
Spain	11	9	3	23
Mexico	*	*	*	4

* Data on size not available
**Only 73 of the 75 firms were able to provioe information on change in prooouct ano process.

[1] Actually twelve. Five separate inoustries oealing with fooo processing will be aggregateo for purpose of analysis in this paper.

Mexican firms is not available. However, it is safe to say that all four are relatively small and comparable to the remaining 98 in terms of size. Three of the Spanish firms had more than 1,000 employees. None of the Irish firms were this large; all but five had fewer than 250 employees. Nine of the Spanish firms had fewer than 50 employees while none of the Irish firms were that small since a lower cut-off of 50 employees was used in selecting the 75 Irish firms.

RESEARCH METHOD

The method used to determine the sources of new technology was very simple and straightforward. The general manager (or his designate), in each firm, was asked to think back over the last several years and then tell us what he thought was the most significant change, in either product or process, that had occurred within the firm. The principals who were involved in introducing the change were then interviewed at length to learn as much as possible about the circumstances surrounding the introduction of the new technology.

Now this approach necessarily introduces a bias in the data, which the reader should bear in mind when evaluating the results. The bias is toward those changes in product or process, which are viewed by the management of the firm as being relatively significant. It is entirely possible that there are many minor changes, involving the introduction of new technology, and if these were studied it might be found that sources which appear to be high contributors in the present study might be poor contributors of this less significant technology, while those appearing here to be low contributors might be very important in introducing minor changes to the firm. There is no way of knowing from the present data

whether this possibility has any basis in fact. However, it must be said that the major proportion of the technological change uncovered in the present study was far from being overly sophisticated or path-breaking in any sense. True, there are a couple of instances of truly innovative action, but most of the changes are of the minor "bread and butter" sort that may keep a firm competitive but will hardly upset an industry.

Interviews with the principals were designed with two main goals in mind. The sources which first brought the new idea to the attention of the firm were sought first. These first sources are extremely critical in the case of the smaller, less technically-oriented firms. Just becoming aware of the possibility of improvement and the means to bring it about is often the most important step in technology transfer. So the question of making the firm aware of the potential for new technology is an extremely important one. Once it became clear just how all of the information was obtained concerning the new technology and its potential, and the decision was made to introduce it to the firm, then further data were sought regarding any problems that might have been encountered in the course of its introduction. Seldom does any form of change occur without problems of some sort. The interview sought to determine what these were and how they were solved. Naturally, what we were looking for was any form of aid from sources external to the firm. Such "technical problem solving" is an extremely important service, which might be provided by outside agencies of many sorts ranging from equipment suppliers to private consultants. These may or may not be the same agencies responsible for the original idea, and they certainly play an important and somewhat independent role.

After learning as much as possible about each firm's "innovation", the interview went on to gather background data from the principals regarding their previous work experience, general use of information sources, and their degree of contact outside of the country.

The case histories compiled during the interviews were each analyzed to determine a number of things. Key among these were the sources of the original information about the innovation. In tracing information to its origin, the unit of analysis used is the "message". Each time a respondent indicated that he had learned something additional about the innovation, that instance was considered a "message" and its source was recorded. Previous research (Allen, 1977) has demonstrated very clearly the obvious fact that new ideas seldom appear full-blown from a single source of information. Bits and pieces of what eventually becomes a new idea arrive from a variety of sources. These are what we call "messages". The individuals, who introduce the new idea to the organization, integrate these messages and in that way make their own creative contribution to the process. What the analysis does is to disintegrate the idea and determine the sources of its component parts. Much of what follows, therefore, will be based on an analysis of the sources of the "messages" that brought information that helped in the solving of a particular problem which was encountered in introducing the idea or technique.

ILLUSTRATIVE CASES OF "INNOVATIONS"

The following examples are presented to illustrate the general nature of the new technology and the kinds of information source from which it was derived.

(i) Tumble Processing of Hams: This is a process in which a number of hams are tumbled together in a large rotating cylindrical container. Over the course of several hours, by a process that is not fully understood, protein migrates to the surface of the ham, thereby increasing the overall yield from a carcass by some three to four percent.

The production manager in one Irish bacon factory first became aware of this technique when he saw it being used in a Danish firm some 12 years before. He put it down at that time as being something of considerable interest but far too expensive for his scale of operations. Then, about two years prior to the interview, he learned that a British manufacturer was supplying the necessary equipment at a price that he could now afford. He learned of this through suppliers' representatives, who visit his plant occasionally. Once he expressed an interest, the supplier sent representatives to conduct a demonstration. The purchase was negotiated. Very few problems were encountered with the process, and these few were solved by the staff of the firm, with no need to seek outside help.

(ii) Ultra High Temperature Cream: The general manager of a large creamery was aware that long life milk, capable of resisting spoilage for relatively long periods without refrigeration, had been produced in Switzerland since about 1960. Since the export of cream from Ireland was a very attractive possibility, if some way could be found to prevent rapid spoilage, the possibility of producing a long life cream seemed attractive. In addition, it was felt that there would be a good market in Ireland, especially in the rural areas for long life cream and to the housewife it would be even more appealing than long life milk.

Further investigation revealed that the Swiss were using a steam injection process and had originally packaged their milk in cans, but

changed over to foil-lined paper "tetra pack" containers in 1964 as a result of the development in Sweden of an aseptic packaging process using this type of container.

At this stage, a delegation was sent to Switzerland to scrutinize ultrahigh temperature milk processing. The firm then brought in a technical man from the Irish Dairy Marketing Board, built a facility to house the experimental operation and obtained an ulra-high temperature milk processing plant and an aseptic tetra-pack packaging unit from Swedish suppliers. The problem now was to convert all of this to the production of ultra-high temperature cream. The Swedish suppliers were generally helpful in suggesting ways to adapt their plant to the higher viscosity encountered in cream. The actual details of the conversion had to be developed by a joint project team comprising representatives from the firm, the Dairy Marketing Board, the Agricultural Research Institute and a professor of agriculture engineering, from one of the universities.

(iii) A Tunable Modulation Meter: Electronic modulation meters have always presented the technician with an annoying problem. They require an almost endless process of balancing various adjustments before a reading can be made. In one Irish firm, this problem was enough to stimulate an engineer to action. He decided to develop a modulation meter that would be essentially self-tuning, and that it would perform the balancing process electronically over a broad frequency range. All of his development was conducted within his own firm. The stimulus was internal, and he never sought any assistance, other than provisions of standard components, from outside his firm. The firm provided him with the necessary time and resources to accomplish the development and were able to diversify into an entirely new product line as a result.

(iv) Canning of Mushrooms: The manager of an Irish cannery, while visiting London, happened to stay in the same hotel as a manager from the British subsidiary of a large American food distributor. During the course of their stay, the two met, engaged in a general conversation over the problems of the industry, and eventually came onto the topic of canning and marketing mushrooms. The man from the British firm reported back to his superiors that he knew of a firm that was potentially capable of meeting the firm's need for an additional supplier. Shortly after that, the British firm approached the Irish cannery on a formal basis with a proposal to buy a substantial quantity of canned mushrooms for marketing in the United Kingdom. This was contingent upon being able to scale up their output sufficiently, while maintaining quality standards. The cannery, as a result, made an investment in new machinery and undertook a one year development project. They were helped in this project by the British firm and by a domestic machinery broker who advised them on the type of machinery to use and who put them in touch with a Dutch cannery to discuss the general problems associated with this process. Some of the necessary machines were purchased from the Dutch firm. A British can manufacturer was also very helpful. Representatives of that firm visited the cannery, ostensibly to provide assistance with the process of seaming the cans; in fact, they were extremely valuable in passing along other information. From their experience in working with many canneries, they had acquired considerable knowledge of the entire process and were able to provide advice on the cooking, packing and wrapping operations, as well.

(v) Process Simplification: One chemical firm had formerly purchased herbicide acids in powder form from foreign suppliers. They

then were required to mix the powder with an appropriate solvent for the product was eventually employed in a liquid form. The only reason for purchasing the material in powder form had been ease of shipping. The acids are originally produced as liquid, and the manufacturer had to dry them into powder for shipping.

With the advent of liquid cargo containers that could be transferred directly from ship to truck-bed, it became apparent to the general manager of this firm that the drying stage could be dispensed with. He contacted shippers and suppliers and negotiated to have his supplies shipped in liquid form. This not only reduced his initial costs, it decreased inventory requiements, and allowed him to move his order date closer to the season in which farmers would need his product. This enabled him to make more accurate predictions of market requirements and reduced the probability that he would over-stock or under-stock the material.

(vi) Bottled Honey (from Hyman, 1980): The company responsible for this innovation had previously been a single product company, manufacturing a chocolate beverage. Market research, which they undertook as part of a diversification effort, led to a conclusion that there would be a potential in manufacturing bottled honey. Honey had previously been sold only in bulk form in Spain. Two of the employees of this company heard of an experienced French producer of honey at an international trade fair. They approached this individual and found him especially receptive to visitors and anxious to describe honey manufacture as an art form, even to potential competitors for the export market. He led them to some relevant literature which also provided them with important information on the processing of honey.

In their initial attempts, high sterilizing temperatures destroyed the first few batches. They then found ways of accomplishing the sterilization process using somewhat lower temperatures. Machinery to sterilize and filter the product, similar to that used by the French manufacturer, was found to be domestically available. They also found that quantity measurement could be performed with a widely available German machine. Another problem that arose was that of a foam that formed on the top of the honey after it was bottled. Some in-house experiments led to the conclusion that by centrifuging the substance, prior to bottling, most of the air could be removed from the honey. This prevented the formation of foam.

Another visit to a foreign competitor introduced them to vacuum-packed "twist-off-cap" technology. This time however the firm had to pay a royalty fee for the use of the technology.

(vii) Cosmetics Container (from Hyman 1980): The Spanish subsidiary of a British cosmetics company received a formula for a new form of cosmetic from its parent. Due to Spanish law prohibiting imports of finished plastic containers, unless they arrive already filled, the Spanish firm was forced to develop its own packaging using domestically available materials. The container had to meet certain strict specifications: it had to be impermeable, because of the volatility of the cosmetic material; it had to provide a minimum shelf life of two years; it had to be transparent to show the colors of the cosmetics and of course it had to be attractive, yet cheap enough, to appeal to the mass market in Spain. Since glass was far too expensive, they began experimenting with a variety of plastics. Domestic suppliers of plastics and molds, mainly subsidiaries of multi-nationals, worked in close cooperation with the company.

There were seven separate components in the package. Several different materials had to be used in forming these seven components. One of the problems that was encountered was that of bonding some of these different materials together. Local suppliers told the firm that an American company was making an adhesive that would accomplish the bonding but that this adhesive material was not locally available. Since the American company had a subsidiary in Spain, the firm signed an exclusive contract with the latter which in turn developed a suitable glue for them.

The finished product was successful not only in Spain but has now been adopted for use in other countries through the parent multi-national.

RESULTS

Data were obtained on 100 innovations. Each of the 100 case studies was analyzed to determine the source of the initial idea and the sources of information that were used in resolving the problems that were encountered in implementing the idea in the host firm.

IDEA SOURCES

Sources for initial ideas were many and varied. Less than 20 percent of the messages came from within the firm (Table III), indicating the degree to which these firms must rely on external sources of technology. Subsidiaries of multi-national companies are scarcely any better off than domestically-owned firms, in this regard (Table IV).

Considering information coming from outside the firm (Table V) several points should be made. First of all there is the usual discovery that nearly all of the information is obtained through direct personal

TABLE III

Sources of Initial Ideas for Innovations

	Number of messages	Proportion
Internal to the firm	46	17.4%
External to the firm	218	82.6%
Total	264	100.0%

TABLE IV

Internal Generation of Innovative Ideas by Foreign-owned and Irish Firms

Ownership of firm	Proportion of messages generated:		
	Internally	Externally	N
Domestic	15.7%	84.3%	204
Foreign	23.3%	76.7%	60

$X^2 = 1.88$; N.S.

TABLE V

Sources (external to firm) of Initial Ideas for Innovations

Source	Number of Messages	Proportion (%)
Supplier or vendor	62	28.9%
domestic	12	
foreign	51	
Firm in same industry	38	22.9
domestic	9	
foreign	41	
Firm in different industry	5	2.3
domestic	4	
foreign	1	
Parent firm	14	6.4
domestic	2	
foreign	12	
Customer firm	10	4.6
domestic	3	
foreign	7	
Private consultant	11	5.0
domestic	4	
foreign	7	
Government sponsored research institute	2	0.9
Other government department	5	2.3
University	5	2.3
Industry association	6	2.8
Trade fair	14	6.4
domestic	4	
foreign	10	
Trade journal	17	7.8
Publications other than trade journals	16	7.3
Total	218	99.9

contact. About 15 percent of the messages came in the form of documentation of some sort. More striking than this however, is the extent to which information comes directly from other firms, even competitors, and the degree to which this contact is international. Nearly 60 percent of the messages came from other firms. Most of these firms were outside the country of the innovating firm.

Once again technology is found to primarily flow through informal channels. Documentation plays a role secondary to that of direct personal contact. But the formal agencies established to introduce new technology into industry appear even less significant in their impact. All three of these countries had research institutes established to support industrial technology. It can be seen that very few of the ideas had their origins in any of these research institutes. In fact, even the universities produced more ideas for industrial use than the research institutes. Universities and research institutes together account for less than four percent of the new technology messages received by these 102 firms.

Far and away the single most important source of new technology for one of these firms is another company, usually a foreign one (Table VI). This holds true even when parent firms are taken as a separate category. Suppliers are naturally very important in introducing new technology, since much of that new technology is embodied in new production equipment. But even when suppliers are disregarded other firms remain as a major source of new technology (Table VII).

The most surprising result is that so many of the firms supplying new technology are apparent competitors. Nearly 23 percent of the

TABLE VI

Sources (external to firm) of Initial Ideas for Innovations

Source (%)	Number of Messages	Proportion
Domestic firms	28	12.8
Foreign firms	100	45.9
Parent firms	14	6.4
Universities and research institutes	7	3.2
Other	69	31.7
Total	218	100

messages were from firms in the same industry. It seems surprising that so much information would be so freely available from apparent competitors. Most of these apparent competitors however, are outside of the country, and there is evidence from the interviews that most of them did not consider themselves to be direct competitors. Remember that we are dealing for the most part with fairly small firms, that lack the highly developed distribution networks required for penetrating foreign markets.

TABLE VII

Suppliers and Other Firms as Sources of Technology

Source	Proportion of message (%)
Supplier firm	28.9
Other firm	36.2
Other	34.9

In a typical scenario, the manager from one of these firms might visit a trade show in another country, and be invited on plant visit by representatives of a foreign firm. While there he would encounter some new manufacturing technique, that he would later introduce into his own firm (Cf., The Tumble Processing Hams Case). In other cases managers approached apparently competing firms in other countries directly and were provided with surprisingly free access to their technology (Cf., The Bottled Honey Case).

FORIEGN OWNERSHIP

More than one quarter (27.5%) of the firms are subsidiaries of foreign firms. Judging from the data in Table VI, one might conclude that foreign parent firms were relatively insignificant sources of new technology for their subsidiaries. Looking only at the foreign owned firms however, the picture is somewhat different. In the case of foreign subsidiaries, 26 percent of the idea generating messages came from parent firms. This was a principal source of new technology for the foreign owned firms (Table VIII).

There are some other interesting differences between domestic and foreign firms. For example, domestic firms tend to obtain more of their technology from within their own industry (Table IX). Since most of the firms from which they obtain ideas are outside of the country, this is a source which is more available to domestic firms than to subsidiaries of multi-nationals. The foreign firms probably tended not to see the domestic firms as direct competitors. They presumably did see the multi-nationals in that way and were less willing to share ideas with them.

TABLE VIII

Sources (external to the firm) of Innovative Ideas as a Function of Ownership

Source	Proportion of Messages	
	Domestically-Owned firms	Foreign Subsidiaries
Supplier or vendor		
domestic	4.7%	8.7%
foreign	24.4	19.6
Firms in same industry		
domestic	3.5	6.5
foreign	21.5	8.7
Firm in different industry		
domestic	0	8.7
foreign	0	2.2
Parent firm		
domestic	1.2	--
foreign	--	26.1
Customer		
domestic	1.2	2.2
foreign	4.1	0
Private consultant		
domestic	2.3	0
foreign	3.5	2.2
Government sponsored research institute	1.2	0
Other government agency	2.3	2.2
University	1.7	4.4
Industry association	3.5	0
Trade fair		
domestic	2.3	0
foreign	5.8	0
Trade journal	9.3	2.2
Publications other than trade journals	7.6	6.5

TABLE IX

Technology from Foreign Firms in the Same Industry as a Function of Ownership
(Messages from external personal contact only)

Ownership of firm	Proportion of ideas
Domestic	26.1%
Foreign	9.5

$X^2 = 4.21$, $p < 0.05$

Table V illustrated very clearly the failure of the universities and research institutes as sources of new technology for industry. Table V is based on the entire sample, including both domestically-owned and foreign owned firms. When the two are separated some interesting differences appear. None of the foreign subsidiaries obtained ideas from trade fairs, research institutes or industry associations (Table VIII). These sources served only domestic firms. The universities however, were more useful to foreign firms than they were to domestic firms. Other government agencies served the two sectors about equally. The research institutes and industry associations are established primarily to serve domestic industry. The universities and possibly even some other government agencies do not see themselves constrained in this manner. The reason for the greater flow of ideas from universities to foreign firms, probably lies in the fact that these firms are more likely to have technically trained staff with whom the university researchers can more readily communicate.

INTER-INDUSTRY VARIATION

The eight industries differed in the extent to which they used different sources for new ideas. In some industries, firms were able to generate a reasonably high proportion of new ideas internally; in other industries firms made greater use of either domestic or foreign sources (Table X). The greatest variance is in the use of domestic sources of technology. Inter-industry variation of this sort should not be terribly surprising. The eight industries differ greatly in many respects, including their structure, technological development and degree of foreign ownership. One might expect patterns of technology

TABLE X

Location of Idea Sources by Industry*

Industry	Proportion of Messages from:		
	Within Firm	Domestic Contacts	Foreign Contacts
food processing	26.0%	30.1%	43.8%
building materials	30.0	10.0	60.0
electrical & electronics	40.0	24.0	36.0
men's and boys clothing	25.0	25.0	50.0
chemicals and parmaceuticals	22.7	22.7	54.6
machinery manufacture	16.7	50.0	33.3
cotton and linen textiles	20.0	30.0	50.0
paper	23.1	30.8	46.2

*excluding documentation

flow, to be dependent upon such industry characteristics. In more specific terms it can be hypothesized that:

1. Firms from industries with a more advanced degree of

technological development (e.g., electrical and electronics; chemicals and pharmaceuticals) will have a higher proportion, than other industries of internally generated ideas. This should result from the fact that even small firms in such industries normally have at least a few technically trained personnel on their staff. Such personnel should be more capable of developing feasible new product ideas or process modifications.

2. In less technologically developed industries, where the reliance is greater on idea sources outside of the firm, the location (domestic or foreign) of these sources will be determined by the degree of foreign ownership of firms in the industry. Where foreign ownership is high, there will be greater use of foreign technology sources, and vice versa.

As a corollary to this, it can be hypothesized that the foreign subsidiaries will, themselves, make greater use of foreign sources of technology.

Comparing the two high technology industries (electrical and electronics and chemicals and pharmaceuticals) with the others (Table XI), the evidence fails to support the first hypothesis. Firms in high technology industries are no more self-reliant in terms of new technology than are those in low technology industries. There is a slight tendency for a greater proportion of new ideas to have originated within the firm in high technology industries, but this tendency is far from significant statistically. Even in the high technology industries the smaller firms are forced to rely on outside technology for the overwhelming majority of their changes in either product or process.

Many of the firms in the sample are subsidiaries of foreign firms. As such, they might be expected to be more inclined toward

foreign sources of technology. In fact, there is little support in the data for this hypothesis at either the industry level (Table XII) or the firm level (Table XIII). Foreign subsidiaries actually used foreign sources of technology less than domestically-owned firms. So there is no support for the hypothesis that ownership influences the extent to which foreign sources of technology are used.

TABLE XI

Internally Generated Ideas as a Function of Level of Technology

Type of industry	Proportion of internally generated messages
High technology (electrical/electronics chemicals/pharmaceuticals)	21.4%
Other	16.1

$X^2 = 0.69$; N.S.

TABLE XII

Technology from Foreign Sources as a Function of Degree of Foreign Ownership in the Industry

Type of industry	Proportion of messages*
Low degree of foreign ownership	71.4
High degree of foreign ownership	69.0%

* Excluding those generated internally or obtained from documentation.
$X^2 = 0.01$; N.S.

TABLE XIII

Technology from Foreign Sources as a Function of Ownership

Ownership	Proportion of messages*
Domestic	71.1%
Foreign	64.3

*Excluding those generated internally or obtained from documentation.
$X^2 = 0.43$; N.S.

NATURE OF THE INNOVATION

Out of the 100 innovations, 42 were product innovations, while 58 were process innovations. This ratio of 1.4 to 1 in favor of process innovations contrasts with that found in the Myers and Marquis study of commercially successful innovations in U.S. industry. The prevalence of process innovations in the present study is probably due to the nature of the industries that were studied. The proportion of process innovations varies widely among industries, ranging from about 17 percent in electrical and electronics all the way to the cotton and linen textile industry, in which all of the innovations were of a process type (Table XIV). It is tempting at this point to speculate that this might be a result of ownership, with foreign firms being more inclined toward process improvements for existing products and domestic firms searching for new products. The data clearly do not support this possibility (Table XV). In fact the trend is slightly in the opposite direction, with a somewhat higher proportion of process innovations by domestic firms.

TABLE XIV

Proportion of Process Innovations by Industry

Industry	Proportion
food processing	58.5%
building materials	83.3
electrical & electronics	20.0
men's and boys clothing	66.7
chemicals and pharmaceuticals	73.3
machinery manufacture	50.0
cotton and linen textiles	100.0
paper	50.0

$X^2 = 14.13$; $p = 0.05$

TABLE XV

Proportion of Process Innovation by Domestic and Foreign Firms

Ownership	Proportion of Process Innovations
Domestic	60.8%
Foreign	50.0

$X^2 = 0.53$; N.S.

An alternate explanation stems from the work of Abernathy and Utterback (1977). All of the industries with the exception of the two high technology industries are relatively mature. Most of the firms in the sample are in what Abernathy and Utterback call "specific" stage of development. The product has become standardized, production volume is relatively high and cost has emerged as a primary basis of competition. Abernathy and Utterback argue that, for fairly obvious reasons, process innovation will dominate in this stage. This is the situation in which most of the firms were found in all industries, with the possible exception of the electrical and electronics industry. This is the only industry in which product innovations formed the majority. The electrical and electronics industry is much closer in most cases to what Abernatny and Utterback call the "fluid" stage of development. Here product design is subject to radical change, product characteristics are in flux and the emphasis in product innovation is on functional performance, rather than cost.

The net result of all of this, is simply that the high incidence of process innovation in the sample should not be surprising. At least according to the Abernathy and Utterback theory, this was determined by the nature of the industries surveyed.

Product and process ideas tend to originate from different sources. Product ideas are more likely to be stimulated by domestic sources. Process innovations rely more heavily on foreign technology (Table XVI).

Consultants were more helpful in initiating product innovations (Table XVII). Foreign vendors were, as to be expected, of greater

TABLE XVI

Technology From Foreign and Domestic Sources as a Function of the Nature of the Innovation

Type of innovation	Proportion of messages from:	
	domestic sources	foreign sources
product	38.6%	61.4%
process	25.4	74.6

$X^2 = 2.93$
$p = 0.09$

TABLE XVII

Technology From Consultants as a Function of the Type of Innovation

Type of innovation	Proportion of messages
prooduct	11.4%
process	2.6

$X^2 = 4.51$; $p < 0.05$

value in initiating process innovations (Table XVIII). This results, primarily, from the sale of manufacturing equipment. What is more surprising than the degree to which foreign vendors influence process innovation is the fact that they were involved in so many product innovations. This resulted in many cases from new manufacturing machinery enabling product improvements. But it also resulted, in at least a few cases, from foreign vendors passing along information on industry developments, which in turn stimulated new or modified product designs.

TABLE XVIII

Technology From Foreign Vendors as a Function of Type of Innovation

Type of innovation	Proportion of messages
product	17.1%
process	33.3

$X^2 = 5.32$; $p = 0.02$

Differences Among the Three Countries

The major difference among the three countries is the type of innovation, which firms reported (Table XIX). Irish firms tended to report a higher proportion of process innovations, than were found in either Spain or Mexico. This is not due to the differences in the industries which were studied in the three countries. Sixty-four percent of the Irish cases were from the four most product-oriented

industries (only 57 percent of the Spanish and Mexican cases came from these industries). Nor is it due to differences in degree of

TABLE XIX

Type of Innovation as a Function of Country

Country	Proportion of:	
	Product Innovation	Process Innovation
Ireland	31.5%	68.5%
Spain	69.6	30.4
Mexico	75.0	25.0

Chi - squared computed for Ireland vs. Spain and Mexico combined in order to gain sufficiently high expected frequencies:
$X^2 = 12.22$; $p < 0.01$

foreign ownership. Approximately 27 percent of the Irish firms were foreign-owned; 29 percent of the Spanish and Mexican firms were foreign subsidiaries. Other factors must be at work. One significant difference, in this study, is in the identity of the interviewers. Different interviewers gathered data in the three countries. Perhaps, through some unconscious bias, the interviewer in Ireland inclined respondents toward process innovations, while those interviewing in Spain and Mexico, again unconsciously, biased respondents toward product innovations. The authors certainly hope that this is not true. But it must remain an open possibility until further investigation. What is clear, is that whatever inclines Irish managers to report a higher incidence of process innovation should be investigated further.

There is a greater tendency for Irish firms to rely on foreign sources of technology (Table XX). Moreover, this difference does not disappear, when the data are controlled for type of innovation (Table XXI). Irish firms rely more heavily on foreign sources for both

TABLE XX

Technology From Foreign and Domestic Sources by Country

Country	Proportion of messages from:	
	Domestic Sources	Foreign Sources
Ireland	25.8%	74.2%
Spain	39.2	60.8
Mexico	60.0	40.0

$X^2 = 5.23$; $p = 0.07$

TABLE XXI

Technology From Foreign Sources by Country
Controlling for Type of Innovation

Country	Proportion of messages from Foreign sources for:	
	Product Innovations	Process Innovations
Ireland	71.0%	75.3%
Spain	53.8	70.6
Mexico	29.0	24.7

product and process innovations. There are at least two possible explanations for this. Either the necessary technologies are not as well developed in Ireland as in Spain and Mexico, or the Irish have been able to develop stronger international contacts, enabling them to make more effective use of foreign technology. History and geography would favor the latter explanation. While all three countries are situated near more technologically developed neighbors, Ireland's small size, coupled with geographic propinquity, probably makes it easier to travel to more developed neighbors. In addition, Ireland's long history of emigration equips it with a strong cadre of overseas "ambassadors" in countries with strong technological bases.

Of course, none of this can be proven or disproven with the present data. The question remains an interesting one for further investigation.

THE PROBLEM SOLVING PHASE

After a firm decides to go ahead with a new product or process, it normally encounters a series of problems which must be solved before implementation is successfully completed. While many of these problems can be solved by the staff of the firm, aid is often sought from the outside. More than two thirds of all the problem solving messages originated outside of the firm (Table XXII). The most important category outside of the firm is, not surprisingly, the supplier or vendor. The manufacturer of production equipment is normally bound under warranty agreement to solve any problems which arise with the use of his equipment. Private consultants are also engaged frequently at this stage. However, there is still precious

TABLE XXII

Sources Used in Solving Problems Associated with the Introduction of the Innovation

Source		Number of Messages	
Internal to the firm		54	31.6
Parent firm		16	6.4
domestic	0		
foreign	10		
Firm in same industry		14	8.2
domestic	2		
foreign	12		
Firm in different industry		2	1.2
domestic	2		
foreign	0		
Supplier or vendor		50	29.3
domestic	15		
foreign	35		
Customer		2	1.2
domestic	2		
foreign	0		
Private consultant		15	8.7
domestic	11		
foreign	4		
Government sponsored research institute		2	1.2
Other government agency		2	1.2
University		6	3.5
Trade fairs		1	0.6
domestic	0		
foreign	1		
Trade journals		7	4.1
Other publications		5	2.9
Total		170	100.1

little resort to the research institutes and nearly as little to the universities.

The importance of foreign sources diminishes in the problem solving phase. The difference is taken up primarily by internal effort within the firm (Table XXIII). This is the point at which the research institutes might be especially helpful, if a means could be devised to encourage firms to approach them when they encounter problems in implementing new technology. Of particular interest, at this point, is the extent to which the research institutes are bypassed in favor of private consultants. Granted that in some instances the consultants were paid for by government grants, the fact remains that the research institutes should be able to fare somewhat better than they do in this competition.

TABLE XXIII

Location of Idea Generating and Problem Solving Information Sources

Source of technology	Proportion of instances used in:	
	Idea generation	Problem solving
within the firm	17.4%	31.8%
domestic outside the firm	21.2	24.7
foreign	48.9	36.5
documentary	12.5	7.1

$X^2 = 16.35$; $p = 0.001$

DEVELOPMENT OF FOREIGN CONTACTS

The principals who were interviewed were generally well acquainted outside of their country. A substantial proportion had actually worked outside of the country for some part of their career. The typical manager, in this study, is an ardent traveller. This can be seen quite clearly in the brief case studies presented at the beginning of this report. Travel is often stimulated by the need for information. A problem develops and the manager travels to visit other firms, to either find out how they dealt with similar problems, or to engage their assistance, as suppliers, in providing part of the solution. Another stimulus for travel is provided by trade fairs. Managers in smaller firms rely very heavily on trade fairs to provide them with information on developments in the technologies, which are important to them. Informal contact often develops among managers from different firms as a result of trade fair visits. These contacts often persist long after the trade show has ended and result in plant visits or in the seeking of help or information when problems are later encountered.

DISCUSSION AND RECOMMENDATIONS

If we take each of the results, in turn, there are a number of lessons that may be gleaned from these data. First of all, the importance, once again, of personal contact, in transferring technology. Informal networks have developed in many industries, for the express purpose of disseminating technological information. The textile industry is a case in point. Managers of textile firms seem to be a migratory breed. Several, who were interviewed, had

previously worked in a large number of other countries. Such movement of key people leads to the development of informal networks among themselves and the people with whom they become associated in different parts of the world. This has resulted in a very extensive technology diffusion network within textiles, which is, of itself, worthy of much further study. There is evidence for similar networks having developed to a lesser degree in other industries.

COMPARISON WITH OTHER COUNTRIES

Unfortunately, there are very few studies that have looked at the problem of the small firm in acquiring technology. There has been an increased interest in this problem in recent years, however, Ghiraroi, et al., (1976) adopted the research method pioneered in the present study to examine the problem in a sample of firms in Sao Paulo State, Brazil. Maguire and Kench (1975), using a somewhat different approach, produced similar results in Austrialia. The results of these studies are compared with those of the present study in Table XXIV.

There are several points of convergence in the three studies that should be noted. First of all, the major source of new technology, for firms in four of the five countries, is direct contact with other industrial firms. In the Australian case, there was no distinction reported between domestic and foreign firms as sources of technology. It is probably safe to assume that, as a result of geography, the majority of these firms were domestic. In the Brazilian case, there is a nearly equal division between domestic and foreign firms. In the Irish case, assuming that the goal is to import foreign technology,

TABLE XXIV

Principal Sources of Technology as Determined by Studies in Five Countries

Source	Ireland (N=140)	Spain (N=29)	Mexico (N=9)	Brazil (N=69)	Australia (N=)
contact with domestic firms	11.4%	13.8%	11.1%	17.6%	91.7%
contact with foreign firms	47.9	34.5	22.2	14.7	
government-sponsored research institutes	14.	0	0	2.9	2.9
trade fairs	6.4	17.2	0	2.9	
publications	9.3	27.6	44.4	8.8	2.9
other	23.6	6.9	22.2	52.9	2.5

Brazilian data from Ghirardi, et al., (1976)
Austrialian data from Maguire and Kench (1975)

geography appears to have produced favorable results. Foreign contacts outweigh domestic ones by a four to one margin. In Spain and Mexico, the ratio is nearly as high.

Another point of convergence is in the evaluation of research institutes. All five countries support such institutes. Brazil, in fact, supports a total of 170 such laboratories. None of these show anything approaching a significant impact in any of the five countries.

Finally, there is the role of documentation. In all but the

Mexican case, it plays a relatively minor role. Once again we find that technology is seldom transferred by the printed word. Hopefully, some day the documentalists will hear this message, and governments will realize that the support of document storage and dissemination systems will not, by itself, solve the problems of technological development.

PERSONAL CONTACT AND INVESTMENT IN DOCUMENTATION SYSTEMS

The overwhelming dominance of personal contact in technology transfer has been replicated in study after study, yet it is consistently ignored by policy-makers (Cf., Cooney & Allen, 1975). If one's goal is to introduce new technology into industry then it should be obvious by now that documentation retrieval and reprint services will not go very far in accomplishing that goal. More than that, they are not only ineffective but since they diver scarce resources from more worthwhile programmes, their net contribution is often negative.

The obvious reason for the concentration of effort in documentation services is that they are relatively easy to implement. Promoting effective personal contact is not quite so easy. Nevertheless, there can be no excuse for pursuing ineffective programmes, only because the alternative is difficult. We must develop policy that effectively utilizes the one proben approach to transferring technology.

THE ROLE OF THE RESEARCH INSTITUTE

The next question that arises, is concerned with the sources of technology or the direction of technology transfer. At the present time, we observe certain sources of technology which are utilized and

other potential sources which are not used at all. This differential usage could be the result of either the perceived value of the sources or of the ease with which information can be obtained from them. Allen and Gerstberger's (1973) research would indicate that it is more likely the latter than the former. One should then not be led to the conclusion that the technology sources being used are the only ones of any value. There may be forces inhibiting the use of even more effective sources.

The research institutes are a case in point. They were established to develop technology that would contribute to the economic development of the country. Judging from the data, they are of little value to industry as sources of new technology. Several of the managers who were interviewed, without knowing entirely the purpose of the study, volunteered their opinion of the research institutes. These were unamimously negative in their appraisal. The comments, furthermore, dealt both with substance of institute activities, which were deemed of low quality and irrelevant to industry needs, and to the inaccessibility of even this irrelevant information. The general belief among this group of managers is that research institutes have no concept of what the small businessman needs in terms of technology and that they have no mechanisms for properly assessing these needs.

In at least one instance, a research intitute was called in for assistance, but in the words of the manager, who was interviewed, "They just threw up their hands and said that they didn't understand the problem. They are too far removed from industrial activity. They just don't understand." The manager eventually went to a foreign firm for assistance and was given advice that got him out of the difficulty.

This may be an isolated case, and it would be wrong to generalize much from it alone. But the number of unsolicited criticisms of research institutes were sufficient to lead one to believe that there must be some serious difficulty in their relations with industry.

There are two general classes of research institute that were encountered in the study. One type is given a broad charter to serve small industry generally, while the other type is intended to focus on a particular industry or class of industries.

The task of the first type of institute is an extremely difficult one. Theoretically it is asked to cover the entire range of technologies that might be relevant to small industry in the country. In practice, these institutes generally develop greater expertise in certain areas than in others, so that a focus develops either though negotiation with government planning and funding agencies or more frequently out of the interests and goals of the institute's management.

At any rate, the general purpose research institute is seldom that general. In actual fact, a focus or set of foci develops, usually in an informal, unplanned fashion. This certainly helps to solve what would otherwise be an impossible problem, but the solution may not be what is actually needed by the country, and often has resulted without the participation of those agencies responsible for economic planning and development.

But what about a more narrowly focused organization? The present data do not show its performance in technology transfer to be very high, either. That is true. But there is certainly some chance for improving this performance, so long as efforts are focused on the relevant sector. There is for example, evidence that communication

between such institutes and R&D performing firms, in their target industries, is very good.

What happens is the following. The research institute hires staff in the technologies most relevant to the industry or sector, which it serves. These staff then discover that they have similarly-minded colleagues in a few of the larger firms of the industry. It is therefore those firms, which themselves do R&D, that attract greater interaction from the research institutes. Once again, "the rich get richer and the poor get poorer." It is far easier for the technical staff of the research institute to interact with and work on problems with the more highly trained R&D staff of the larger firms. This is certainly easier and more attractive in many ways, than digging out problems from people in smaller more backward firms, who oftentimes don't even understand that they have a problem. It is for this reason that so many research intitutes appear to have been "captured" by the larger, more technically capable firms, who really have less need for their services. There is a very high cultural barrier deterring interaction between institute staff and those smaller firms with less technical capability, whom they are really supposed to serve.

This barrier operates in both directions. Not only do institute staff members find it easier to interact with the technically trained staff of the larger firms, but the staff of those firms find it easier to approach the research institute with problems, as well. The smaller firms with few, if any, technically trained personnel have great difficulty understanding the work of a research institute, and have an understandable reluctance to even attempt to communicate with such an institution. There is a perceived barrier that prevents firms,

particularly small backward firms, from using this potential source of technology. In the words of one of the respondents, "Why don't I go to the (research institute) with my problems? Well, I'm just an uneducated man trying to run a little business. Those professors wouldn't be interested in the kind of problems that I have." In this man's perception, the research institute staff were academically oriented and only interested in the kind of problems, which would enhance their image in the eyes of academic colleagues. Whether this were true or not (and unfortunately it might have been), it is the perception which will determine the man's behavior, and this perception certainly deterred him from using the resources of the research institute.

How can these barriers be reduced? One way would consist of having teams of R&D personnel visit a sample of firms periodically, preferably just prior to the institute's project review and budgeting time. This team would be knowledgable in the technologies, underlying the firms' activities and would seek out problems and areas which might be improved by systematic research or development effort. A case in point: at the time of the first interviews, no one really understood why the process of tumbling hams together for a period of time results in protein migration and increased yield. This appears to be a reasonably fundamental research problem with very definite practical benefits. There are no doubt a very large number of such problems, begging to be undertaken. A research institute must actively seek out such problems. A first step would be the suggested formation of technically competent teams of individuals from potentially relevant disciplines to go on site inspections of firms in specified

industries. The team's goal would be not to help individual firms per se, but rather to search out general problem areas where the applications of their research might benefit an industry. The experience of cataloguing areas for potential improvement of either production processes or products will prove invaluable in directing and selecting research projects later on. That is why it is strongly suggested that such tours be tied to the project selection and budgeting cycle. An additional benefit could result from the development of informal contacts, which would aid in reducing the cultural barriers between small firms and research institutes.

THE PELLUCIO PLAN

Another possible incentive to interaction between industry and both universities and government research institutes would be to funnel at least part of the government's funding of the universities and research intitutes through industry. This concept has been proposed by Jose Pellucio, former Director of Financiadora de Estudios e Projetos, the agency responsible for funding most of the Brazilian institutes. Industrial firms would be provided budgets, or vouchers, that can only be spent to support research in a research institute or university. The firm itself, however, has complete authority within these limits over selection of both project and source, and may even choose not to spend the money, at all. Such a scheme would motivate industry to be more directly concerned with the activities of the institute or university department. Most research institutes have boards or steering committees to oversee their activities now. Such boards are often little more than "rubber stamp" affairs. The members have

neither the time nor the inclination to delve very deeply into an institute's activities. If they were spending money (even someone else's money) in an institute, they would be much more careful in monitoring the activities of that institute, and in seeing how the money was spent.

For their part, institute personnel will quickly seek out customer interests once the fact becomes clear that the customer has money to spend on research. Researchers are eminently capable of discovering a customer's needs once it becomes clear that the customer has money to spend. That is not to say that they will completely re-orient their work. They will adapt, and try to convince the customer that his needs will be met, if they pursue their interests. The customer can allow himself to be convinced or seek his help elsewhere. Through this negotiation process, both user needs and supplier capabilities become more fully explicated and understood by both sides. The work of the institute cannot help but become more relevant and more widely used by industry.

Creation of a properly structured reward system can motivate interaction with industry even by university faculty. At MIT firms pay an annual fee to belong to what is known as an Industrial Liaison Program. To stimulate faculty cooperation, ten percent of the income from this program is placed in a pool for distribution to participating faculty, in the form of relatively unrestricted budgets. Points are awarded for different forms of cooperation, and at the end of each year, these points are assigned monetary value. Budget is then allocated to faculty on the basis of the number of points accumulated. This system has been so successful that additional firms have had to be

recruited to increase the amount of the ten percent pool to prevent the point from being devalued as faculty cooperation sharply increased.

A program of this sort can serve as a two-way stimulus. It not only provides an incentive for faculty to see that the results of their work reach potential users; it opens a channel through which the university researcher can be influenced in his selection of research problems. This is not to say that he sacrifices any of his freedom in this regard. Rather, he is now provided with more information, and should be able to make a better decision, whether it is in accord with industry's current desires, or not.

FOREIGN OWNERSHIP

Since so many of the firms in the study are subsidiaries of foreign firms, it is interesting to note the different patterns that have developed for foreign and domestically owned firms. Foreign firms are overwhelmingly the captive of their parent. Parent firms are heavy providers of technology. That this technology is biased in terms of the overall corporate plan is a foregone conclusion. While this is not necessarily bad, it can stifle creativity in the subsidiary, and prove extremely frustrating to the more inventive or entrepreneurial managers in the subsidiary. There is among the cases, at least one local project, which was strongly discouraged by a foreign parent firm. There were also some stories volunteered of "very promising" projects which had been quashed, because they did not fit well in the overall business plan of the multinational. This can be extremely frustrating for local managers and can stifle projects of potential value to the country.

Nevertheless, there is no denying the evidence that parent firms serve as a rich source of technology for their subsidiaries, and may have a generally positive effect on domestic technological development. Furthermore, since there is some turnover of personnel between firms, there is a potential for transfer beyond the subsidiary, and some evidence that this is indeed happening. In Ireland, a current study (Onyenadum, in preparation) indicates that a substantial amount of technology has been transferred to domestic industry by people who worked for just one of the multinational firms with subsidiaries in that country, and who subsequently moved into domestic industry.

DOMESTIC TECHNOLOGY

In the technologically more advanced industries (chemicals, electronics, etc.) we find a significantly higher proportion of internally generated ideas. There is also a slight, but non-signficant, tendency for firms in these industries to be less reliant on foreign technology. There is no evidence that the firms in these industries are being aided at all by the technological infra-structure of the country. They are not helped by the research institutes and universities any more than firms in other industries. One might suspect that, since these firms have developed, on their own, a slightly higher degree of technological sophistication, that they might find some basis for greater interaction with the research institutes and universities. The data indicate very clearly, that this has not happened. This is equally true for both domestic and foreign-owned firms.

All three countries have, oevelopeo a reasonably sound technological base in their universities ano research institutes. Unfortunately this system operates largely indepenoent of the inoustries which it could potentially support. This is a situation that is certainly not unique to these three countries. Most small countries have attempted to aio the technological oevelopment of their inoustry through support of research universities ano research institutes. What evidence there is, on the effectiveness of these measures would indicate that this strategy has generally failed. The universities ano research institutes may develop a very high oegree of technological competence, but this is seloom successfully utilizeo by inoustry. Drastic measures are calleo for, to stimulate such utilization. Unless the situation can be raoically improveo, there can be no justification for government support of such a system.

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