The Induce versus Purchase Decision: An Empirical Analysis of Industrial R&D

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Abstract:

With the recent slowdown in productivity growth within the economy, R&D has come under scrutiny as a policy target variable. If such targeting is to be effective, it must be realized that not all innovations employed within a firm are induced by the firm through its own R&D: many innovations are purchased through technological licensing or in the form of new capital equipment. Here, interfirm differences in this "make" versus "buy" strategy are analyzed within the context of the Utterback-Abernathy production process lifecycle. Our findings suggest that (1) alternative sources to a firm's R&D for stimulating innovation may prove a viable strategy for federal targeting and (2) extrapolating the Utterback-Abernathy model to an industry formulation has empirical validity.

Keywords: R and D | economic analysis | organization | management theory

Article:[*]

INTRODUCTION

Productivity growth is a pressing concern for the United States and for most industrialized nations since it is believed to be a major stimulant for economic well-being. Fabricant [15], for example, elaborated on this idea in recent testimony before Congress: higher productivity, he

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noted, is essential to a higher standard of living and is vital to a sound international, economic, and political position. The rate of productivity growth in the United States, however, has been falling since the mid-1960s; in the manufacturing sector, for example, the average annual rate of growth in labor productivity was 3.13 percent between 1948 and 1965, 2.47 percent between 1965 and 1973, and 1.70 percent between 1973 and 1978 [35]. Quite naturally, this decelaration has attracted the attention of both policy makers and researchers.

While numerous factors-such as energy prices, capital intensity, and workers' hours and attitudes-are cited as contributing to the slowdown in productivity growth (See [10] for an excellent review of this literature.), the slowdown in R&D expenditures over the past several years has received particular attention. Total R&D as a percent of GNP peaked at 3.0 percent in 1964, then fell to 2.3 percent by 1975, where it has essentially remained. It is estimated that this continued decline may trough at 2.0 percent by 1985 [20]. Although there is not complete agreement on the quantitative importance of this relative decline in R&D, the decline is generally viewed as one contributing factor to the downward trend in productivity. Nadiri [33], for example, contends that the reduction in the stock of R&D, through the slowdown in R&D spending, may account for as much as one-third of the productivity decline in the economy since 1973. Griliches [17], however, avers that the slowdown in R&D accounts for at best one-tenth of this productivity retardation.

Policy makers are concerned about reversing this observed trend in productivity growth. Many suggest that federally financed R&D be increased or that tax incentives be considered for strengthening industrial R&D activities [12]. Such a view was recently elaborated on by Thomas:

> Identifying target variables that could be affected by government policy with some confidence that productivity growth rates would be increased has become more than an academic question. For those interested in science and technology policy ... R&D as a target variable naturally comes in for scrutiny. [42, p. 2]

In fact, an R&D tax plan is part of the Economic Recovery Act of 1981. This Reagan tax plan provides a 25 percent tax credit for increases in the base (calculated as a three-year average) of firms' nominal R&D expenditures, as defined under Section 174 of the IRS tax code.[1]

Clearly, R&D funding and R&D tax incentives (along with actions regarding patents, regulation, and antitrust) are becoming policy targets for improving productivity growth. It is important, however, that care be taken to subsidize industrial R&D in a way that maximizes the social return to those public investments: in other words, R&D policy should be directed in such a way as to generate the largest positive externalities.

One consideration, for instance, is that the relative effects of federal R&D policies are likely to differ across industries [28] [44]. This point is especially well made by Utterback:

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[1] There are a number of problems with this tax credit plan. First, firms that may need it the most may not benefit because they have to prove that their R&D is *in place.* Second, firms that receive the credit are, in effect, being encouraged to continue to do the same kind of R&D that they are already doing rather than the more radical and risky work that is thought to be socially important [27].

> To stimulate a firm's investment in innovation requires a consideration of the differences among industries in the innovation process. An effective incentive in one setting might be ineffective in another. [44, p. 65]

Myers and Marquis [32], for example, find quite different innovative contexts within the railroad and computer industries: the railroad industry was characterized by more adoption and modification, whereas the computer industry was characterized by more invention. Similar observations have led others [37] to suggest that federal policy in certain industries, such as those experiencing rapid technological change, be tailored to encourage a symbiosis between established and new, smaller firms (revealed through new venture, spinoff, and merger/acquisition activities).

A second consideration is that productivity growth in a given industry cannot always be encouraged most efficiently by stimulating *that* industry. Ettlie [13], among others, has suggested that greater attention be given to the role of suppliers in the innovation process-particularly with process innovations. The policy alternative of encouraging innovative activity within an industry by stimulating the industry's suppliers thus naturally arises.

The technological basis of a firm is much broader than the activities of its own R&D programs. Technologies can enter a firm not only as the result of its own R&D—we call these *induced* innovations—but also through such channels as licensing of others' technology or purchasing new capital equipment that embodies new technology (perhaps the results of a capital supplier's R&D as shown in Figure 1)—we call these *purchased* innovations.

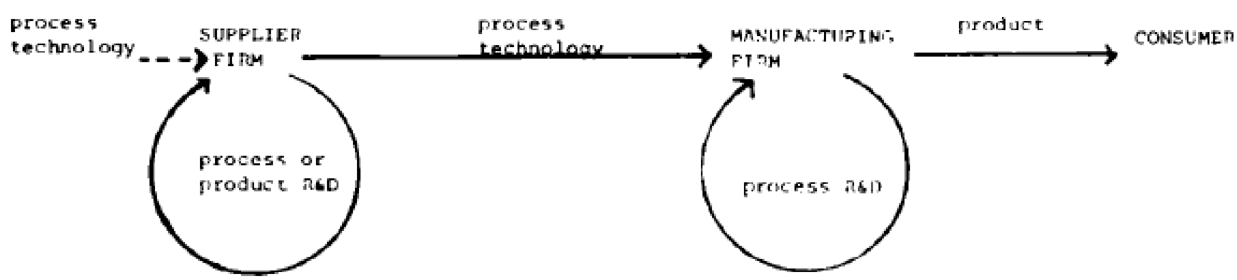

Figure 1. Alternatives for Acquiring New Process Technology

This induce versus purchase, or "make" versus "buy," distinction would consequently seem to be an important consideration in developing federal R&D policies: productivity growth in a given industry could be stimulated either by subsidizing the R&D of firms in that industry or by subsidizing the R&D of firms supplying products to that industry. It would thus seem appropriate, along with other concerns, for federal R&D targeting to vary across industries in accordance with industry differences in the propensity of firms to induce ("make") or purchase ("buy") technical knowledge-a decision reached through each firm's profit maximizing calculations.

It is the purpose of this paper to examine empirically some of the determinants of this "make" versus "buy" decision. Factors related to this choice are initially discussed. Then, an empirical model is formulated and tested. Finally, implications from the empirical findings are discussed.

THE DECISION TO INDUCE OR TO PURCHASE TECHNOLOGY

In a broad sense, one may view the firm's decision to invest in its own R&D program as a conscious plan to internalize an activity for which an alternative external market exists. Therefore, one may hypothesize that the induce versus purchase decision is a rational aspect of the firm's overall innovation strategy. Accordingly, interfirm differences in the percentage of new technology induced through the firm's own R&D reflect interfirm differences in the perceived net benefits from internalizing the innovation search.[2] In other words, a firm will choose, at the margin, the alternative that is cost efficient in net terms.

Consider first the firm's decision to purchase a given technology from a supplier. One obvious cost is the purchase price; however, other costs arise if the supplier's product (a process technology) fails to meet the firm's specific requirement set. These added costs reflect, among other things, expenses involved in modifying the product to meet a specialized requirement or opportunity costs associated with relaxing a particular requirement. A rational supplier will market a technology only when a demand for that technology exists. In order to enlarge potential demand, the process technology is designed to meet the generalized needs of a number of manufacturing firms. While some flexibility (regarding the attributes of the products to be manufactured, the linkages with in-place manufacturing processes, the precise functions to be performed, etc.) will be incorporated in the design, in many instances the successful adoption of the technology occurs only after considerable adaptation. Also, purchasing technology is always accompanied by the possibility that a firm's internal capability to innovate effectively with regard to its manufacturing processes will be diminished, thus weakening the firm's long-run competitive stance within its industry. But there are benefits to purchasing, namely, a reduction in technological uncertainty [14], which refers to a lack of understanding regarding the most appropriate process design for handling a particular set of manufacturing activities. Much of this uncertainty reflects the fact that at its inception a design is essentially an abstraction. Only by observing, examining, or experimenting with an evolving or existent design can technological uncertainty be reduced.

Regarding the costs of inducing technology, the direct costs of inducement replace the purchase price component of the purchased alternative. These generally would be expected to exceed the sale price of a purchased technology since the supplier could spread development expenses among all purchasers. These direct inducement costs are compounded by the technological uncertainties the firm must incur as it begins the inducement process with an abstract idea and attempts to develop it into a workable process design [45]. There are, however, benefits to inducement. First, the output is likely to correspond well to the firm's requirement set and, second, the firm can sometimes appropriate any technical knowledge that arises during the innovation process. This ability to appropriate technical knowledge increases in importance in direct proportion to the extent to which R&D is a form of nonprice competition. A similar argument was made more than two decades ago by Nelson [34]; the greater a firm's capacity for utilizing technical knowledge, the more likely it is to invest in basic research. Specifically,

[2] Coase's [11] pioneering article provides the first theoretical insights into the nature of the firm's nonmarket activities. His concepts have been extended in [3], [38], [39], [46], and [47], among others, but very little empirical work has been done to test the applicability of the theoretical issues. One exception is Mowery's [30] historical case study of in-house R&D versus contracted work.

Nelson hypothesized the relationship between the extent to which a firm is diversified and its incentive to invest in basic research.

It is quite likely that firms may differ in the way they perceive these benefits and costs. For example, the costs associated with internally developing technology may be weighted less heavily if the firm in question already possesses the requisite financial capabilities and technical facilities for successful induced activities. Also, if the firm's climate is supportive of risk taking, or if it places a high relative value on innovation, then the potential uncertainties associated with inducement relative to the expected benefits from an investment in new process technology should diminish [14] [18].

We hold, however, that these benefits and costs are largely a function of the firm's manufacturing environment. One representation of this environment that seems particularly relevant to process innovation is the Utterback and Abernathy [45] product-process lifecycle model. Although some [36] have criticized this formulation, it still remains intuitively appealing and widely used [13] [19] [37].

Utterback and Abernathy [45], and later Abernathy [2], suggest that the induce or purchase decision is related to the firm's production process lifecycle:

> Characteristics of the [firm's internal] innovation process ... will vary systematically with the firm's environment. . . *and* with the state of development of process technology used by a firm and its competitors. [45, p. 640, emphasis added]

Major product innovations often arise in small firms characterized by unique technical capability, market understanding, or both. We recognize that large firms may also innovate: one example was the development of nylon. As a product attains market success, production volume increases (stimulating the need for new process technologies), other firms enter the market, and cost competition (via process technologies) commences. Because these requirements for new process technologies arise as a result of evolutionary forces, internal development of new process technology peaks during this transition stage in the lifecycle. As a product line fully matures in the specific stage, product design stability and intensive price competition lead to the use of fully integrated and automated production processes. In such endeavors, economies of scale increase in importance, and the firms competing successfully in the market tend to be large. With the emergence of a dominant process design, a supplier industry develops. The significant expenses and risks associated with changing an integrated, automated production process tend to weigh heavily the technological uncertainty of inducing new process technology in the specific stage, and the relative advantage of purchasing this technology increases. These ideas are summarized in Table 1.

The original Utterback-Abernathy framework is a descriptive model of production process development within a single plant that anticipates a common pattern of change among different industries [1] [45]. This expectation of uniformity across firms has been criticized along the the model's limited focus; that is, a single plant [13] [36]. Ettlie [13] has recently proposed that the Utterback-Abernathy model may be most appropriate when a firm (e.g., a plant) and its environment (e.g., its industry) move together in development.

Table 1. Key Elements of the Utterback and Abernathy Model

Stage of Process Development	Product Characteristics	Process Characteristics	The Induce Versus Purchase Decision
Fluid	• rapid, frequent product changes • product diversity • high margins	• rapid, frequent process changes • process inefficiency • labor intensive • general-purpose process equipment • use of available materials	• reluctance to invest R&D funds into process innovation • purchase of general purpose equipment and available materials
Transition	• maturing product group • emergence of dominant product design	• emergence of process specialization islands • increasing importance of process development to boost output volume and to meet cost competition	• extensive internal process development • lack of a supplier industry
Specific	• product standardization • low margins	• emergence of dominant process design • integrated automated process technology • capital intensive • process changes major and costly	• emergence of a supplier industry • purchase of specialized process technologies

Recent conceptual advances in organizational theory adopt a similar view. Brittain and Freeman [7], for example, suggest that while a given industry may simultaneously exhibit a number of production process lifecycles, only one—that most closely linked with the industry's generic underlying technology—will dominate:

> The basic ecological dynamic prevails in all organizational populations, with the outcome in any industry specific to the environmental conditions under which organizational forms seek to exercise their relative advantages. [7, p. 338]

Very similar notions can be found in the views of Hage [18]. After examining the dialectic of whether organizations choose strategies or whether environments constrain strategic choices, Hage concludes that over the long haul most strategies are institutionally rather than organizationally determined:

> The argument running through this whole discussion is that in general there is not much strategic choice. *Given certain constraints that determine the resources and performances of the organization, then there are appropriate ... strategies.* [18, p. 451]

The constraints alluded to by Hage involve the technological, economic, and political forces that operate within an organization's specific environment while the organizational performances refer to a firm's choices between quality and quantity and between innovation and efficiency.

While the validity of extrapolating the Utterback-Abernathy model [45] from a plant to an industry lifecycle has not, to our knowledge, been empirically demonstrated, we believe such an extrapolation can be applied to explain a firm's decision to purchase or induce new process technology. It is consequently posited that the propensity of firms within an *industry* to induce process technology will roughly follow an inverted U-shape: firms in industries categorized as being at the fluid or specific stage of process development will purchase new process technology, whereas firms in industries at a transitional stage will induce this technology. Industry characteristics likely to influence a firm's decision to induce or purchase new process technology would be those descriptive of an industry's stage of process development.

We realize as well there will be exceptions to such a generalization. A firm's stage of process development reflects only one of Hage's [18] environmental constraints—an economic factor representing manufacturing economies of scale. If a firm operates in a technology-intensive environment rich in opportunities for innovation [44] [48], the incentive to induce is heightened since whatever technical knowledge results from one project may be appropriated by the firm and spill over into other projects [2] [18]. If, however, a firm operates in a politically poor environment where organizational autonomy is limited, the incentive to induce is lessened as fewer opportunities to exploit any innovations or any appropriated knowledge exist [18]. It is also recognized that individual firms may effectively behave in a manner different from an industry norm *if they are successful.* If their success is significant, this behavior might very well radically change the nature of competition within the industry [18]. Thus, firms that possess relevant technical capabilities or that can be categorized as either risk taking or pro-change are more likely to induce new process technology. Finally, it has long been observed that large firms are generally more innovative than are small firms. Larger firms can exploit economies of scale to enjoy the financial (i.e., slack resources) and technical (i.e., greater knowledge) capabilities necessary for inducing new process technology. This assumption underlies the vast economic literature concerned with testing the Schumpterian hypothesis that firm size (and monopoly power) is a prerequisite for innovative activity.

THE ANALYTICAL FRAMEWORK

The discussion from the previous section suggests that interfirm differences in the decision to induce or purchase new process technologies may be systematically related (a) to certain *industry* characteristics that describe the dominant stage of process development, the opportunities for innovation, and the degree of autonomy experienced by individual firms and (b) to certain *firm* characteristics that reflect each firm's abilities and desires to deal with technological uncertainty. The probability that a firm will induce, rather than purchase, technology is thus hypothesized to be functionally related to a vector of industry and firm characteristics as

$$\text{Probability to induce} = f(\text{industry characteristics}, \text{firm characteristics}). \qquad (1)$$

Three specific industry characteristics are considered here. The first is the capital intensity of the industry in which a firm operates as measured by the industry's capital-to-labor ratio, *K/L.* Industries at a fluid stage of process development tend to be labor intensive, and industries at a specific stage tend to be capital intensive. Since incentives to induce new process technology are believed greatest at the transition stage of process development, it might be expected that industries characterized by an intermediate degree of capital intensity would induce rather than purchase technology. Accordingly, a nonlinear capital-to-labor ratio variable, $(K/L)^2$, is also examined.

The second industry variable represents the technological opportunities within an industry for successfully introducing a new or modified product. Such opportunities should influence a firm to induce rather than purchase new technologies because of the potential symbiotic relation between its own process and product innovations. The extent of such opportunities is denoted by the variable HIGH.

And third, an index of product standardization, STAND, is employed to capture the extent an industry's firms are able to exercise competitive autonomy. With high product standardization, innovation targeted at product innovation realizes little gain as the risk associated with introducing new products is high. Furthermore, the emergence of a dominant product design is likely to be accompanied by the evolution of a supplier industry marketing manufacturing processes for producing the standardized product [23] [26]. Thus, it might be expected that firms in such an industry would purchase rather than induce new process technologies.

The three firm characteristics considered as influencing the decision, or ability, to induce or purchase technology act in a similar fashion. The larger a firm, the more talent a firm enjoys regarding industrial R&D and the less risk averse the firm, the lower the perceived cost embodied in technological uncertainties associated with developing a new process technology and thus the greater the likelihood the firm will induce technology. Firm size is denoted by the variable SIZE. The firm's ability to deal with technological uncertainty is approximated by an index of its previous economic success in R&D activities, SUCC.

One approach to measuring a firm's attitude toward risk-taking is to employ the firm's form of ownership as a surrogate. According to managerial theories of the firm [5] [6], manager-controlled firms arc relatively more risk averse than owner-controlled firms because of an asymmetry in the manager's reward structure: hired managers do not internalize the benefits from successful risk taking but do internalize the costs attributable to unsuccessful risk taking. Following McEachern and Romeo [29], among others, forms of ownership control can be classified into three categories: (1) externally controlled, EC, if there is a dominant stockholder, not part of management, holding 4 percent or more of the common stock; (2) manager-controlled, MC, if no single party owns 4 percent or more of the common stock; and (3) owner-managed, OM, if the chief executive officer directly or beneficially owns 4 percent or more of the common stock. In this trichotomy, the owner-managed firm is considered the least risk averse, coming closest to the classical entrepreneur; and the externally controlled firm is presumed to be the most risk averse, since an outside stockholder may have little knowledge about the daily activities of the firm and hence his/her judgment may be myopic and reactionary.

Equation (1) can thus be written as

$$INDUCE = \alpha_0 + \alpha_1 K/L + \alpha_2 (K/L)^2 + \alpha_3 HIGH + \alpha_4 STAND + \alpha_5 SIZE + \alpha_6 SUCC + \alpha_7 EC + \alpha_7 OM + \epsilon, \qquad (2)$$

where MC is subsumed in the intercept term. The dependent variable, INDUCE, represents the percentage of a firm's technological advances that come from its own (self-financed) R&D activities. The independent variables were previously defined. The error term, ϵ, is assumed to obey the ordinary least-squares assumptions. Table 2 summarizes the hypothesized directions of the coefficients in Equation (2) based on the arguments posited above.

Table 2. Hypothesized Direction of Influence of the Independent Variables

Variables	Direction
K/L	$\alpha_1 > 0$
$(K/L)^2$	$\alpha_2 < 0$
HIGH	$\alpha_3 > 0$
STAND	$\alpha_4 < 0$
SIZE	$\alpha_5 > 0$
SUCC	$\alpha_6 > 0$
EC	$\alpha_7 < 0$
OM	$\alpha_8 > 0$

The Dependent Variable

The dependent variable, INDUCE, represents the percentage of a firm's technological advances that come from its own (self-financed) R&D activities. This variable reflects the firm's subjective evaluation (as reported by the R&D vice president for 1976) of the role of the in-house R&D program within the firm's overall strategy for acquiring new technologies. A total of 275 major R&D firms within the manufacturing sector were surveyed and interviewed, as described in [21], in an attempt to quantify the dichotomy between the use of the firm's own R&D resources relative to the use of existing external technology markets.

The variable INDUCE simply dichotomizes the source of the firm's technology as being related to its R&D program or not. Obviously, there are several external sources for acquiring new technology or technological information, such as consulting [30], licensing arrangements, or government contracts [9]. An analysis of the relative importance of any particular source would be useful but is beyond the scope of the data. The range for INDUCE is .12 to .83 with a standard deviation of .27 and with a mean of .46.

To our knowledge, this research represents a first attempt to quantify (at any level of aggregation) the make versus buy decision across a large number of manufacturing firms. Hence, there are no other data with which to compare our values on INDUCE. Buer [8] has empirically analyzed the make versus buy decision for a small sample of firms in five select industries. While his pilot study is not formulated in the form of an econometric model, as is ours, the dependent variable is calculated in a similar manner. However, an indirect attempt to validate the predictive capabilities of the INDUCE variable is in [25]. There is a well-established body of literature in which researchers have examined the relationship between firm and industry productivity growth and the firm's own R&D expenditures [16]. Terleckyj [40] [41] has shown there to be a positive correlation between industry *i*'s productivity growth and the R&D done in industry *j* which reaches industry *i* through capital and intermediate input purchases. Link's [25] results, at the firm level, arc very similar when purchased technologies are approximated as (1 – INDUCE).

The Independent Variables

The industry capital-to-labor ratio variable, *K/L,* associated with each firm is measured as the ratio of gross book value of depreciable assets in millions of 1976 dollars divided by the total number of employees, in thousands, in 1976. These data, at the four-digit SIC level, come from the *Annual Survey of Manufactures.* Each firm's four-digit classification was obtained from either Compustat or the *Register of Corporations.*

HIGH is a binary variable equaling 1 for industries rich in opportunities for new product breakthroughs and 0 otherwise. Following Wilson [48] and others, and verified by Link [24], industries likely to have HIGH = 1 are basic chemicals, plastics, synthetics; pharmaceuticals; computers; electronic equipment and components; aircraft and missiles; scientific instruments; optical and photographic equipment; and medical instruments and supplies. Link [24] has shown that firms in these industries are relatively more intensive in product development R&D.

Firm size, SIZE, is measured as the natural logarithm (to account for nonlinearity) of the firm's 1976 gross sales and other operating revenue less discounts, returns, and allowances (in millions of dollars) as reported by Compustat.

Each firm's success rate in previous R&D endeavors was obtained as part of the survey information. SUCC represents the firm's R&D vice president's subjective assessment of the percentage of its R&D projects that profitably reached commercialization. As noted above, there are no other sources with which to measure the accuracy or representativeness of our survey responses. We attempted, through interviews, to establish interfirm consistency in the responses. Thus, although the magnitude of SUCC may be biased, cross-firm variability in its values is presumed to have some meaning. Data related to a firm's form of ownership control were obtained from its published proxy statement. Both EC and OM are measured as binary variables as described above.

There are no published statistics related to any aspect of the degree of product standardization within an industry. We attempted to calculate a four-digit industry index of the intensity of voluntary product standards using information from the National Bureau of Standard's *Tabulation of Voluntary Standards and Certification Programs for Consumer Products* [43] and from the unpublished documentation to that publication. Specifically, our index (STAND) measures the proportion of seven-digit product lines within a four-digit category for which at least one voluntary standard existed by 1976. (For a complete discussion of STAND, see [23] and [26].) However, since STAND applies only to consumer goods industries, it is initially omitted from our estimation of Equation (2) using the entire sample of firms. Then, STAND is included in a second estimation of Equation (2) using the smaller sample consisting of only firms in consumer goods industries.

The Empirical Results

The least squares results from Equation (2) are reported in column 1 of Table 3.

Table 3. Estimated Regression Results from Versions of Equation (2) (*t*-statistics in parentheses)

Independent Variables	1 ***n* = 275**	2 ***n* = 115**	3 ***n* = 115**
Intercept	7.67 (2.49)**	9.31 (2.03)**	9.40 (1.94)*
K/L	1.09 (.72)	.59 (66)	.62 (.53)
$(K/L)^2$	–.052 (–1.95)*	–.038 (–2.09)**	–.039 (–2.13)**
HIGH	5.31 (1.87)*	7.27 (2.07)**	6.85 (2.15)**
STAND	—	—	–.513 (–2.09)**
SIZE	2.41 (3.03)***	3.27 (2.58)***	2.83 (2.25)***
SUCC	.087 (2.03)**	.109 (2.37)**	.117 (2.41)**
EC	–4.16 (–1.73)*	–3.98 (–1.84)*	–4.03 (–1.81)*
OM	8.92 (2.01)**	9.47 (2.01)**	9.36 (1.98)**
R^2	.577	.602	.684

*Significant at the .10 level.
**Significant at the .05 level.
***Significant at the .01 level or better.

The industry characteristics considered in the analytical model performed as predicted. The signs on the *K/L* terms suggest the inverted U-shaped relationship, although only the estimated coefficient on the $(K/L)^2$ terms is statistically significant. The estimated coefficient on HIGH is positive, as predicted, and it is statistically significant at the .10 level.

The estimated coefficients on the firm-specific variables are as predicted, too. Larger firms exhibit a greater tendency to induce technologies than do smaller firms. The estimated coefficient on SIZE is significant at the .01 level or better. Also, firms that have in the past enjoyed economic success in their R&D programs are more likely to allocate R&D funds to induce technology. The estimated coefficient on SUCC is significant at the .05 level. Owner-managed firms, which presumably have a greater taste for risk, are more likely to induce technology; the estimated coefficient on OM is significant at the .05 level. Similarly, externally controlled firms are less likely to induce technology; however, the estimated coefficient on EC is significant only at the .10 level.

Overall, the explanatory power of the regression equation is rather robust. Nearly 58 percent of the explanatory power has been accounted for by this set of independent variables.

As explained above, a subsample of 115 firms from consumer goods industries was also examined.[3] The regression results reported in columns 2 and 3 of Table 3 consider versions of Equation (2) with and without STAND. That firms within this subsample behave in a manner similar to that of the complete sample is evidenced by the consistency between columns 1 and 2 of Table 3. Of particular note is the increased regression coefficient on SUCC in column 2. This probably reflects the fact that R&D activity in consumer goods firms is more development intensive (i.e., less basic research) than in the rest of the manufacturing sector [21].

Standardization, as measured by STAND, docs appear to be an important determinant of induced technological activities. Its inclusion accounts for over 8 percent of the explained variance in INDUCE. The inclusion of STAND reduces, somewhat, the size and significance of the estimated coefficient on SIZE. The collinearity between these variables reflects the fact that standardization is more likely to occur in technologically complex industries [23] [26], and such industries are often more R&D intensive. Of course, R&D intensity and firm size are likely related [21] [22].

LIMITATIONS OF THE STUDY

These empirical results should be viewed somewhat cautiously. First, the dependent variable is subject to "noise" caused by, among other things, intermanager differences in interpretation of the survey instrument [21] [22]. Also, as it is used in this paper, it implicitly treats new technologies as being homogeneous in their expected impact on the firm.

Second, several of the independent variables may be capturing attributes broader than those defined by the theoretical model. For example, our *K/L* variable captures not only production but also administrative facets of firms within the industry. Also, our variable HIGH is a crude dichotomization of technological opportunity, but a finer categorization would require extensive subjectivity. Although *n*-chotomous variables, such as HIGH, are commonly used within the literature, we hesitate to interpret literally the estimated coefficient. Rather, we viewed $\hat{\alpha}_3 > 0$ as indicating that interfirm variability in INDUCE is systematically related to industry characteristics not captured by the other independent variables. We did divide the sample of 275 firms into two groups corresponding to the HIGH variable and estimated a version of Equation (2) for each sample. The only significant finding was with respect to the estimated coefficient on SUCC: Previous R&D success is a relatively more important determinant of INDUCE in firms which are in HIGH industries. This may simply be reflective of the symbiotic relationship between process and product innovations in technology-intensive industries. (These results are available upon request from the authors.)

Third, because of data availability, our variable SIZE was based on firm revenues rather than on the more usual number of personnel. Finally, the variable SUCC is qualitative. It reflects the R&D vice president's perception of commercial success in both product and process innovations

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[3] Our listing of four-digit SIC consumer goods industries comes from [31]. Each firm's four-digit SIC classification was taken from Compustat. In those few cases where Compustat's classification was at the three-digit level, a disaggregated coding was taken from Standard and Poor's *Register of Corporations.* This sample of 115 firms appears quite representative of the total R&D activity in all consumer goods industries within manufacturing. The R&D coverage ratio, based on 1976 data, for the sample of 115 firms is 67.2 percent.

although our model is specific to processes. Even subject to these caveats, the estimated results are encouraging and suggest that the theoretical constructs of our model are being partially measured.

IMPLICATIONS OF THE FINDINGS AND CONCLUSION

The stated aim of this paper was to explain interfirm differences among decisions by manufacturing firms to purchase or induce new process technologies. Even with the limitations discussed above, the study's results are striking: the hypothesized industry and firm characteristics proved significant. We find this particularly important given that firm size—a variable often linked to innovation—was included as a predictor. Four major implications follow from these findings.

First, these results support the notion that identifying alternate sources (primary and secondary) for stimulating process innovation may prove to be a viable strategy in targeting federal policies for achieving technological opportunities. More importantly, it was apparent that with certain industries (e.g., those dominated by products in the specific stage of process development, those characterized by low technological intensity, and those exhibiting high levels of product standardization) the most efficient means of encouraging process innovation may be by stimulating the R&D efforts of the industries' suppliers. Such an outcome adds emphasis to the cited call for research aimed at better understanding the role of suppliers in industrial R&D.

Second, a direct outgrowth of this first implication involves a strategic perspective for firms marketing process technologies to other firms. Decisions to offer new products or to market a major as opposed to a minor product should be made in recognition of the competitive environment of targeted industries. Two markets, in fact, might be involved: one involving general purpose process equipment directed toward firms competing on a basis of product quality and innovation and the other involving firms competing on a basis of product quantity and efficiency. Further research investigating the nature of these markets for new process technologies is advocated since such knowledge would result in a better understanding of the strategic decision to purchase or induce new process technology.

Third, these findings also support the recently advanced views that federal policies directed toward encouraging industrial R&D must be cognizant of the potential for differing effects across industries. Clearly, research aimed at identifying industry groupings most amenable to specific federal R&D policies is encouraged. These results also indicate that Hage's [18] ideas regarding the influence of environmental constraints on organizational strategic choices may provide fertile ground for segmenting manufacturing firms into relevant industry groupings. Research aimed at formally examining the hypotheses put forth by Hage is consequently encouraged. For example, neither this nor other known studies have assessed the relative importance of environmental forces vis-à-vis individual firm attributes. One might expect this to vary across industry groupings and with regard to the particular strategic choices being observed.

Finally, the relative success of our model indicates that extrapolating the Utterback-Abernathy model to an industry formulation may possess merit. Further empirical and theoretical research examining the validity and implications of such a formulation is highly encouraged.

Correspondingly, firm characteristics as well as industry characteristics were observed to be significant. This serves notice that innovation behavior is far too complex to be captured by any limited set of variables [4]. Studies examining industrial R&D, or other organization innovations, must select from a wide variety of variables that are believed to reflect best the particular behaviors being investigated. Nonetheless, when concern is at a policy or strategic level regarding manufacturing organizations, an industry-based formulation of the Utterback-Abernathy model may very well prove to be a useful *starting point* for identifying an appropriate collection of predictor variables.

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