How Rapidly Does New Industrial Technology Leak Out?

Edwin Mansfield

The Journal of Industrial Economics, Vol. 34, No. 2 (Dec., 1985), 217-223.

Stable URL:
http://links.jstor.org/sici?sici=0022-1821%28198512%2934%3A2%3C217%3AHRDNIT%3E2.0.CO%3B2-3

The Journal of Industrial Economics is currently published by Blackwell Publishing.

THE JOURNAL OF INDUSTRIAL ECONOMICS 0022–1821 $2.00
Volume XXXIV December 1985 No. 2

HOW RAPIDLY DOES NEW INDUSTRIAL TECHNOLOGY LEAK OUT?*

EDWIN MANSFIELD

There have been no systematic empirical studies of the speed at which various kinds of technological information leak out to rival firms. To help fill this gap, data were obtained from 100 American firms. According to the results, information concerning development decisions is generally in the hands of rivals within about 12 to 18 months, on the average, and information concerning the detailed nature and operation of a new product or process generally leaks out within about a year. These results have important implications both for incentives for innovation and for public policies aimed at stemming the outflow of technology.

I. INTRODUCTION

TO UNDERSTAND the process of industrial innovation and how rapidly innovations are imitated, it is obvious that economists should study the nature and extent of the information that firms have about their rivals' technology and R & D programs. Yet there have been no systematic empirical studies of the speed at which various kinds of technological information leak out to rival firms. In this paper, I summarize briefly the results of an investigation of this sort based on data obtained from 100 American firms. These results are some of the first that are available concerning this important topic.

II. LEAKAGE OF INFORMATION CONCERNING DEVELOPMENT DECISIONS

How quickly is a firm's decision to develop a major new product or process known to its rivals? To obtain information on this score, a random sample of 100 firms was chosen from a list of firms in thirteen major manufacturing industries (chemicals, pharmaceuticals, petroleum, primary metals, electrical equipment, machinery, transportation equipment, instruments, stone, clay, and glass, fabricated metal products, food, rubber, and paper).[1] Each firm's chief executive officer was asked to provide an estimate of the average length

*The research on which this paper is based was supported by a grant from the National Science Foundation, which, of course, is not responsible for the views expressed here. I am indebted to the very large number of firms that provided the basic data without which this study could not have been carried out. Also, thanks go to Lawrence J. White of New York University for useful suggestions in revising the manuscript.

[1] This sample was chosen at random from a list of all firms in these industries spending over $1 million (or 1 percent of sales, if sales were at least $35 million) on R & D in 1981.

TABLE I

PERCENTAGE DISTRIBUTION OF FIRMS, BY AVERAGE NUMBER OF MONTHS BEFORE THE FIRM'S DECISION TO DEVELOP A MAJOR NEW PRODUCT OR PROCESS IS REPORTED TO BE KNOWN TO ITS RIVALS, 10 INDUSTRIES, UNITED STATES

Industry	*Products (Average Number of Months)*					*Processes (Average Number of Months)*				
	Less than 6	*6 to 12*	*12 to 18*	*18 and more*	*Total*[a]	*Less than 6*	*6 to 12*	*12 to 18*	*18 and more*	*Total*[a]
	(Percentage of Firms)									
Chemicals	10	20	40	30	100	0	11	11	78	100
Pharmaceuticals	29	14	14	43	100	0	0	33	67	100
Petroleum	0	44	44	11	100	10	40	10	40	100
Primary Metals	40	20	20	20	100	20	60	20	0	100
Electrical Equipment	22	33	33	11	100	0	43	0	57	100
Machinery	0	43	21	36	100	0	25	25	50	100
Transportation Equipment	25	25	25	25	100	0	33	33	33	100
Instruments	18	27	36	18	100	20	20	20	40	100
Stone, Clay, and Glass	20	0	20	60	100	0	0	20	80	100
Other[b]	33	17	25	25	100	20	30	20	30	100
Average	20	24	28	28		7	26	19	48	

Source: see section II.

[a] Because of rounding errors, figures sometimes do not sum to total.

[b] Fabricated products, food, rubber, and paper are included in the "other" category.

of time before such information is in the hands of at least some of its rivals. Of course, it is not easy to pinpoint exactly when the decision is made to develop a product or process, because for each product or process there generally is a series of such decisions, not one. Thus, we asked each firm to base its estimate on the first such decision it made concerning a particular product or process. For obvious reasons, this should result in a conservative estimate of the speed at which such information leaks out.

According to the firms in our sample, information concerning development decisions of this sort is generally in the hands of at least some of their rivals within about 12 to 18 months, on the average, after the decision is made (Table I).[2] For about one-fifth of the firms, information leaks out within 6 months, on the average, in the case of new product development. (In chemicals and glass, leakage of this sort occurs somewhat more slowly than in other industries.) Although firms ordinarily cannot tell precisely when such information is in the hands of their rivals, the firms in our sample seemed to feel that the averages they presented were accurate enough for present purposes. Nonetheless, it is obvious that the data in Table I (as well as Table II) are rough approximations.

Because new processes can be developed with less communication and interaction with other firms than can new products, process development decisions tend to leak out more slowly than product development decisions in practically all industries.[3] However, the difference, on the average (measured by the median), is less than 6 months. Thus, for both processes and products, the odds are better than 50-50 that a development decision will leak out in less than 18 months. If it takes about three years or more before a major new product or process is developed and commercialized (which is fairly typical in many industries), this means that there is a better-than-even chance that the decision will leak out before the innovation project is half completed.

III. LEAKAGE OF INFORMATION CONCERNING A NEW PRODUCT OR PROCESS

Although rival firms are interested in a firm's development decisions, they generally are even more interested in the detailed nature and operation of the new product or process developed by the firm. That is, they would like to know how it functions and is made. According to the firms in our sample, this information is in the hands of at least some of their rivals within about a year,

[2] Although there are 13 industries, four (fabricated metal products, food, rubber, and paper) are lumped together as "other" in Table I because the sample contains relatively few firms in each of these industries. There was little or no problem of nonresponse. Only one firm provided no information. Besides the firms in the sample, other firms were contacted to obtain related types of information and to test the questionnaire. Practically all of the data were obtained through mail questionnaires and correspondence.

[3] For further discussion of the differences between products and processes in the ease of imitation, see Mansfield, Rapoport, Romeo, Villani, Wagner, and Husic [1977].

TABLE II

PERCENTAGE DISTRIBUTION OF FIRMS, BY AVERAGE NUMBER OF MONTHS (AFTER DEVELOPMENT) BEFORE THE NATURE AND OPERATION OF A NEW PRODUCT OR PROCESS ARE REPORTED TO BE KNOWN TO THE FIRM'S RIVALS, 10 INDUSTRIES, UNITED STATES.

Industry	*Products* (*Average Number of Months*)					*Processes* (*Average Number of Months*)				
	Less than 6	*6 to 12*	*12 to 18*	*18 and more*	*Total*[a]	*Less than 6*	*6 to 12*	*12 to 18*	*18 and more*	*Total*[a]
	(Percentage of Firms)									
Chemicals	18	36	9	36	100	0	0	10	90	100
Pharmaceuticals	57	14	29	0	100	0	33	0	67	100
Petroleum	22	33	22	22	100	10	50	10	30	100
Primary Metals	40	20	0	40	100	40	40	0	20	100
Electrical Equipment	38	50	12	0	100	14	14	57	14	100
Machinery	31	31	31	8	100	10	20	30	40	100
Transportation Equipment	25	50	0	25	100	0	67	0	33	100
Instruments	50	38	12	0	100	33	33	33	0	100
Stone, Clay, and Glass	40	60	0	0	100	0	20	20	60	100
Other[b]	31	15	15	38	100	27	0	36	36	100
Average	35	35	13	17		13	28	20	39	

Source: see section II.

[a] See note a, Table 1.

[b] See note b, Table 1.

on the average, after a new product is developed (Table II).[4] Indeed, for over one-third of the firms, it is in their hands within 6 months. For processes, this information leaks out more slowly, for reasons cited above. But even in this case, it generally leaks out in less than about 15 months. The major exception is chemical processes which frequently can be kept secret for a number of years.

There are many channels through which this information spreads. In some industries there is considerable movement of personnel from one firm to another, and there are informal communications networks among engineers and scientists working at various firms, as well as professional meetings at which information is exchanged. In other industries, input suppliers and customers are important channels (since they pass on a great deal of relevant information), patent applications are scrutinized very carefully, and reverse engineering is carried out. In still other industries, the diffusion process is accelerated by the fact that firms do not go to great lengths to keep such information secret, partly because they believe that it would be futile in any event. Thus, the intelligence-gathering process varies considerably from industry to industry (and from case to case).[5] In view of this diversity, it is remarkable that, with the exception of processes in a few industries like chemicals, there seems to be so little difference among industries in the rate of diffusion of such information. In practically all industries in Table II, the median time lag for products is between 6 and 12 months, and the median for processes (other than chemicals and drugs) is 6 to 18 months.

Of course, the fact that information of this sort leaks out relatively quickly does not mean that imitation will occur equally fast. It often takes considerable time to invent around patents (if they exist), to develop prototypes, to alter or build plant and equipment, and to engage in the manufacturing and marketing start-up activities required to introduce an imitative product or process. (The factors determining the cost and length of time taken by these activities are taken up in Mansfield, Schwartz, and Wagner [1981].) Nonetheless, the basic information concerning the nature and operation of the innovation, even if it is not sufficient in many cases to permit the immediate introduction of an imitative product or process, is of great importance to the innovator's rivals. And if it is true (as Table II indicates) that information of this sort is very likely to find its way into the hands of rivals within a year or two, this has obvious and important implications for both the incentives for innovation and for public policies aimed at stemming the outflow of technology to other countries.

[4] As in the case of Table I, the data in Table II should be viewed as rough approximations. See section II.

[5] For some relevant discussion concerning the electronics industry, see Rogers [1982]. Based on interviews I carried out with a sample of European and Canadian firms, there is a widespread feeling that information of this sort spreads more rapidly in the United States than in Europe, but the evidence is fragmentary.

IV. IMPLICATIONS AND CONCLUSIONS

Specifically, the above findings seem to have at least three major implications. First, they help to explain why industrial innovations so often are imitated relatively soon after first introduction. Mansfield, Schwartz, and Wagner [1981] found that about 60 percent of the patented innovations in their sample were imitated within four years. Given that development decisions and new technology leak out so quickly (and that it is so often possible to invent around patents), it is easy to understand why this was the case. Moreover, these results provide new insight into the problems involved in providing proper incentives for innovation in a free-enterprise economy. The fact that information concerning new industrial technology spreads so rapidly helps to explain why many firms have great difficulty in appropriating much of the social benefits from their innovations.[6]

Second, the results suggest that differences in the rate of diffusion of technological information do not play a major role in explaining inter-industry differences in the ease with which innovations can be imitated. The interindustry differences in Table II seem too small to be of major importance in this regard.[7] In a previous paper,[8] we estimated the average cost of imitation in a variety of industries, studied the determinants of this cost, and showed that this cost was directly related to an industry's concentration level. Although one might suppose that there are considerable differences in the rate of diffusion of technological information, and that these differences are responsible for substantial differences in imitation costs (and thus for differences in concentration levels), this does not seem to be the case.

Third, turning to issues of public policy, the results help to indicate the magnitude of the difficulties faced by recent (and not so recent) attempts by the US government to prevent the outflow to other countries of new American technology. As is well known, the United States has tried in a variety of ways to stem the flow of defense-related industrial technology to various Communist countries.[9] Also, both government agencies and firms (like IBM) have been concerned about improper leaks of industrial technology

[6] Of course, it should be stressed once again that Tables I and II reflect firms' perceptions of how quickly technological information leaks out to their rivals, and that these perceptions undoubtedly contain errors. However, the fact that Tables I and II are so consistent with the data in Mansfield, Schwartz, and Wagner (1981) suggests that these tables, while only rough approximations, provide a reasonably adequate general picture. Moreover, for many important purposes, the firms' perceptions are what matter most. For example, firms' perceptions of how rapidly their new technology will leak out to their rivals determines how much of the social benefits of a prospective innovation they believe they can appropriate, and thus whether or not they are willing to develop and introduce such an innovation.

[7] Also, there is no direct relationship between an industry's average four-firm concentration ratio and its median in Table II. However, evidence of this sort is obviously very crude.

[8] See Mansfield, Schwartz, and Wagner [1981].

[9] For example, see 'Technology Transfer: A Policy Nightmare', *Business Week*, April 4, 1983. Also, Stobaugh and Wells [1984] and US Department of Commerce [1983] contain relevant material.

to foreign firms. If the leakages typically are as quick and as great as our results seem to indicate, such efforts clearly face enormous problems.[10]

EDWIN MANSFIELD,
Department of Economics,
University of Pennsylvania,
Philadelphia,
Pennsylvania 19104,
USA.

ACCEPTED APRIL 1985

REFERENCES

MANSFIELD, E., SCHWARTZ, M. and WAGNER, S., 1981, 'Imitation Costs and Patents: An Empirical Study', *Economic Journal*, 91 (December), pp. 907–918.

MANSFIELD, E., ROMEO, A., SCHWARTZ, M., TEECE, D., WAGNER, S. and BRACH, P., 1982, *Technology Transfer, Productivity, and Economic Policy* (W. W. Norton, New York).

MANSFIELD, E., RAPOPORT, J., ROMEO, A., VILLANI, E., WAGNER, S. and HUSIC, F., 1977, *The Production and Application of New Industrial Technology* (W. W. Norton, New York).

ROGERS, E., 1982, 'Information Exchange and Technological Information', in D. Sahal (ed.), *The Transfer and Utilization of Technical Knowledge* (Lexington Books, Lexington).

STOBAUGH, R. and WELLS, L. (eds.), 1984, *Technology Crossing Borders* (Harvard Business School, Boston).

US DEPARTMENT OF COMMERCE, 1983, *An Assessment of US Competitiveness in High Technology Industries* (Government Printing Office, Washington, DC).

[10] In this connection, it is worth noting that the technologies transferred by US-based multinational firms to their overseas subsidiaries seem to leak out to non-US firms more slowly than is indicated by Table II. See Mansfield, Romeo, Schwartz, Teece, Wagner, and Brach [1982], pp. 38–40. Where possible, these firms may tend to avoid transferring overseas those technologies that are likely to leak out relatively quickly. (There is evidence that these firms are more hesitant to send overseas their process technology than their product technology, because they feel that the diffusion of process technology, once it goes abroad, is harder to control. See *ibid.*, p. 54.) Also, holding other factors constant, one would expect that American technology would leak out more rapidly, on the average, to US firms than to non-US firms.