

A Review of Data Bearing on
The Users Role in Industrial Innovation

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ABSTRACT

The contribution of the user to the industrial product innovation process has been shown to vary greatly. In some industries the user input appears minimal, while in others it is typical for users to undertake the entire product design effort. In this paper, 16 studies containing empirical data on the matter are briefly reviewed. Next, two current hypotheses regarding the cause of variations in the innovation process role of the user are discussed. One focuses on the novelty of the need which an innovation project attempts to address; the other on returns which users might expect to capture from their innovation efforts. Some empirical evidence in support of each is noted. Finally, some implications of the fact of varying user involvement and the innovation process for firm and governmental innovation policy are discussed.

1.0 Introduction

Students of product and process innovation have long sought variables which characterize firms, industries, technologies, regulatory environments etc., and which correlate with and might "cause" successful innovative activity. Over the past few years, a body of empirical data has been built up regarding a variable seldom examined before in this context. Since the variable shows promise, it is perhaps time to summarize briefly available evidence for the convenience of interested researchers.

The studies we will review all deal with the varying role of the user in industrial product and process innovation. In the sections which follow, we will begin by reviewing three categories of empirical data which bear on the fact of user involvement in the industrial innovation process: (1) the sources of designs for industrial product and process innovations; (2) the sources of "ideas" for industrial product and process innovations; and (3) the sources of problem statements for research whose results were key to the development of industrial product and process innovations. Next we will discuss two hypotheses as to when and why the user adopts a major role in the industrial innovation process, and finally, we will consider some implications of what is currently known about the user's role in that process for firms and government.

2.0 Users as Developers of Industrial Innovations: The Evidence to Date

Table 1 offers a summary of the results of all studies we are currently aware of which provide numerous data points on a single industry and which contain empirical data on the "source" of successful industrial product and process innovations. In table 1 attribution of an innovation to a user or manufacturer "source" depends on who first builds and utilizes it in conformance with his economic function. Thus, attribution to a user source is made

if a user builds and uses an innovation before a manufacturer builds and sells a commercial version. And conversely, attribution to a manufacturer source is made if a manufacturer builds and sells a commercial version of an innovation before a user builds and uses a home-made version.

Insert Table 1 Here

An initial glance at the data in Table 1 will show something very interesting: users seems to frequently be the "sources" of new product and process innovations. This is striking, because the conventional assumption is that product manufacturers are the developers of new products.¹⁰ Since this is so -- and since the impact on innovation research and practice would be considerable if the conventional assumption were proven often incorrect (for example, the prescriptive literature on "how to manage the innovation process", is currently built around the conventional assumption) -- we should be especially clear about key definitions and methodologies by which some of the studies in table 1 have come to a different conclusion. To this end, we will first provide an example of a user-developed industrial product to convey the flavor of what may well be an alien concept to the reader, and then will move on to a summary of key definitions and methods.

2.1 Solderless Wrapped Connection: An Example of a User-Developed Industrial Product

Solderless wrapped connection is a means of making a gas-tight, reliable electrical connection by wrapping a wire tightly around a special terminal whose sharp edges press into the wire. The system is much faster than the preceding system used to make such connections -- soldering -- and allows much closer spacing of terminals.

The entire solderless wrapped connection system, including a novel hand tool needed to properly wrap the wire around the terminal, was invented

Table 1: Empirical Data on the Source of Industrial Innovation

Study	Nature of Innovations and Sample Selection Criteria	n	Innovation Source ^a		
			User	Mfr	Other
Knight ¹	Computer innovations 1944-62: - systems reaching new performance high	143	25%	75%	
	- systems with radical structural innovations (level I)	18	33%	67%	
Enos ²	Major petroleum processing innovatons	7	43%	14%	43% ^b
Freeman ³	Chemical processes and process equipment available for license, 1967	810	70%	30%	
Berger ⁴	All engineering polymers developed in U.S. after 1955 with >10mm pounds produced in 1975	6	0%	100%	
Boyden ⁵	Chemical additives for plastics: All plasticizers and UV stabilizers developed post World War II for use with 4 major polymers	16	0%	100%	
Lionetta & von Hippel ⁶	All pultrusion processing machinery innovations first introduced commercially 1940-76 which offered users a major increment in functional utility	13	85%	15%	
von Hippel ⁷	Scientific instrument innovations: - first of type (e.g. first NMR)	4	100%	0%	
	- major functional improvements	44	82%	18%	
	- minor functional improvements	63	70%	30%	
von Hippel ⁸	Semiconductor and electronic sub-assembly manufacturing equipment: - first of type used in commercial production	7	100%	0%	
	- major functional improvements	22	63%	21%	16% ^c
	- minor functional improvements	20	59%	29%	12% ^c
Peck ⁹	New product or production technique described as advance in state of art by industry trade journals 1946-57 ^d				
	- in Aluminum joining (w)	52	17%	50%	33%
	- in Aluminum finishing (x)	27	33%	48%	19%
	- in Aluminum fabricating (y)	76	30%	49%	21%
	- in Aluminum alloys (z)	39	3%	79%	18%

Notes

^a See text for definition of "innovation source"; NA data excluded from percentage computations.

^b Attribute to independent inventors/invention development companies

^c Attribute to joint user-manufacturer innovation projects

^d Table 1 data categories were translated from those used by Peck as follows.

Mfr. = Equipment manufacturer for (w,x,y); primary and secondary aluminum producer for (z)

User = End product manufacturer for (w,x,z); primary aluminum producer for (y)

Other= Primary and secondary aluminum producers, commercial R&D companies, government labs and foreign sources for (w); primary aluminum producers, commercial R&D companies and individual inventor for (x); end product mfrs, commercial R&D companies, govt. labs and foreign sources for (y); Independent fabricators, end product mfrs, gov't labs and foreign sources for (z)

and developed at Bell Labs for use in the Bell System in 1947-48. After several years of testing by the labs, it was given to Western Electric for implementation. Western Electric decided to have the hand tool portion of the system built by an outside supplier and Keller Tool (now part of Gardner-Denver Company) bid for and won the job in 1952-53. Keller engineers suggested some modifications to the Bell-designed tool which they felt would make the tool easier to manufacture and operate and, Western agreeing, began manufacture.

Keller had other customers who did electronic assembly work and realized that some of these would also find the system useful. It therefore requested and obtained a license to sell the tools on the open market. Currently, solderless wrapped connection is a major wire connection technique and Gardner-Denver (Keller) the major supplier of equipment for that use.¹¹

2.2 Key Definitions and Study Methods Used

The definitions and methodologies used by the several studies whose results are summarized in table 1 differ in many particulars. Nevertheless, some imprecise generalizations can be made, under the headings of definitions and sample selection criteria, which the reader may find useful for purposes of overview.

2.21 Key Definitions

- Innovation, as distinct from invention, is the first utilization of a new product or process. In the usage of the studies reviewed here, first utilization means first world use, not simply first use within a particular firm.
- An innovation "user" uses an innovaton but does not manufacture it for sale. An innovation "manufacturer" manufactures an innovation for sale but does not use it. The industries studied in table 1 were in

the main structured in such a way that the distinction between the user and manufacturer could be made quite clearly via organizational boundaries: few firms both used a given innovation and manufactured it for sale. Two exceptions are (1) computer manufacturing firms, which have many sophisticated uses for computers in-house, and (2) petroleum product and chemical manufacturing firms (process users), which often derive additional income from their process innovations by licensing these to others. In studies of these industries (1,2,3) coding for table 1 was done by taking the major role of these two classes of firms as controlling: all innovations by computer manufacturing firms were attributed to "manufacturer" and all process innovations by petroleum product and chemical manufacturing firms attributed to "users."

2.2 Sample Selection Criteria

- Most of the studies reviewed in Table 1 focus on innovations of "major significance" (cf. table 1 for criteria of significance used by each). Such innovations are comparatively rare and, while there is some evidence that minor innovations follow a pattern similar to major ones (7,8) this cannot be taken as a given at present.
- The innovation samples of the studies reviewed in table 1 consist of successful innovations only. The high level of user-designed products and processes observed cannot therefore be used as a predictor of success: a sample of failing innovations might show an equal -- or higher or lower -- incidence of user involvement.
- Several of the studies reviewed in table 1 (studies 1, 6,7,8) judge innovation success in terms of benefit derived by the user

("...offers a major increment in functional utility when judged relative to previous best practice..."). Innovations selected on this basis may be major commercial successes for product manufacturers as well -- but not necessarily (functionally important innovations are not necessarily of commercial importance to their manufacturer(s)).

3.0 Evidence Regarding Requests for Innovations from Users (Customers)

To this point, we have reviewed only studies which attribute an innovation to the party which actually builds the first version "used". It should be noted that this is a very conservative measure of user involvement in the innovation process in that it ignores user inputs such as requests for innovations from customers containing vague or precise specifications which, while falling short of that criterion, may nonetheless be significant contributions.

I have focused on studies which use this measure, despite its conservative bias, for a simple but very important reason: data on the source of the first functioning version of a given innovation can often be collected retrospectively with far greater reliability than can data on such measures as the presence (absence) of "Innovation Requests" by customers and any associated product/process specifications. The latter are evanescent and seldom documented contemporaneously. In contrast, a first-functioning version of an innovation tends to leave substantial contemporaneously-generated traces such as the physical device itself, records of prototype construction and results, patents, publications noting the accomplishment and its date.

Despite the difficulty of the work, however, several empirical studies have explored the frequency with which innovation requests from customers are associated with the decision to: develop new industrial products (table 2A); engage in research which ultimately led to new industrial and military

products (table 2B) (in the latter studies the "customer" for the research results solicited was an engineering group). The relevant finding of all studies of these two types which we are aware of are summarized in table 2.

Insert Table 2 Here

(The interested reader will find a more detailed review of the studies in (18).)

Note that with one exception, these studies do not indicate the content of the customer request. The data they provide is compatible with a request as vague as: "Please think up a new product for me", or as precise as: "Please make me 10,000 units of X according to my design." (The exception is the study by von Hippel.¹¹ In the sample examined there, it was determined that customer requests, when present, contained complete design data for the desired product). Even given this caveat, however, it is useful to find that the data provided by these two types of studies are clearly congruent with the central finding of the studies reviewed in table 1, viz: product users play a significant role in the innovation process in some industries -- and a minimal role in others. Some of the authors of the studies reviewed in table 2 find the evidence for significant user involvement in the innovation process quite striking, as do we. For example, the Material Advisory Board, in its discussion of the findings of its study of innovation histories of ten important materials innovations, such as silicones, observes (emphasis theirs):

In all but one of the cases studied, the recognition of an important need was identified in a majority of the events as an important factor in bringing about the research-engineering interaction.

* * *

Table 2: Frequency with which Manufacturers Initiated Work on an Industrial Innovation in Response to a Customer Request.

<u>Study</u>	<u>Nature of Innovations and Sample Selection Criteria</u>	<u>n</u>	<u>Data Available Regarding Presence of Customer Requests</u>
<u>A. Studies of Industrial Products</u>			
Meadows ¹²	All projects initiated during a two year period in "Chem Lab B", a lab of a chemical company with \$100-300mm annual sales in "industrial intermediates"	29	9 of 17 (53%) commercially successful product ideas were from customers.
Peplow ¹³	All "creative" projects carried out during a 6 year period by an R&D group concerned with plant process, equipment and technique innovations.	94	30 of 48 (62%) successfully implemented projects were initiated in response to direct customer request.
von Hippel ¹¹	Semiconductor and electronic sub-assembly manufacturing equipment: first of type used in commercial production (n=7); major improvements (n=22); minor improvements (n=21).	49	Source of initiative for manufacture of equipment developed by users (n=29) examined. Source clearly customer request in 21% of cases. In 46% of cases frequent customer-manufacturer interaction made source of initiative unclear.
Berger ⁴	All engineering polymers developed in US after 1955 with >10mm pounds produced in 1975	5	No project initiating request from customers found.
Boyden ⁵	Chemical additives for plastics: all plasticizers and UV stabilizers developed post World War II for use with 4 major polymers.	16	No project-initating request from customers found.
Utterback ¹⁴	All scientific instrument innovations mfd. by Mass. firms which won "IR-100 Awards" 1963-68 (n=15); sample of other instruments mfd. by same firms (n=17)	32	75% initiated in response to "need input". When need input originated outside product manufacturer (57%) source was "most often" customer.
Robinson ¹⁵ et al.	Standard and non-standard industrial NA products purchased by three firms		Customers recognize need, define functional requirements and specific goods and services needed <u>before contacting suppliers</u>

Table 2: continued

<u>Study</u>	<u>Nature of Innovations and Sample Selection Criteria</u>	<u>n</u>	<u>Data Available Regarding Presence of Customer Requests</u>
<u>B. Studies of Research-Engineering Interaction</u>			
Isonson ¹⁶ (Project Hindsight)	R&D accomplishments judged key to successful development of 20 weapons systems	710	85% initiated in response to description of problem by application-engineering group.
Materials ¹⁷ Advisory Board	Material innovations "believed to be the result of research-engineering interaction".	10	in "almost all" cases the individual with a well-defined need initiated the communications with the basic researchers.

In almost all of the cases under consideration, it was an individual with a well-defined need who was the initiator of the communications.

It was most frequently he who began the dialogue with the basic researchers and determined its continuation until the need was satisfied. ¹⁹

Determinants of the User's Role in the Innovation Process

To this point, we have presented and discussed evidence for the fact that product and process users often play a major role in the industrial innovation process. Next, we wish to explore current hypotheses as to "causes" of a high -- or low -- level of user participation in the innovation process of a given industry.

At this point, two hypotheses regarding the cause of a high or low level of user participation in the industrial good innovation process are under active consideration. The first of the hypotheses, offered in somewhat different formulations by Utterback and Abernathy²⁰ and Knight,²¹ is that performance requirements are poorly understood by manufacturers in the early stages of a new product area, and that new product innovations in these early stages are therefore carried out by those closest to the need, e.g., users. This hypothesis also predicts a shift from a user to manufacturer "locus of innovation" as, over time, the needs become more generally known and well-defined. This shift occurs, Utterback and Abernathy go on to propose, because when needs are well-defined, the key to successful innovation becomes new technological insights -- and product manufacturers, it is suggested, have an advantage over product users in the latter arena.

The shift in locus of innovation predicted by this first hypothesis has been observed in three of the industries studied to date. A statistically significant shift in the predicted direction is shown in two of the studies

summarized in table 1 during the time spans examined as follows: Knight's data¹ showed a shift from user to manufacturer innovation as a function of time $p < .001$ for systems reaching new performance highs and $p < .01$ for systems containing radical structural innovations (Mann-Whitney U Test); von Hippel⁸ found process machinery innovation which were the first of a "type" (e.g.: the first to be used to carry out a new "process step" in the industries studied) to be significantly more likely to be developed by users ($p < .05$, $\chi^2 = 4.1$) than the major and minor improvement innovations which followed. Some indication of the predicted shift is visible in the Scientific Instruments⁷ data (basic innovations vs. major plus minor improvements to these $p = .34$ (Fisher exact test), but not in the studies of petroleum processing innovation or pultrusion process equipment innovation.^{2,6}

The above-mentioned five studies are the only ones of the studies summarized in table 1 appropriate to test the Utterback, Abernathy, Knight hypothesis because their samples included both innovations from when the product area "was new" and later innovations. On the basis of the evidence they provide, we suggest that their hypothesis is an interesting and promising one.

At present, the second hypothesis I would like to bring to the readers attention has a rather global formulation, e.g.: the locus of innovation activity (and cost) is a function of the locus of benefit from such innovation. This hypothesis, of course, quickly reduces to that basic premise of market economics: investment is a function of expected return. For a long time, however, it was not clear that innovation had any relationship to such a premise. In fact, as Schmookler²² notes, economic theory tended to treat technological progress as an exogenous factor -- a factor not determined by economic forces -- to be introduced into economic analysis ad hoc "like war or an earthquake".

Painstaking work by economists such as Schmookler, Mansfield²³ and others, however, have now empirically established that economic measures such as the level of investment in certain categories of capital equipment, and proxy measures for innovation, such as rates of patent application bearing on those types of capital equipment, are strongly correlated. Further, by showing that rises in rates of invention follow rises in rates of investment, they have been able to provide support to the hypothesis that increases in investment cause increases in the frequency of invention (and, presumably, related innovation) -- by raising the expected value of such.

Once it is established that invention and innovation are a function of expected value, it is a short logical step to the hypothesis that the locus of invention and innovation expenditure --user/or manufacturer and/or "other" -- is a function of the locus of expected benefit. Peck, in his study⁹ of the sources of invention in the aluminum industry, made a pioneering attempt to test the correlation between the amount and time-distribution of profits logically derivable by potential "sources" of aluminum-related-invention -- producers of aluminum, producers of fabricating equipment for aluminum, producers of products using aluminum, etc., vs. the actual invention record compiled by these sources. Attempts to move the next logical step and correlate actual profits obtained by firms having different functional relationships (e.g. users of, manufacturers of, etc.) to certain categories of innovation vs. their actual record of innovation in these categories unfortunately face severe methodological difficulties notably:

- Simply obtaining needed economic data on the costs and benefits of innovation is very hard. (Corporations are understandably loath to provide data on profits, etc. related to particular products.)
- Proper attribution of costs and benefits is often difficult. (For

example, what is the proper benefit to be attributed to an innovation which is sold as part of a larger system? It may contribute to system sales -- but how large is that contribution?)

- Making various important types of costs and benefits commensurable is sometimes a problem. (For example, user-innovators of scientific instruments are largely university-based scientists who are rewarded primarily in terms of increases in understanding, reputation among peers, etc.²⁴ How does one make such benefits commensurable with those with the benefit which might induce an instrument company to innovate -- an increase in annual sales?)

Given this rather grim list of methodological difficulties, one might well wonder how hypothesis 2 might be further explored. A possible answer may be that, given real-world conditions, a small subset of data might be adequate to test the hypothesis in numerous categories of industrial products and processes. We elaborate as follows: the benefit to a potential innovator is the benefit he can capture. Easily observable features of market structure and institutional factors such as patent policy serve to put an upper bound on what an innovator can capture which may be easily computable and be so low for some classes of potential innovators as to allow us to predict where the locus of innovation will not be. Thus, a user who innovates has two potential ways to capture benefit from his innovation to compensate for innovation-related costs incurred. He may benefit from in-house use of the innovation and/or he may benefit from the diffusion of the innovation to others who wish to use and/or manufacture the innovation. In the instance of the first method of capture -- in-house use -- the upper bound on the percentage of total benefit available from an innovation which a user-innovator may capture is simply determined.

Assuming use of the innovation does not change market share, in-house benefit captured is, simply, the same percentage as his share of the market to which the innovation benefit applies. (e.g., if the innovation is a processing machine which reduces the cost of manufacturing product A only, and the user-innovator manufactures 20% of the total benefit potentially derivable from the innovation via in-house use. (We emphasize that share-of-relevant-market is an upper bound to the user's benefit from in-house use because, depending on market circumstance and company strategy, the user may choose or be forced to pass along some of the benefits to customers or others.)) The second source of benefit potentially available to the user-innovator involves the "capture" of some of the benefit obtained by others when they use and/or manufacture the innovation. Mechanisms available for such capture are royalties, license fees, sale of "know-how", etc.

Similar reasoning applies in the instance of capture of benefits by a manufacturer-innovator: capture via in-house manufacture and sale has an upper bound equal to the manufacturer's market share. A share in the remaining available benefit must be sought via royalties or other fees from other manufacturers and/or users. (In the instance of the independent inventor -- who neither uses his innovation nor manufactures it for sale -- all benefit captured must be via fees from manufacturers and/or users.)

Clearly, many different strategies for capture are available as a function of market structure, patentability of a given innovation, etc.²⁵ In principle, this plethora of options could lead to difficulty in predicting -- as opposed to explaining post hoc -- the locus of innovation in any particular industry. In practice, however, we speculate that, in many industries, capture of benefits resulting from non in-house activity by user or manufacturer is either restricted to a few clear mechanisms (e.g., licensing in chemicals)

or absent. (In our studies of scientific instrument⁷ and process equipment innovations^{6,8} we have seldom found any capture of benefit by innovators other than via in-house use. Patents were either seldom applied for (scientific instruments) or the innovations were of such a nature that patents could easily be skirted by imitators (process machinery). Other possible mechanisms for capture (e.g., effective brand-name "franchise") were also largely ineffective in these industries.)²⁶

Without an ability to prevent imitation or share in the benefits derived from imitation, the potential benefit to some classes of innovators can, as I mentioned above, have an exceedingly low upper bound. In the pultrusion industry, for example, total sales of pultruded product distributed among approximately 30 users of pultrusion machinery were found by Lionetta and von Hippel⁶ to be approximately \$60 million in 1976. Sales of pultrusion machinery by the single commercial builder of such were found to have climbed to a plateau of only \$300 thousand annually. (Many users in this industry build their own process equipment). Machine manufacturers and users alike were seen unable to protect their innovations by patent or other means in this industry. This observation plus the relative sales volume of users and manufacturer observed seems to us to be a reasonable, hypothesis 2-based, explanation for our finding that 85% of the innovations sampled had a user source (It is also a reason to suggest that, in this industry, the shift in the locus of innovation predicted by hypothesis 1 would not occur unless and until the ability of the manufacturer to capture benefit from innovation costs incurred improves. Currently, total before-tax pultrusion-related profits -- a potential source of additional R&D funding -- is on the order of \$7 million annually for the total user community versus only \$30-40

thousand annually for the single commercial manufacturer of pultrusion equipment.

In sum, I suggest that the above two hypotheses regarding causes of variation in the locus of innovation hold interest and are worthy of further research. As research progresses, further hypotheses will doubtless emerge.

Implications

As we noted at the beginning of this paper, the fact of varying user and manufacturer involvement in the industrial innovation process is currently clear but the cause of these variations is not. And, as the reader will understand from the discussion in the preceding section, a good deal more research remains to be done before the cause(s) is well understood. Fortunately, many major implications for innovation research and practice may be derived from the fact of user and manufacturer loci of innovation development (which may be empirically determined for any industry of interest), even if the cause is currently unknown. This is so because knowledge of where innovation occurs is an essential prerequisite to effective management of the process by those working at the firm, industry or government level. In the remaining paragraphs of this paper we will suggest a few implications for the firm and then moving to implications for government.

Implications for the Firm

Users and manufacturers share the industrial innovation process no matter which party is the "source" of an innovation -- the manufacturer picking up the work where the user leaves off. As we noted at the beginning of the paper, the currently prevailing assumption among practitioners of innovations in industrial firms -- and of the prescriptive, "how to develop new products" literature addressed to them¹⁰ -- is that the user's share in

the innovation process is simply to have "needs" which the manufacturer can explore via marketing research. Yet, as we have seen in this paper, in some industries the user's role is typically far greater, involving the design and fabrication of a "home built" version of the innovation and proof of its value via field use.

Clearly, a manufacturing (or using) firm facing the latter situation should organize its innovation effort differently than would be appropriate in the former situation: both what the firm should be looking for at the user-manufacturer innovation activity interface and what the firm itself should do are significantly changed. Consider the following changes which might logically be prescribed for a manufacturing firm wishing to switch its innovation activities from manufacturer-sourced to user-sourced innovations:

- Marketing research, now chartered to seek need data, analyze it, develop responsive "product concepts" and estimate market sizes, would be reoriented to search out data on user prototypes, analyze the utility these have displayed in field use, and estimate their potential as commercial products.
- The sales force, now designed primarily to disseminate information on present products, would acquire the added function of acquiring information on promising user prototypes during visits to customer facilities.
- R&D, now motivated and staffed to develop a product from concept data supplied by marketing research, would be reoriented to perform only product engineering work on user prototypes.

Of course, such changes in the established role of an organizational group would not be easy to accomplish because they require related changes in the interests and skills of group members. For example, salesmen are

now neither trained nor motivated (sales compensation systems generally reward large volume sales of existing products, not possible sales of future products) to seek user prototypes or report back what they see. And R&D groups are presently staffed by people trained and motivated to do the entire product development job, rather than by product design specialists only.

Clearly, the finding that users often undertake a major role in the innovation process in a given industry will have major implications for innovation-related practice for firms participating in that industry.

Implications for Government

Government has a major and pervasive impact on the innovation process. It is a major funder of R&D, a major purchaser of innovative products, and it sets the ground rules according to which others may innovate (FDA) and be rewarded for innovation (patent policy). When it is demonstrated that, in certain industries, users rather than manufacturers undertake the bulk of the innovation work, some problems which have traditionally concerned government policy makers will disappear and others will emerge. An example in each category:

- Government, correctly cognizant that innovation in process equipment plays a major role in the economy's improvement in productivity, has often cast a worried eye at the fact that producers of many types of process equipment (e.g. machine tools) tend to be small and financially unable to support sophisticated R&D programs.²⁷ This fact, I suggest, will cease to be worrisome if and when it is demonstrated -- as we have already seen done for some classes of process machinery -- that manufacturers of many classes of such equipment seldom innovate

themselves, but simply provide the manufacturing function for innovative users.

- Government has tended not to worry when firms which use innovative industrial goods and are labor intensive (e.g. textiles) depart U.S. shores. After all, it is reasoned, the comparative advantage of our economy does not lie with goods of a high labor content -- and we will still sell such off-shore industries the sophisticated capital goods they need. It has been observed in two industries, however,^{6,11} that innovative process plant and machinery developed by users is very likely to be transferred to machine builders in the same country. An implication which government may find wise to test is: in the case of industries characterized by user dominated innovation patterns, does the departure of users of innovative industrial goods from the U.S result in the decline of domestic manufacturers of such goods due to the inaccessibility of innovative users?

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21. Knight, op cit. chapt. 7, p. 11.
22. Schmookler, J., Invention and Economic Growth, Harvard University Press, 1966, p. 3-4.
23. Mansfield, E., "Innovation and Technical Change in the Railroad Industry," in Transportation Economics, New York: National Bureau of Economic Research, 1965.
24. Merton, R., The Sociology of Science, University of Chicago Press, 1973.
25. See Nelson, R.R., and Winter, S.G., "In Search of a Useful Theory of Innovation," Research Policy, January 1977 for an excellent discussion.
26. Economists have noted that the inability of innovators in some industries to capture benefit from the diffusion of their innovation to imitators suggests that society as a whole may under invest in R&D, e.g.: many innovations whihc would pay if cost and benefit were computed on an industry-wide basis will not be undertaken because an innovator who may bear the entire cost cannot capture commensurage benefit. Cf.

Mansfield, E., et al., "Social and Private Rates of Return from Industrial Innovations," Working Paper, Wharton School, University of Pennsylvania, September, 1975.

27. See, for example, Arthur D. Little, Inc., Patterns and Problems of Technical Innovation in American Industry: Report to the National Science Foundation, Office of Technical Services, Department of Commerce, September 1963, PB 181-573.