RADICAL TECHNOLOGY, ORGANIZATION SIZE, STRUCTURE, AND CONTEXT
IN THE INNOVATION PROCESS

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EXECUTIVE SUMMARY

In a study of 371 new products, introduced primarily since 1978 in the U.S. manufacturing industries of food, chemical, rubber, machinery and measuring instruments, we found the following:

- Large firms (500 or more employees) were significantly more likely to introduce radical new products than small firms—evidently because larger firms have resource advantages. Small firms were significantly more likely to report initial cost and debt service (high interest rate) problems in innovating.

- Large firms were significantly more likely to require an innovation champion to introduce a new product, but small firms were significantly more likely to have champions among top managers. Innovation champions were significantly correlated with the introduction of radical technology innovations.

- In mature industries, larger firms were more likely to introduce radical innovations and require significant processing innovation in order to offer the new product for sale.

- Larger firms report a greater proportion of government funding support for new product introduction, but most firms did not use any government funding for innovating.

- There is no apparent difference between small and large firms for difficulties encountered in regulatory compliance in innovating, but the proportion of firms reporting significant nonfunding, government influence is so small, this conclusion is very tentative at best. A better conclusion is that most firms in this sample were not significantly influenced by the government, in funding or otherwise.

- Small firms had a greater tendency to favor external sources of information than large firms for production needs leading up to the introduction of a new product. There does not appear to be a difference between large and small firms on preference for external or internal sources of information for development and marketing of new products. Internal information sources were favored overall for development and production by all firms.

- New products that had an absence of continuing cost problems and incorporated radically new technology are more likely to be successful overall (technical and commercial success).

- Very few firms in the sample were substantially influenced by customers in the design of their new product. When there was an effect (albeit infrequent), large firms
are significantly more likely to be influenced by customers. 

- There was no statistically significant difference between the success of innovation in the sample that were developed as the result of a stimulus from customer demand versus technological capability of the firm. Stimulus category does not appear to influence the success probability of type of innovation we studied in this sample.

Based on these, and the other findings of the study, we recommend the following:

- The success rate of small firm innovation would probably be substantially enhanced if measures were taken to ensure continuing funding and provide other resources available to small firms that have made a substantial start with significant new technology products.

- Policies and measures that allow and encourage joint funding of innovative new products ought to be promulgated.

- Nonfunding government influence on the innovation process should be monitored on a periodic basis for adverse impacts.

- Production innovation information should be made available to small firms, perhaps as part of government-university-industry cooperative agreements. Regional development efforts ought to incorporate this recommendation to enhance the probability of successful implementation.
1. INTRODUCTION

This report is divided into four major sections. In the first section we review the background of the study, develop propositions and summarize the purpose of the study. In the second section the methodology of the study is presented. Section three contains the primary results of the data analysis, and in section four we summarize, draw conclusions and make recommendations based on the study. Section five contains references while supporting materials are appended, as referenced in the text.

1.1 Background of the Study

For the purposes of this study it was assumed that organizational innovation, both the adoption of and origination of new products and services, is a significant contributor to organization effectiveness (Mansfield, 1980; Hambrick, 1983; Dollinger, 1983), and the declining innovativeness of U.S. firms, especially in the manufacturing sector, is a major cause of the erosion of the U.S. world competitive position (Schlie, 1983).

The causal position, relative importance of and measurement of organization size in the innovation process has become a widely debated, frequently researched and even controversial issue (Richman, 1983). While most studies and conjectures have assumed size to be a determinant of innovation at the firm level, size may, in fact, be an intervening variable or result of the innovativeness as well. It is rather easy to find examples of both large and small firms that have grown as the result of being successful innovators.

The relative importance of size as a predictor of organization innovativeness and the direction and nature of the causal influence of size on innovativeness is not a topic of widespread agreement in the research literature. Some studies have found that smaller firms are more innovative (Rothwell, 1978; Globerman, 1975), while others (Moch and Morse, 1977; Armour and Teece, 1980; Kimberly and Evanisko, 1981) found that organization size was directly related to innovation. That is, larger organizations are more likely to be innovative. To the extent that Rothwell (1978) qualifies his results by saying that when large capital investment is required to be innovative, it is not the small- and medium-sized firms that are innovative, one could conclude that it is the type of innovation that moderates...
the size-innovativeness relationship. That is, for radical innovations, which might involve more funds for things like technical work, capital investment for plant and equipment, and funds for marketing and promotion, large size is a key enabling condition, because of access to resources. This is a variant of the "organization slack" hypothesis in innovation research (Bourgeois, 1981). Discretionary resources are a necessary condition for innovating.

Another aspect of the size and innovation issue is raised by the findings that small organizations are relatively more innovative in proportion to their size. This is the so-called "innovation efficiency" issue. For example, one recent study found that "small firms produce 2.5 times as many innovations as large firms, relative to the number of people employed," (Gellman Associates, 1982, p.ii).

In an earlier study, using a similar methodology, it was found that for a total of 319 innovations, "the data shows that, over the 21 year period, 47.3% of the innovating organizations had less than 1,000 employees and 52.6% of the firms had over 1,000 employees. This suggests that during the 21 year period small and medium sized firms have kept pace with the innovative activities of large firms." (Gellman Associates, 1976, p.51). Both of these studies did report that large organizations were more frequently the sources of significant innovations. In a recent study of 46 firms in Quebec and Belgium employing 15-200 people, it was found that "innovation in firms of modest size is largely of the imitative variety as a result of resource limitations in these firms," (Gasse, 1983, p.1). Gasse (1983, p.4) further reports that for 85% of the sampled firms, "introduction of radical changes is a rare occurrence," which applied to both products and processes. This finding has important implications for proposition one which is developed below.

In an extensive evaluation of significant innovations in the U.K. since 1945, Pavitt (1983) recently reported percentages considerably below the Gellman numbers. Small firms (up to 1000 employees) accounted for only 20% of over 2000 significant, successful commercial introductions of new or improved products, processes and materials over the period 1945-1980 in 30 manufacturing sectors. However, he reports that this is "considerably greater than their share of R&D performed in industry (4% in 1975) but less than their share of employment (47% in 1958; 37% in 1978.) or net output (40% in 1958; 32% in 1978.)" (Pavitt, 1983, p.116). This has often been taken as evidence of small firm greater efficiency in R&D utilization, but he offers a plausible rival hypothesis that "the lower degree of functional specialization in small firms means that a higher proportion of innovative activities takes place outside what is recognized and reported as R&D activities." (p. 116). Although small firms have maintained
their share of significant innovations over this 30 year period, "the share of medium-sized firms (1000-9999) has declined, and that of large firms (10,000 or more employees) has steadily increased (p. 116)". Because the size of the innovating unit has not increased over the same period, Pavitt contends that medium-size firms may have been purchased and become divisions or subsidiaries of larger firms during this period.

He also reports considerable variance across industry sectors in the size distributions of innovating firms, similar to those reported for U.S. industry. For example, in electronics, inventive activity tends to be concentrated in larger firms. On the other hand, innovative small firms tend to be concentrated in mechanical engineering, instruments, and leather and footwear.

A number of researchers have advocated controlling for organization size in innovation studies. Rogers and Eveland (1975, pp. 344-46) suggest that size has been found to be a predictor of organizational innovations because it can be measured easily with precision and it is a surrogate measure of several other organization dimensions that may cause innovation. They suggest, for example, controlling for size by matching two organizations of equal size, one that is highly innovative and one that is not innovative. Hage (1980, p. 173) suggests that innovation rates be standardized by organization size, or that the rate of throughput (process) or output (product or service) innovation for a given period of time be divided by organization size. In this way one could see what differences among organizations really account for variance in innovation. This becomes particularly important when heterogeneous samples or organizations are studied, a point taken up elsewhere in this report. "Organization size" presents both theoretical and methodological problems in the literature or organizations. Kimberly (1976, pp. 587-588) identifies four "substantively important aspects or organizational size...": the physical capacity of an organization, the personnel available, organizational inputs and outputs, and discretionary resources.

Although the most likely correlate of size that makes a difference in innovation research is available slack resources, including money, people, and facilities (Hage, 1980; Ettlie, 1983; March, 1981), there are theoretical reasons to suspect that organization size is both an advantage as well as a disadvantage to innovating for an organization. Small firms have to overcome the disadvantage of inadequate slack resources that comes with small size. A recent NSF report (1981) found that among the major problem areas faced by small high-technology firms believed to be engaged in R & D, "The lack of adequate funds appears to be an underlying
factor in most, if not all, of the problem areas. For example, small firms with sufficient funds could offer more competitive salaries and benefits..." (p. 3, NSF-81-305). In some ways, the absence of slack acts as an entry barrier into many established industries and it is not surprising that often small firms are the first firms in a startup industry (Globerman, 1975).

Case studies often report the advantage small firms have over large firms in being able to adapt to environmental pressure and innovation because there is less organization structure to get in the way. For example, at Sinclair Research, Ltd., which has tripled in size in two years to 70 employees, one principal was quoted as saying that "because the company does not have a massive structure... 'it moves quickly'" (Business Week, October 17, 1983, p. 92). It was also reported that Sinclair Research relies on outside design collaboration and purchase for success which supports Pavitt's (1983) finding that total R&D activities and expenditures are under-reported for small firms. Innovators in an established industry are often the newcomers (Goodman and Abernathy, 1978).

Large firms, on the other hand, have to overcome the resistance to change when success has led to growth, the maturing of technology, and the maintenance of large volumes and lower prices (Utterback and Abernathy, 1975). Although it is difficult to document and generalize, it is often reported that because the dominant coalition of decision-makers in a large firm attempts to minimize risk-taking, it is unlikely that the organization, even in a crisis, will respond with innovation as a strategy (Hage, 1980). A performance gap (March and Simon, 1958) does not appear to be a sufficient condition for innovation. Ettlie, et al (1984), reports that for small firms in the mature (slow growth) food processing industry a performance gap significantly inhibits innovation, whereas, when sufficient slack resources are available for innovation (measured by the log number of employees), performance gaps were directly related to innovation outcomes (Ettlie, 1983).

Organization size is also a methodological problem in organizational research. In addition to being a possible surrogate for any number of other variables (Duchesneau et al, 1979), organization size measures have not been generalized across different types of organizations and industries. Although about 80% of the published studies on organization size and structure have used number of employees as the primary measure (Kimberly, 1976), most studies of specialized populations of organizations have often picked the measure of size most meaningful to that group. For example, studies of hospitals frequently use the number of beds as the measure of size.
The intercorrelations of various size measures may be consistently high within a given industry, but for heterogeneous samples of organizations this is unlikely to be the case. In one unpublished study, for example, reported in Jackson and Morgan (1982, p. 288) the average relationship among measures of size over thirteen years as indicated by correlations between employees, assets, gross plant and net sales varied from .335 to .936 (n varied from 263 to 335). The latter correlation was for net sales and employees. Also, the relationship between sales volume and number of employees can vary greatly from industry to industry. This suggests that studies that have lumped firms together on any one measure of size, including number of employees, without establishing the homogeneity of the industry or analysis grouping, may have produced results that should be viewed with extreme caution. A "large" firm in one industry may be small in another. In addition to these problems, distributions of size measures like number of employees are often skewed and curvilinearly related to other variables. Using the log of number of employees may not always be justified as a remedy to this problem (Kimberly and Evanisko, 1981).

In summary, given the relative importance of organization size not only in innovation studies but in the more general area of multidisciplinary research on organizations, little systematic theoretical or methodological rigor is evident in the literature. There appears to be a pressing need to begin to remedy this situation if government science and technology policy are to be effectively informed by empirical research in this area.

1.2 Propositions

1.2.1 Incremental vs. Radical Innovation and Firm Size

One of the consistently useful categories of type of innovation has become the dichotomy of "radical versus incremental". This designation appears to be at least as important as the fundamental difference between a product and process innovation (Utterback and Abernathy, 1975; Rubenstein et al, 1974--doc. no. 74/96; Chakrabarti, 1975--doc. no. 75/89), or the difference between a technological and an administrative innovation (Daft and Becker, 1978; Kimberly and Evanisko, 1981).

The reason for making these distinctions is because so many contingencies involved in supporting propositions seem to hinge on a few fundamental innovation characteristics (Downs and Mohr, 1976). For example, product innovations are more typical of firms in less mature industries, while process innovations are more typical as
a firm grows and attempts to reduce the cost of existing products with high volume (Utterback and Abernathy, 1975). The causal pattern is usually found to be different for radical vs. incremental innovations (Duchesneau et al, 1979; Ettlie et al, 1984).

What makes an innovation "radical"? This has proved to be a difficult question to answer. Duchesneau et al (1979) used the Science Indicators definition of radical change to study process change in the shoe industry that defines revolutionary innovation as one that incorporates technology that is a significant departure from existing technology at the time of its commercialization. Respondents answered in three categories: 1) "No new knowledge contained in the machine or process; 2) the machine or process is an improvement of existing technology; and 3) the machine or process is a major technological advance" (p. 429).

Gellman Associates (1976, pp. 9, Appendix C), measured the degree to which an innovation embodied radical technology with responses to one question: "20. Radicalness Classification - The technological change underlying the innovation is best characterized as a: (check one), radical breakthrough, major technological shift, improvement, imitation, no new technological knowledge required, (or) not known."

The variable was called "technological worth", and the actual data tended to group in one of three of the first three response categories of: radical breakthroughs, major technological shifts, and improvements. A greater number of radical innovations were attributed to the United States than three of the four other countries studied. Only the United Kingdom scored higher in that extreme category; France, Japan, and West Germany were lower on radical innovation. The hypothesis that composition of senior management in educational and professional background spurs radical innovation was not clearly supported. Radical innovations were more likely to come from concentrated U.S. industries, and small and large sized firms had the highest percentages of radical breakthrough and major technological-shift innovations at the time of market introduction. Small firms were defined as having sales less than $5 million; medium sized firms were from $5 million to $50 million; and large firms were greater than $50 million.

It is noteworthy to recall the evidence of at least two studies that show that when significant financial and other resources are required, small and medium-sized firms are less likely to be innovative or mount radical change efforts (Rothwell, 1978; Gasse, 1983).

These two efforts at characterizing radical vs. incremental innovation are based primarily on innovators' perceptual measures, although the innovations selected for investigation in both studies resulted also, in part, from independent expert opinion. Hage (1980) suggests at
least four other criteria that might be used to distinguish a radical from an incremental innovation: 1) the degree of risk involved in adoption, or the uncertainty of outcomes of using the technology; 2) the degree to which the innovation is new to the adopting unit and new to the referent group of organizations, e.g., an industry; 3) the degree to which the innovation requires both throughput (process) and output (product or service) change in order to be successfully used; and 4) the magnitude or cost of change required for adoption by an organization, either in relative or absolute terms. Truly radical innovations are rare by these definitions. Hage's (1980, p. 191) examples are the automobile, airplane, radio, and the (main frame) computer. In two studies, only about 10% of new product introductions were found to be the first of their kind or new to the world (Pavitt, 1983, p. 124; Booz Allen and Hamilton, 1983). It is relatively easy to see how the simple dichotomy of radical and incremental is probably insufficient for this variable. Perhaps an index incorporating both perceptual and objective (e.g., cost) measures might be constructed to more reliably measure this construct. Unfortunately, reliable cost information is seldom publicly available.

One of the probable reasons that there have been inconsistencies in the findings on firm size and innovativeness is that we have failed to adequately distinguish between radical and incremental technological departures from existing practice in a sector. As organizations grow, they experience control problems and divert resources, attempting to maintain a balance between both integration (coordination) and differentiation (specialization) of functions (Lawrence and Lorsch, 1967). On the other hand, small firms often lack the resources needed to initiate and sustain radical change. It is not too surprising that joint ventures and mergers often occur between large and small firms for innovating purposes (Hlavacek and Dovey, 1977; Globerman, 1975; Owen, 1977). Large firms are likely to be protecting market shares while small firms are just beginning to respond to increased market demand pressures. Large organizations that have institutionalized incremental change are not likely to respond to a crisis with radical change (Hage, 1980). Taking this and the preceding discussion on firm size and radical innovation into account, the following proposition is offered for testing:

Proposition 1: Small business innovations are more likely to incorporate technology that represents a radical departure from existing practice in the industry, while large firms are more likely to innovate using incremental technology. The exception to this tendency is the case where radical change requires substantial resources that are not normally available to small business, and where no joint
venture or alternative source of funds can be found (e.g., venture capital or government funds).

1.2.2 Firm Size and Innovation Champion

Large firms tend to have more complex organization structures, are often more formalized, and are usually more decentralized in their operations (Jackson and Morgan, 1982). It is not surprising that the emergence of an "innovation champion" has been necessary for innovation under these conditions (Chakrabarti, 1974; Ettlie et al, 1984). Because small firms are more informal and centralized, top (often founding) management can take on the characteristics of an innovation champion during the strategy formulation process. The following proposition is offered:

**Proposition 2:** Small firms innovate primarily as a result of top management strategic commitment to change in a structure that is relatively simple, while large firms are more likely to innovate after the emergence of an innovation champion (or other structural adaptation) which is necessary in a more complex, more formal and a more decentralized structure.

1.2.3 Firm Size and Product vs. Process Innovation

In the Utterback and Abernathy (1975) evolutionary model of the development of the productive segment of the firm, it is hypothesized that firms (Stage I) that are in less mature industries (Abernathy and Townsend, 1975), and that are early in the life cycle of processes, products, and market expansion, will be more likely to concentrate on product as opposed to process innovation. Process innovation and a general, lower level of innovativeness, are more typical of firms in mature industries. It also follows that product innovation has a more important position in the competitive strategy of these less mature firms. They support these two propositions using a secondary analysis of the Myers and Marquis (1969) data. Ettlie (1979) found support for the first hypothesis in a sample of 34 transportation innovations. Utterback and Abernathy (1975) also found (for a much smaller subsample) that Stage I firms tend to be "small" (having sales of less than one hundred million dollars). Based on these findings, the following proposition is offered:

**Proposition 3:** Small firms that have been more recently founded in less mature industries (Stage I) are more likely to produce product innovations,
whereas larger (Stage II) firms will concentrate on process innovation, and still larger firms (Stage III) in mature industries will be less innovative than either Stage I or Stage II firms.


Although the government represents an important force in the firm's environment (Ettlie and Bridges, 1982), there is no consistent evidence as to whether this force generally inhibits or stimulates innovation (Marcus, 1981). There are a variety of possible influences the government can have on a firm that might have an impact on its capability and inclination towards innovation. The government can directly support innovation through grants, cost-sharing and tax credits for innovation. Regulations in health and safety or environment apply for most operating organizations. Economic regulation varies considerably by industry. Public Services like utilities and telecommunication are heavily regulated, while manufacturing enjoys more freedom from economic regulation. Activity needed to meet a regulatory standard may cause the firm to hire professionals who increase the firm's capability to innovate in other areas in the future.

It was recently reported that large firms are more likely to be assisted in innovation by public funds (Gellman Associates, 1982); but this statistic does not control for radical vs. incremental innovation, does not measure the magnitude of the support, and does not allow for other types of assistance like information and tax credits. In a recent study of the mature (slow growth) food industry, it was reported that larger firms with greater concentration of technical specialists are likely to prefer less dependence on the government for assistance in innovating (Ettlie, 1983b). It was also found that larger firms are more likely to utilize a variety of information sources in developing a radical packaging innovation, but they are not necessarily likely to go ahead and act on this information. It may be that small firms depend more on information services like the government and trade associations because of lack of in-house resources. Government policy concerning direct support of R & D has favored areas that industry normally would not develop and basic research, which small firms might benefit most from in establishing entry into an industry or establishing a new industry.

Small businesses have a more difficult time complying with government regulation. Small businesses collectively bear the burden of at least 60% of all regulatory
costs (Graham, 1980). In addition, small business has a relatively small voice in the formulation of government policy (Lang, 1976).

The following propositions are offered:

Proposition 4: Large firms are more likely to be assisted in innovating by public funds, but the relative magnitude, proportionately, of the assistance will be less than when small firms are assisted by public funds for innovation.

Proposition 5: Regulatory compliance is more difficult and relatively more expensive for small businesses but, over a period of time, compliance that requires hiring and concentration of technical professionals will increase the likelihood of small firm innovation.

Proposition 6: Small firms are more likely than large firms to utilize external, especially government sources of information for innovating.

2. METHODOLOGY

2.1 Scope of the Study

The overall design of the study called for two separate phases. The first phase was devoted to focusing the study on a limited but varied set of manufacturing industries and then developing a nomination process to generate a set of candidate innovations that had been offered for sale since 1970. Particular attention was given to more recent offerings during the last four years (1979-1982). The second phase of the study was devoted to locating and obtaining data from the firms originating these innovations. The industries that were ultimately targeted were:

1. Food and Kindred Products (SIC 20)
2. Paper and Allied Products (SIC 26)
3. Chemicals and Allied Products (SIC 28)
4. Rubber and Misc. Plastic (SIC 30)
5. Machinery, Except Electrical (SIC 35)
6. Electrical Machinery (SIC 36)

These six major group SIC categories were selected because of project team experience with the industries and the range of R & D intensities* concentration ratios,*

*The percentage of sales spent on R & D, and median concentration ratios for these SICs are

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<tr>
<td>% Sales on R&amp;D</td>
<td>0.4</td>
<td>0.9</td>
<td>3.6</td>
<td>2.4</td>
<td>5.0</td>
<td>6.3</td>
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and other variety they afforded, like product type mix in the consumer and industrial sectors. We also attempted to complement earlier studies (e.g., Gellman) that had rather large proportions of innovations in the instruments area. (SIC 38). As will be indicated below, some considerable care was taken to select significant innovations from these categories—not just new products. One of the major limitations of previous research in this area that was indicated earlier is that little attention has been paid to the distinction between radical and incremental innovation at any stage of the research effort, including sampling the cases. We attempted to overcome some of these limitations in the present study.

2.2. Nomination of Cases

Two primary methods were used to nominate cases for the study. The general strategy was to include as many award cases in the sample as possible—that is, innovations that had been offered for sale and that had also received some industry award. Awards given exclusively to individuals were excluded because the firm was taken as the unit of analysis in this study. In order to locate award case innovations, as opposed to just new products that were being introduced, a one-page survey questionnaire (see appendix) was mailed to industry (trade and professional) associations that seemed to be serving the targeted six major SIC code groupings to inquire about awards either that the association gave directly, or that they were aware of in the industry. We also asked as many experts in firms of these industries about awards that we could locate during the planning phase of the project. Although the response rate of the industry survey was acceptable (82 of 134 eligible case questionnaires were returned or a return rate of 61%) very little new award information on firms as opposed to individuals was obtained. We were already aware of most of the awards suggested, e.g., the IR 100, or the awards were very narrow, outside our primary SIC focus, or were for individual inventors. Our preference was to concentrate on well-known awards that subsequent research might replicate in major industry groupings. Awards also tend to get around one of the limitations of expert-informant nominations. A variety of awards covers a broader spectrum of innovating activity, and are usually the result of a panel of experts rather than one person or one firm. For example, several large firms do give awards to individuals for innovation. We decided to exclude these types of awards.
There were eight primary awards that were used to nominate this type of case for the study:

1. The IR 100, which covers all industrial R & D
2. The Vaaler awards in Chemical and Chemical processing industries
3. The Putman awards in food processing and food processing supply
4. Plastics World awards
5. Manufacturing Engineering awards
6. Food Technology achievement awards
7. Flexible Packaging Association awards
8. Production Engineering awards

Most of the target SIC major groupings were well covered by these awards. Some of these awards were given for innovations outside the target SIC groupings but were also included. An example of an award recipient is presented in Exhibit 1 on page 37. This case was not included in the survey.

Non-award cases were nominated by screening new product and technology news sections of trade publications that approximately covered these same SIC major groupings. We also used some of the more general sources available on new technology offerings like High Technology. A listing of trade journals that were ultimately used for the years 1979-1982 is given below:

1. Food Processing (e.g., food processing equipment and new products)
2. Production Engineering (e.g., industry-wide review of new machinery, computers, instrumentation)
3. High Technology (e.g., electronics and computer technology, instrumentation)
4. IEEE Spectrum (e.g., electronic and electrical engineering technology)
5. Chemical Engineering (e.g., machinery, processes related to chemical processing and engineering)
6. Chemical Engineering Progress (e.g., machinery, processes related to chemical processing and engineering)
7. Newspapers (e.g., New York Times) (e.g., new machinery, instrumentation, and processes industry-wide)
8. News Magazines (e.g., Newsweek) (e.g., new machinery, instrumentation, and processes, industry-wide)
9. Business Periodicals (e.g., Barrons) (e.g., new machinery, instrumentation, and processes, industry-wide)
10. **Chemical Processing** (e.g., machinery, processes related to chemical processing and engineering)

11. **Scientific Magazines** (e.g., *Science*, *Scientific American*) (e.g., new instrumentation)

12. **Direct Input from Experts**
Our target mailing population was chosen to be 1000 award and non-award cases. This number was obtained based on a projected desired minimum of 300 completed "originator firm innovation cases" and with an expected minimum response rate of 40% from the originator mail questionnaire survey. However, in order to obtain 1000 good candidate cases for the survey, it had been our experience in the past that extensive telephone screening of candidate cases was necessary (Cf. Ettlie, 1981). This was needed to minimize the number of mail-returned ineligible cases (e.g., product never offered for sale, foreign case, etc.) and cases that could not be located because of moves, mergers, business failures, etc.

Approximately 2500 telephone calls were made to screen candidate cases to generate the original target population of 1000 cases. Both award and non-award cases were screened alike for correct mailing address. This screening had the added benefit of alerting the potential respondent and originator organization of the impending mailing which, in most cases, seemed to create a positive expectation—especially if the primary originating person in the firm could be located for the address mail label. To give an idea of the usefulness of this screening, approximately one hundred award cases alone were eliminated from the population by this screening. Firms had never offered the products mentioned in the awards, could not be located, refused participation in the survey, were foreign owned, and other reasons.

Eventually, the 1000 population cases were generated: a total of 535 award and 465 non-award cases, predominately in the six major SIC code groups of the targeted industries: SIC 20, 26, 28, 30, 35 and 36.

Archival data on firm size as measured by number of employees was available on part of the 1000 population cases. These data are presented in contingency table form by firm size category (small, with 499 employees or less; large, with 500 or more total employees) and award or non-award status in Table 1 on page 38.

In Table 1, the percentage of small firms receiving awards for innovations was 38.5% (42 of 109) while 67.9% (288 of 424) large category firms received awards. It is not surprising that there is a significant inverse relationship between firm size category and award status, Kendall tau b = -.47 (p < .01). Larger firms are significantly more likely to receive awards for their innovations based on archival size (number of employees) data. Overall, only about 21% (109) of these known size firms were in the small category. This should be contrasted with Table 5a presented later where 53.6% (199 of 371) of innovating firms returning the mail questionnaire were small—yet the correlation between firm size category and award status is still in the same direction and remains significant (tau b = -.24, p < .01, n = 371). Small firms are less likely to get awards.
2.3 Mail Survey Questionnaire for Originating Firms

The compilation of candidate questions for the originator questionnaire was guided by the conceptual content of the six propositions to be tested and the variables of these propositions. Special attention was given to proposition one which probes the relationship between firm size and degree of radicalness of the innovation. A literature review and series of colleague discussion sessions seemed to point to two rather distinct treatments of radical versus incremental innovation. First, radical innovation seems to incorporate significant differences at the input side of the innovation process: substantial R & D, new science, or discontinuous technological break (through) from the past. The NSF Science Indicators reports are consistent with this approach. A second approach to radical innovation is on the output side of the innovation process—primarily the economic effects of significant technological change. The roots of this approach go back at least as far as the economic growth that resulted from the Industrial Revolution of the 1760s in England. The argument is simple: significant technological change is that which results in significant economic gain—usually to the originators. It is the former of these two approaches to defining radical or significant innovation that guided this study. Resulting indicators and questions for each variable of interest and others that were added during the course of the study are presented in Table 2. The questionnaire which was used in the mailing is included in the Appendix. The questionnaire was developed in three phases, including a literature review, and three pilot testing phases: 1) colleagues pilot tested, 2) technical and R & D managers pilot tested, and 3) mail survey of nine cases* using the revised questionnaire. A total of five of these nine cases (55%) were returned—all fully completed, with no significant missing data. The fourth and final redraft of the questionnaire was ultimately used in the originator survey.

As part of an agreement with the contracting agency, the questionnaire was divided into two parts. Page one contained: the verification of public information, including award status; firm size; and originating firm organizational unit. Pages two through six contained the other items.

*Maximum number of cases allowed by OMB guidelines for pilot testing.
2.4 Summary of Data Collection: Mail Survey of Originating Firms

The data collection consisted of two mail survey waves using the originator questionnaires, mailing labels compiled during telephone screening, and a cover letter. The questionnaire and cover letter are included in the Appendix. The first wave mailing (sent August 5, 1983) produced a response rate of 26.3% or 249 of 946 eligible cases. This was below expectation, but telephone calls from respondents indicated that vacations interfered considerably during this period. The second mailing (September 1, 1983) ultimately resulted in the final or total response rate of 46.45% or 406 returned questionnaires of 874 eligible cases. The distribution of ineligible cases appears in Table 3. Different commemorative stamps were used for the return envelopes on the second mailing so we could keep track of the relative effectiveness of the two waves. A total of 163 "medal of honor" stamps came back; or about 40% of the returns resulted from the second mailing. This percentage return on the second wave is higher than expected, so vacations may indeed have been a problem with returns for the first wave. A total of 371 complete data cases resulted from these 406 returned questionnaires. A total of 57 companies refused to participate based on their returns.

Post cards were included with the first mailing, giving potential respondents the option of requesting a telephone interview to obtain the questionnaire information. This technique did not substantially increase the response rate. Only 9 post cards were returned, some without telephone numbers and convenient times of calling. Post cards were, therefore, not included in the second wave envelopes. Given that a modest response rate of 46.45% resulted from the first two data collection waves, a random sample of 100 nonrespondents was called to determine if nonresponding was related to the key variable of the study: firm size. An analysis was also done on the 13 incomplete returns from wave one of the mailings to see if there was any apparent relationship between firm size and nonresponse. The results of this data collection and these analyses are presented in Table 4a and 4b. Of the 100 nonresponding firms called, 54 told us the total number of people employed. Of these, 31 (57.4%) were small (499 or fewer employees). Of the first batch of 13 incomplete questionnaires, a total of 8 or 61.5% were small. These percentages are almost identical, but at first glance, quite different than the proportion of known size firm cases, based on archival data, in the population of the survey (see Table 1), which indicated that about 20% of the firms were small. However, if one examines the distribution of cases in the 371 complete data returned.

NOTE: See Appendix. Of 380 usable cases, 9 had complete data except for number of employees, which diminished the usable sample to 371. Of these 371 cases, 7 were outside the manufacturing SICs or the SIC could not be determined. However, with the exception of Table 8a, these 7 cases were included in the analyses.
questionnaires (Table 5a), the proportions are comparable. Of the 371 complete data cases, 199 (53.6%) were small or assumed to be small (499 or fewer employees) and 172 (46.4%) are large. The proportion of nonresponding and responding firms by firm size appear to be almost identical. It is also apparent that large firms are over-represented in the archival data sources, which don't even agree among themselves on number of employees.*

The crosstabulation of firm size category and year sold is presented in the Appendix. The majority of responding firms introduced the new product in 1982 (115 or 31% of the 371 cases). The majority of the cases were introduced in 1980-1983 (262 or 71%). There was no significant correlation between year sold and firm size category ($r=.05$, $p=.15$, n.s.).

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>A</th>
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<tr>
<td>D&amp;B</td>
<td>230</td>
<td>10,700</td>
<td>340</td>
<td>15,000</td>
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<td>5,000</td>
<td>4,000</td>
<td>35,400</td>
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<tr>
<td>S&amp;P</td>
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<td>9,600</td>
<td>160</td>
<td>17,100</td>
<td>4,800</td>
<td>4,000</td>
<td>10,000</td>
<td>34,000</td>
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</tbody>
</table>

*Number of employees for 12 candidate cases (cont'd)

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<th>J</th>
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<tbody>
<tr>
<td>D&amp;B</td>
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<td>11,851</td>
<td>6,613</td>
</tr>
<tr>
<td>S&amp;P</td>
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<td>200</td>
<td>10,750</td>
<td>5,300</td>
</tr>
</tbody>
</table>

D&B is Dun & Bradstreet; S&P is Standard and Poor's
3. RESULTS

3.1 Overview

The results section is divided into four parts: 1) this outline, 2) analysis of data to test the six primary propositions of the study, 3) other findings; and 4) a summary. Although some interpretation of these results appears here, the implications of the findings are discussed to a greater extent in the following section (4) along with policy recommendations.

3.2 Proposition Tests

Proposition one states that small firms are more likely to introduce innovations that incorporate technology representing significant breaks with past or existing practice—radical or discontinuous innovations. The exception is where radical innovation requires substantial resources not normally available to smaller firms. The barrier to testing this proposition in the past has been a good measure of radical technological innovation. Multiple indicators were used in this study. The primary indicator was the award status of the innovation case. A case receiving an award was assumed to be an example of radical technological change for sampling purposes, but other indicators were also included on the questionnaire, following on other precedents like whether or not the innovation was new to the world (Booz, Allen & Hamilton, 1982; Pavitt, 1983). These earlier studies seem to indicate that only about 10% of new products are new to the world, and its not clear if all of these are commercially successful. Since more than 10% of the population and sample cases were award innovations, a higher percentage of "first of their kind" innovations was expected and obtained (based on opinion of respondents) in this study. In Table 5a, the crosstabulation of award status and firm size category is presented. This includes new award information on cases that respondents provided. The Pearson product-moment correlation between award status and firm size is -.24 which is significant at the .01 level. About 75% of the large firm cases received awards, while about 51% of small firm cases received awards. Based on award status, larger firms are significantly more likely to introduce radical new products.

Is award status a good indicator of radicalness? The largest correlations between award status and the seven other indicators of radicalness were for

* A total of 231 (85%) of the 371 complete data cases received awards.
novelty—whether the product was new to the world—and whether or not the innovation incorporates breakthrough technology. The correlations were $r = .27$ ($p < .01$, $n=355$), and $r = .26$ ($p < .01$, $n=361$) respectively. These two alternative indicators of radicalness are arguably the most popular indicators used today. It appears that award status is a good indicator of radicalness, and the correlations between firm size (by category) and novelty, $r = -.11$ ($p=.02$, $n=364$); and firm size (by category) with radical technology, $r = -.09$ ($p=.04$, $n=370$), tend to bear this out.

In order to fully test proposition one, however, it is necessary to see if small firms are prevented from introducing radical new products because of lack of sufficient resources. An indirect measure of the resource variable used in this study was the relative cost to develop and to bring the innovation to market. Pilot test data indicated that absolute cost was a sensitive question and was dropped from the final version of the questionnaire. Tables 5b and 5c present the results of crosstabulating award status with firm size (category) controlling for cost to introduce.

For the condition of "most costly product to introduce" (Table 5b), the correlation between award status and firm size (category) is not statistically significant; $r = -.07$. For the condition of "not most expensive", there is a significant correlation between firm size (category) and award status, but not in the predicted direction, $r = -.32$ ($p < .01$). That is, large firms are more likely to introduce innovations that are radical, based on award status, even when the innovation is not the most costly to introduce. For the third, and final category of cost—"the only product of the firm"—there is a direct relationship for awards and size ($r = .27$, $p = .12$), but it's not statistically significant. There are only 20 cases in this category. Eighteen of those 20 were small firms, as would be expected. Nine of the 18 received awards, so this condition should probably be disregarded. In addition, relative selling price at time of introduction was not significantly correlated with firm size category ($r = .05$, $p = .21$). However, price of award products was significantly lower than for comparable products ($r = -.18$, $p < .01$, $n=255$).

A total of eight specific funding problems were covered on the questionnaire. These included accounting for development as expense vs. capital budget, lag in funding, timing in funding, obtaining the total amount, debt service (high interest rate), initial cost, continuing cost, and over-budget requests. The most frequently mentioned problem by respondents was expense versus capital budget for development, with 59 (15.9%) indicating this problem. Second was continuing cost with 42 mentions (11%).
Crosstabulations of size category by problem mentioned were run for the eight problems, and for two of these funding problems, significant correlations were found: debt service and initial cost were mentioned significantly more often for small firms, \( r = -0.26 \) (\( p < 0.01 \)), and \( r = -0.12 \) (\( p < 0.01 \)), respectively. The qualifying condition of proposition one appears to apply to this sample of organizations and industries and is supported. That is, small firms are less frequently the radical innovators because of the initial cost of radical innovation. However, as will be seen later, it is the absence of continuing cost of innovation that is most likely to predict innovative success (Table 14).
Proposition two states that an innovation champion is more necessary for innovating in a large firm than a small firm. This does not assume that championship is not present in small firms—quite the opposite—it is predicted that championship does not require any special structural adaptation in small firms, that it resides in existing, usually general management positions in smaller firms.

In Table 6, we present the crosstabulation of innovation champion and firm size (category). As predicted, there is a significant correlation between these two variables in the direction expected, $r = -0.12$, ($p < 0.02$). Although the size of the coefficient is smaller than expected, larger firms are significantly more likely to report that there was an innovation champion for the new product. In Table 7, the crosstabulation of firm size and organizational level of the champion is summarized. As predicted, there is a significant correlation between firm size category and level of champion in the organization, $r = -0.27$ ($p < 0.01$), but in this case, the smaller the organization the higher the organizational level of the champion, as predicted. Almost 80% of the small category firms had champions at or above the general manager level, whereas, only about 50% of large firms had champions for innovations at that level.

Further, the presence of an innovation champion was significantly correlated with the degree to which the innovation incorporated new technology, $r = 0.19$ ($p < 0.01$, $n=342$), and significantly correlated with the degree to which the innovation was new (or novel) to the world, $r = 0.224$ ($p < 0.01$, $n=338$).
Proposition three is a portion of the Utterback-Abernathy hypothesis about firm size and stage of development of an industry. This is a difficult proposition to test because of the grouping of industries and categorization by stage of development. Older, more mature industries tend to be stage III (less innovative overall) than stage I and II industries and, therefore, firms in these industries are hypothesized as more innovative. There is only very minimal support of this general hypothesis based on available product data, reported in Table 8a, although this is a very marginal test of the theory. Larger firms received proportionately more awards for innovations in four of the seven industries tested, (SICs 28, 35, 36 and 38), but the correlation is significant for only two of these: Kendall tau b = -.31 (p<.01) for SIC 35, Machinery; and Kendall tau b = -.36 (p<.01) for SIC 38, Instruments. There was a slight, but not statistically significant, tendency for smaller firms to get proportionately more awards in the rubber industry (SIC 30), but the sample size was small at only 16 cases; Kendall tau b = .16 (n.s.). Since none of these are high growth, high technology industries, as grouped here, this was some support for the general model, and the proposition.

In Table 8b we present the crosstabulation of firm size category by the reports of required new and significant processing innovation needed to introduce the new product. There is a significant correlation between size category and required processing change, r = -.12 (p=.02, n=355). Larger firms are more likely to introduce processing innovation along with new products than small firms. This is strong support for the Utterback-Abernathy model that states that as firms go out of stage I into stage II, they are very likely to emphasize process innovation. It also suggests that perhaps the most innovative (both product and process) firms are medium sized rather than either small or large. This proposition clearly deserves attention in further research in the area. It may also be that the greatest pressure for innovation is on medium sized firms, and this is the crucial test of a small firm's ability to grow--can small firms sustain innovation when they become medium-sized?

It is not surprising that we also find the requirement for new processing innovation to be significantly correlated with radical new product indicators. For example, new process innovation requirements were significantly correlated with award status, r=.08 (p=.052, one-tail test, n=355), with the novelty of the new product, r=.13 (p=.007, one tail test, n=342), whether or not the product was the first in
a line, \( r = .20 \) (\( p < .001 \), one-tail test, \( n=342 \)), and, finally, whether or not the new product incorporated significant new technology, \( r = .30 \) (\( p < .001 \), one-tailed test, \( n=348 \)). It may be that small firms are at a distinct disadvantage in their ability to offer significant new products that have new processing requirements, and perhaps significant capital investment requirements for new plant and equipment.
Proposition four suggests that larger firms are more likely to be aided by public funds for innovating, but the proportion of assistance is less when compared to smaller firms. In Table 9, the crosstabulation of firm size category and percentage of total cost of bringing the new product to market (e.g., R & D, capital investment, tooling, production and marketing) resulting from government sources is presented. It should be noted first, that only 124 of the 371 complete data cases report any percentage figure in this category, and 97 of these 124 firms report the percentage to be 0. The Kendall tau c for this relationship is significant at .13 (p=.04), but the magnitude of the coefficient is relatively small. There is a tendency for large firms to report a greater proportion of government funds used to bring the innovation to market, but with only 27 of 371 cases reporting any positive percentage, this result is highly suspect without further validation.

In addition, there was a significant correlation between the percentage of government funds supporting the innovation and degree to which it incorporated new technology, r=-.29 (p<.01), n=123, and whether or not the innovation received an award, r=-.15 (p<.051), n=124.

However, for this sample of innovating firms, most of the innovation funding was obtained from sources other than the government. Based on reports in the other funding categories, divisional funds provided 100% of the support for 145 of the cases and corporate funds provided 100% of the support for another 112 cases. Joint funding occurred in only 13 cases, of which only two had 100% support.
Proposition five states that regulatory compliance is relatively more difficult for small firms but may ultimately lead to greater innovativeness for small firms because it forces concentration of technical specialists that promote innovation. Government influence on the total development, production and marketing of the innovation cases was divided into two categories on the questionnaire: funding and nonfunding influences that either facilitated or hindered innovating. Proposition four probes the former type of government influence, and proposition five tests the latter.

The crosstabulation of firm size category and significant, nonfunding government influence on the innovation case is presented in Table 10a. Again, it can be seen that the vast majority (89%) of responding firms indicate no significant, nonfunding influence. Only 37 firms report any type of significant influence by category--either a significant barrier (8 or 2.3% of the 341 reporting) or a significant help (29 or 8.5%). The chi-square for this table is 0.79 (df=2) which is not statistically significant. Small and large firms appear to be equally affected, but most are not significantly influenced by the government for the particular cases investigated. The reports of content for this significant nonfunding influence, when it is present, is summarized in Table 10b.
Proposition six states that small firms are more likely to utilize external, and especially government sources of information for innovating. In this study, respondents were asked to indicate, from a list of 13 possible information sources, which was most important for three stages of innovating: development, production, and marketing. All but one source ("in-house information") were external sources, e.g. trade shows, suppliers, etc. Two of these external sources were government: "government, other than military," and "military (U.S. Government)."

The most frequently chosen information source for development and production was, by far, in-house information with 112 of 331 (34%) and 167 of 291 (57%) mentions respectively. For development, "customers" was second with 74 (22%) of mentions, and for production, suppliers was second with 64 (22%) of mentions. For marketing, however, trade shows were mentioned most frequently at 114 of 319 mentions (39%), with in-house information second (69 or 21.6%) and customers (67, 21%) third. This differentiated pattern of information utilization by stage of innovation process is very consistent with recent empirical findings, and theory on information utilization and innovation (Ettlie, 1976; Allen, et al, 1979).

Consistent with the data reported in testing propositions four and five, government influence, here as an information source, is only rarely important. Government sources, either military or nonmilitary, were reported as most important in only 12 (3.6%) of the cases for development, three (1%) of the cases for production, and two (0.6%) of the cases for marketing. These frequencies are just too small to adequately test the government information part of this proposition. However, it is possible to test the more general proposition that small versus large firms rely more on external sources of information. Tables 11a, b and c present the crosstabulations of internal/external information source importance and firm size category for the three stages of innovating: development, production and marketing.

Only one of the three information category crosstabulations approaches significance (r=.09 \( p=.06 \)) for production information, where smaller firms tend to say external sources of information are more important, as predicted. This can only be taken as very weak support, at best, for the proposition, however. It appears that, overall, small and large firms tend to use similar information seeking patterns for innovating.

A summary of these proposition tests is presented in Table 12. Overall, the first two propositions concerning size, radical innovation and innovation champion were supported.
Propositions three and four were moderately supported, and the last two propositions were not supported. Large firms are more likely to introduce radically different innovations, and to require innovation champions in order to innovate.
3.3. Other Findings

During the course of the design of this study, it was decided to explore several other areas relevant to the main focus of the study—firm size and the innovation process. First, we examined the crosstabulations of firm size category and the other items on the questionnaire. Second, we did a controlled correlation analysis using multiple regression of innovation success, and a scale that was developed using six indicators on the questionnaire. We discuss these separately below.

3.3.1 Relationship Between Size Category and Other Variables

We ran crosstabulations of size category by the other items on the questionnaire, not specifically discussed or relevant to the six primary propositions of the study. First, there was no significant correlation between firm size category and any of the single item indicators of innovation success: technical success (technical performance, at budgeted cost, during a required time) and commercial success (overall commercial success, market share and return on investment). The correlations (Pearson r) for these crosstabulations, respectively, were, r=.03, .01, -.02, .02, .05 and .07 (with "uncertain" coded at the end point of the item for the latter two items). The Chi-square was also nonsignificant for these six contingency tables. Therefore, we concluded that for this sample of innovating firms, there was no significant difference between small and large firms in innovation case success propensity, as measured by single indicators of success. There were some noteworthy correlations between firm size category and other items on the questionnaire. First, as would be expected, larger firms are more likely to have an R&D department, r= -.30 (p< .01, n=368). Large firms are, again unsurprisingly, more likely to have more people employed in this R & D department, r=.24 (p< .01, n=259), and are more likely to spend divisional funds on innovating, r=.15 (p< .01, n=253). Small firms are more likely to report spending a higher percentage of corporate funds, r= -.24, (p< .01, n=220). Finally, relevant to the Von Hippie work on "locus of innovating," we found larger firms are more likely to be influenced by customers in the design of the new product, r= -.11 (p< .03, n=364): Kendall tau c = -.13 (p< .02).

This crosstabulation is presented on page 50, because it is rather interesting, in Table 13. Note that only 4 (1.2%) of the reporting small and large firms said that customers actually design the new product and asked the originating firm
to produce it. Only 23 (6.6%) of the firms said customers made specific design suggestions that were actually incorporated into the product. Most said that either the customer made general suggestions that stimulated design (102, 30.4%) or had little or no influence (207, 61.6%). Since 231 or 62.3% of the 371 cases in the sample were recipients of awards and, based on correlations with other radical technology indicators, most appear to be significant new product innovations, these findings fail to support the Von Hippel hypothesis of locus of innovating for this sample. That is, special, one of a kind, innovations tend to be greatly influenced by customers: while mass market, large volume innovations tend to be designed by originators. The opposite appears also to apply, based on our results.

3.3.2 Predicting New Product Success

A considerable amount of attention and effort in the innovation literature has been devoted to studying new products. In particular, researchers and practitioners have been interested in finding out why some new products fail and why some are a success. Three studies in particular have examined this issue. The first is the Sappho study conducted in the United Kingdom (e.g., Rothwell, 1972); the second is the NewProd study done for 100 new product successes and 100 new product failures in Canada (Cooper, 1983); and the third was done for primarily U.S. west coast firms by Maidique (1982). All find market factors at least important and in the case of the Sappho study, dominant, in predicting success. However, none of these studies has made an attempt to distinguish between radical and incremental innovations. Mowery and Rosenberg (1979) suggest that the reason market factors--so called "market pull" vs. "technology push" forces--appear to predict success so well, is because most new products are really not innovations at all but only minor modifications of existing technology.

In order to explore the causes of innovation success in this study, we first attempted to construct a reliable scale of success--assuming that success is a combination of both technological and commercial success. We were reasonably satisfied with this effort. A six-item scale did emerge from our factor and item-analysis (detailed in the Appendix) with a Cronbach alpha of .62 for 295 complete data cases on all six items. Successful innovations achieve a satisfactory level of technical performance, at budgeted cost, during a required time period, and achieve overall commercial success, reasonable market share and good return on investment.* This summed scale from the six questionnaire items, 10a, b, c

*Corrected item-total correlations for these six indicators suggests this scale is a slightly better representative of commercial success than technical success.
and lla, b, and c (see Appendix) was used as the dependent variable in a multiple step-wise regression summarized in Table 14. The supporting correlation matrix and descriptive statistics, including missing data estimation procedure, are included in the Appendix. Missing data assumptions, and inclusion of number of employees as an interval variable, rather than by size category appear in the Appendix as well.

Although the total proportion of variance in new product success accounted for by these four valid predictors is relatively small (about 5%), all four regression equations are statistically significant. The fifth predictor to enter was a number of employees (inversely related) but valid variance ($R^2$) begins to decline on the fifth step, so it was excluded. Based on these results, successful new products in this sample are likely to have had an absence of over-budget requests, incorporate substantially new technology, have an absence of continuing cost problems and received an award. The second and fourth predictors, especially, tend to shed light on the new product innovation literature which has not adequately accounted for the radical vs. incremental technology variable in the past. This may also explain some of Cooper's (1983) findings that show that "me too" type products tend to be failures. Successful new products have to offer something substantially different—especially if sold in existing markets.

3.3.3. Stimulus and Success of Innovation

In the literature on new product success and other literature on innovation processes (Utterback and Abernathy, 1975), there is considerable debate over the relationship between the type of stimulus for innovating and the success or failure of the new product. In order to evaluate the usefulness of including category of stimulus for innovating in the multiple regression evaluation discussed above and summarized in Table 14, zero-order correlations for stimulus category and success were run. When one codes technology capability as category 1, production quality (time or cost) as category 2, and market demand specifically from customer's suggestions as category 3, the Pearson r correlation with stimulus category and success (summed scale) is $r = -.06$ ($p = .189, n=233$) which is non-significant.

Therefore, we concluded that, although there is a slight tendency for technology push to be directly related to success of the new product, the relationship is not statistically significant for this sample. Stimulus category was deleted from the regression analysis discussed above.
4. CONCLUSIONS AND RECOMMENDATIONS

We have found that, although small firms in the industry groups we sampled introduced over 50% of the new products during the last four years, larger firms (500 or more employees) were significantly more likely to get awards for their new products, to incorporate new technology in their new products, and to introduce new products that were the first of their kind. Findings suggest that it may be that funding and personnel (e.g., champions) resources necessary to be a radical product innovator are not usually available to small firms. On the other hand, there are no statistically significant size category differences in the success of these innovations. This suggests that large and small firms play complementary roles in the innovation process of these industries and are both necessary for innovative stability on the more macro levels of analysis.

Small firms do report significantly more funding difficulties than large firms on initial cost problems, whereas, the absence of continuing cost problems significantly predict new product success (summed scale). Therefore, the success rate of new product introduction by small firms probably would be enhanced by making both initial and continuing funding available to small firms. Sustaining these innovating efforts appears to be a key to the innovation process for both small and large firms. Making joint ventures and other resource-sharing opportunities available for small firms, and even perhaps for large firms, appears to have great potential for stimulating and maintaining the innovative capability, as well as the probability of innovative product success in these industries. Joint funding was reported by only 13 of the 371 complete data cases and only two of these were supported 100% by joint funding.

Other funding sources currently available to small firms for innovation ought to be maintained, given these findings. For example, the National Science Foundation's Small Business Innovation program should be sustained, given the apparent dependence of significant innovation on resources in the U.S.

The area of nonfunding government influence (e.g., regulatory compliance) on the innovation process is more difficult to comment on in light of the results of this study. The vast majority (89%) of complete-data responding firms said there was no significant government influence on developing, producing or marketing
the innovation. Only 37 firms report any type of significant nonfunding government influence, and large and small firms appear to encounter barriers and facilitation about equally often. That does not mean that any currently pending or unimplemented government policy or law will not ultimately change this condition. This issue needs continual monitoring and further testing if we are to have a complete understanding of the government portion of the innovating firm's environment.

There is a tendency for small firms to favor external sources of information in the production (vs. the development or marketing) of innovations in the sample. This may be an area where the government or joint government—university—industry information source development may be helpful. This trend very closely approaches statistical significance and may be an indication of the practical significance of the apparent realization of production and operations to be a more valued and integral part of the innovating process in organizations. The Japanese emphasis on quality and production innovation, and the lead that several U.S. manufacturing firms are taking in installing the factory of the future for their operations (e.g., John Deere, Caterpillar Tractor, GE, Harris Corporation, etc.) is a strong indication of this trend. There is a serious question of whether small manufacturing firms will be able to participate in this process innovation trend in this country. Small firms may be very responsive to joint government—university overtures in this area.

It should be recalled that we found a significant tendency for larger firms to report substantial new process requirements in order to introduce their new products, which supports the Utterback—Abernathy model for the difference between stage I and stage II firms in the innovation process. This further suggests that smaller firms may be at a distinct disadvantage in their ability to mount radical new products if they require new plant and equipment resources. There is a statistically significant and very consistent tendency in our data to suggest this. New process requirements are greatest for award cases, novel products (first of their kind), and products that incorporate significant new technology. We recommend that a concentrated effort be mounted to evaluate the feasibility of offering production innovation and process planning assistance to small firms through whatever means is cost-efficient. The decentralization of this assistance through regional development programs at the state and local level would be most likely to accomplish this result (OECD, 1982).
5. REFERENCES


Dollinger, Mare J., "The Relationship Between Innovation and Performance in the Non-Technical Small Business," working paper, Department of Management, University of Kentucky, 1983.


Lawrence, P. R., and Lorsch, J. W., Organization and Environment, Boston, MA: Harvard University Graduate School of Business Administration, Division of Research, 1967.


Inventor attracts praise with new magnetism gauge

By Jon Van

LIKE THE mythical inventor of the better mousetrap, Charles Castronovo expects the world will soon beat a path to his door or, more appropriately, he will just arrive customers like a magnet.

Castronovo has invented a better means of measuring magnetism.

"Anyone working with magnets should have a gaussmeter," Castronovo said. "Just as people working with electricity need a voltmeter to measure volts, people working with magnets need to measure magnetism, and the unit of measurement is the gauss."

"Magnetism is an unseen force. You can see its effects when iron filings are drawn to a bar or when a note holder sticks to the refrigerator door, but you cannot see the force itself. A gaussmeter lets you detect and measure that force."

GAUSSMETERS have been available for years but usually are found only in specialized industrial laboratories or on university campuses because they are large, delicate pieces of precision equipment that cost a lot of money and consume significant power.

Castronovo, director of Applied Magnetics Laboratory Inc. of Randallstown, Md., predicts that his new, relatively inexpensive hand-held gaussmeter will expand greatly current interest in measuring magnetism.

"University labs that might have purchased one gaussmeter for $3,000, can now get two or three at $300 each and still have money left over," he said. "I think that when we develop an instrument that is even cheaper, we'll see the hobbyists buying them."

"People have a lot of interest in magnets. You can buy magnets now at places like Radio Shack, and getting an instrument to measure magnetism is the next logical step."

FOR EXAMPLE, a hobbyist building a picture tube for a television set needs to work in a magnetically neutral area. Castronovo said, and the only way to assure this is to scan the work area with a gaussmeter.

Castronovo's invention will operate for up to 100 hours on the same kind of 9-volt battery that powers a transistor radio, and it is the product of the same microchip technology that produced desktop minicomputers.

Castronovo and his invention were among 100 honored by Industrial Researcher and Development magazine as being the best new applications of technology in the last year.

A DIRECTIONAL attachment option available with Castronovo's gaussmeter converts it for use as an extremely precise compass, providing readings of changes in the Earth's magnetic field as directions change.

"It was inevitable that someone was going to invent a new, easy-to-use and highly accurate gaussmeter," said the inventor. "I'm just lucky enough to be the one who did it. Actually, I built this instrument because I needed one myself for my own work with magnets."

"There was nothing on the market to meet my needs, so I built one," he says. 

Inventions are on display through Oct. 30 at Chicago's Museum of Science and Industry.

Charles Castronovo with his gaussmeter, which measures magnetism. "There was nothing on the market to meet my needs, so I built one," he says.
**Table 1: Crosstabulation of Firm Size Category (Archival Data Source) and Award Status**

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>Award</th>
<th>NonAward</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>42 (38.5%)</td>
<td>67 (61.4%)</td>
</tr>
<tr>
<td>Small (499 or less)</td>
<td>288 (67.9%)</td>
<td>136 (32%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>330 (61.9%)</td>
<td>203 (38.0%)</td>
</tr>
</tbody>
</table>

Kendall tau b = -.47 (p < .01)

This table is particularly interesting when compared with the ultimate resulting sample (n=371 cases; cf. Table 5a) table that obtained for the same data categories: size and award status presented later.
Table 2: Variables, Indicators and Questionnaire Items.

<table>
<thead>
<tr>
<th>Variable (Proposition)</th>
<th>Indicators</th>
<th>Questionnaire Item Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Organization size</td>
<td>Number of full-time, year-round employees for total enterprise</td>
<td>2a, 2b</td>
</tr>
<tr>
<td>(all six propositions)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Radical vs. Incre-</td>
<td>Novelty (new to the world); Relative cost; imitated by competitors; price;</td>
<td>13; 14a,b,c,d;</td>
</tr>
<tr>
<td>mental Innovation</td>
<td>new technology incorporated; new skills needed; new production process</td>
<td>15; 16; 17; 18.</td>
</tr>
<tr>
<td>(Proposition 1)</td>
<td>required. Control for Cost and funding problems (see 6. below)</td>
<td></td>
</tr>
<tr>
<td>3. Innovation Champion</td>
<td>Individual sponsorship; level in organization of champion</td>
<td>21a and 21b</td>
</tr>
<tr>
<td>(Proposition 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Input, throughput,</td>
<td>Products by industry group; SIC grouping by first 2 digits.</td>
<td>(coded from archival</td>
</tr>
<tr>
<td>output innovation.</td>
<td></td>
<td>information on case)</td>
</tr>
<tr>
<td>(Proposition 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Degree of evolution</td>
<td>New products (see 4. above); process changes</td>
<td>see 4.</td>
</tr>
<tr>
<td>of the productive</td>
<td></td>
<td>17a, b</td>
</tr>
<tr>
<td>segment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Proposition 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Use of public funds</td>
<td>% of total funded cost from various sources, including government and military.</td>
<td>6; 7; 8a, 8b</td>
</tr>
<tr>
<td>(Proposition 4)</td>
<td>Nonfunding government influence</td>
<td>9a, 9b</td>
</tr>
<tr>
<td>7. Difficulty and impact of regulatory compliance on innovating. (Proposition 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Sources of informa-</td>
<td>By stage of: development, production, marketing</td>
<td>23</td>
</tr>
<tr>
<td>tion for innovation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Proposition 6)</td>
<td>Technical and market success (see Appendix for scale development)</td>
<td>10a,b,c; 11a,b,c</td>
</tr>
<tr>
<td>9. Overall success</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Table 3: Distribution of Ineligible Cases**

<table>
<thead>
<tr>
<th>Reason Ineligible</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Not offered for sale</td>
<td>8</td>
</tr>
<tr>
<td>2. Foreign</td>
<td>9</td>
</tr>
<tr>
<td>3. Product too old</td>
<td>9</td>
</tr>
<tr>
<td>4. Do not manufacture that particular product</td>
<td>10</td>
</tr>
<tr>
<td>5. Not applicable</td>
<td>15</td>
</tr>
<tr>
<td>6. Cannot locate</td>
<td>14</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>65</strong></td>
</tr>
</tbody>
</table>

**Table 4a: Firm Size Distribution of a Random Sample of 100 Nonrespondents (Telephone Call-Back)**

<table>
<thead>
<tr>
<th>Size Category</th>
<th>f (% of 54 responding)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (499 or less)</td>
<td>31 (57.4%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>23 (42.6%)</td>
</tr>
<tr>
<td>Firms that did not give number of employees, or could not be reached</td>
<td>46</td>
</tr>
</tbody>
</table>

**Table 4b: Firm Size Distribution of First Wave Incomplete Questionnaires (n=13)**

<table>
<thead>
<tr>
<th>Size Category</th>
<th>f(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (499 or less)</td>
<td>8 (61.5%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>5 (38.5%)</td>
</tr>
</tbody>
</table>
Table 5a: Crosstabulation of Award Status and Firm Size

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>AWARD STATUS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Small (499 or less)</td>
<td>102</td>
<td>97</td>
<td>199</td>
</tr>
<tr>
<td></td>
<td>(51.3%)</td>
<td>(48.7%)</td>
<td>(53.6%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>129</td>
<td>43</td>
<td>172</td>
</tr>
<tr>
<td></td>
<td>(75.0%)</td>
<td>(25.0%)</td>
<td>(46.4%)</td>
</tr>
<tr>
<td></td>
<td>231</td>
<td>140</td>
<td>371</td>
</tr>
<tr>
<td></td>
<td>(62.3%)</td>
<td>(37.7%)</td>
<td>(100.0%)</td>
</tr>
</tbody>
</table>

Pearson's $r = -0.244$  
Significance = 0.000  
(same as phi and kendall's tau b for a 2x2 contingency table)

Table 5b: Crosstabulation of Award Status and Firm Size, Controlling for Cost of Introduction; Cost Category: Most Expensive

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>AWARD STATUS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Small (499 or less)</td>
<td>28</td>
<td>20</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>(58.3%)</td>
<td>(41.7%)</td>
<td>(52.7%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>28</td>
<td>15</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>(65.1%)</td>
<td>(34.9%)</td>
<td>(47.0%)</td>
</tr>
<tr>
<td></td>
<td>56</td>
<td>35</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>(61.5%)</td>
<td>(38.5%)</td>
<td>(100.0%)</td>
</tr>
</tbody>
</table>

Pearson's $r = -.07$  
Significance = .256

Table 5c: Crosstabulation of Award Status and Firm Size, Controlling for Cost of Introduction; Cost Category: Not Most Expensive.

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>AWARD STATUS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Small (499 or less)</td>
<td>56</td>
<td>59</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>(48.7%)</td>
<td>(51.3%)</td>
<td>(50.0%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>91</td>
<td>24</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>(79.1%)</td>
<td>(20.9%)</td>
<td>(50.0%)</td>
</tr>
<tr>
<td></td>
<td>147</td>
<td>83</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>(63.9%)</td>
<td>(36.1%)</td>
<td>(100.0%)</td>
</tr>
</tbody>
</table>

Pearson's $r = -32$  
Significance = .000
Table 6: Championship and Firm Size Category

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>Innovation Champion</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>yes</td>
<td>143</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>(75.3%)</td>
<td>(24.7%)</td>
<td>(54.0%)</td>
</tr>
<tr>
<td>Large</td>
<td>no</td>
<td>137</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>(84.6%)</td>
<td>(15.4%)</td>
<td>(46.0%)</td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>280</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>(79.5%)</td>
<td>(20.5%)</td>
<td>(100.0%)</td>
</tr>
</tbody>
</table>

Pearson's r = -.115

Table 7: Crosstabulation of Firm Size and Level of Champion in Organization.

<table>
<thead>
<tr>
<th>Level of Champion</th>
<th>Staff (1)</th>
<th>Supervisor (2)</th>
<th>Middle Mgmt. (3)</th>
<th>VP, Gen. Mgr. or above (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm Size</td>
<td>Small</td>
<td>Large</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(499 or less)</td>
<td>3 (2.6%)</td>
<td>6 (6.0%)</td>
<td>18 (15.8%)</td>
<td>91 (79.8%)</td>
</tr>
<tr>
<td></td>
<td>2 (1.8%)</td>
<td>9 (8.6%)</td>
<td>36 (34.3%)</td>
<td>54 (51.4%)</td>
</tr>
<tr>
<td></td>
<td>9 (4.1%)</td>
<td>11 (5.0%)</td>
<td>54 (24.7%)</td>
<td>145 (66.2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>219 (100.0%)</td>
</tr>
</tbody>
</table>

Pearson's r = -0.268, sig. = .0000
Kendall's tau c = -.29, sig. = .0000
Table 8a: Summary of Correlations between Award Status and Firm Size Category by Industry Grouping (2-Digit SIC)

<table>
<thead>
<tr>
<th>Two-Digit SIC Major Grouping</th>
<th>n</th>
<th>Award Status with Firms Size Category, Kendall Tau B Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R &amp; D, Concent. % Sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4 40-49 20 (Food)</td>
<td>24</td>
<td>.00</td>
</tr>
<tr>
<td>0.9 30-39 26 (Paper, Allied)</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>3.6 30-39 28 (Chemical)</td>
<td>23</td>
<td>-.23</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2.4 50-59 30 (Rubber, Misc.)</td>
<td>16</td>
<td>-.16</td>
</tr>
<tr>
<td>1.2 40-49 32 (Stone, Clay.)</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>0.8 40-49 33 (Primary Met.)</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>1.2 20-29 34 (Fab. Metal)</td>
<td>28</td>
<td>-.02</td>
</tr>
<tr>
<td>5.0 30-39 35 (Machinery)</td>
<td>132</td>
<td>-.31*</td>
</tr>
<tr>
<td>6.3 40-49 36 (Elec. Machinery)</td>
<td>26</td>
<td>-.2</td>
</tr>
<tr>
<td>3.1 50-59 37 (Trans. Equip.)</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>6.1 30-39 38 (Meas. Inst.)</td>
<td>84</td>
<td>-.36*</td>
</tr>
<tr>
<td>30-39 39 (Misc. Mfg.)</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

Avg 3.1 20-29

*significant at the .01 level
#not including aircraft

@TOTALS TO 364 CASES; 7 cases fall outside the manufacturing SICs (20-39) or SIC could not be determined at this writing.
Table 8b: Crosstabulation of Firm Size Category and Requirements for Significant Process Innovation to Introduce the New Product

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>Significant New Process</th>
<th>Some Modification</th>
<th>No Process Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (499 or less)</td>
<td>38 (20.3%)</td>
<td>69 (36.9%)</td>
<td>80 (42.8%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>55 (32.7%)</td>
<td>53 (31.5%)</td>
<td>60 (35.7%)</td>
</tr>
<tr>
<td></td>
<td>93 (26.2%)</td>
<td>122 (34.4%)</td>
<td>140 (39.4%)</td>
</tr>
</tbody>
</table>

Kendall Tau $c = -0.13$ (p=.014)
Pearson $r = -0.12$ (p=.011)
Table 9: Crosstabulation of Firm Size Category and Proportion of Government Funding for the Innovation Case

<table>
<thead>
<tr>
<th>% GOVERNMENT FUNDING OF TOTAL</th>
<th>0%</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>87</th>
<th>95</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (499 or less)</td>
<td>57</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>40</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Kendall tau c = .134; significance = .0361
Pearson's r = .188; significance = .0161
Table 10a: Crosstabulation of Significant, Nonfunding Government Influence on Innovating by Firm Size Category

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>Yes, Sig. Help</th>
<th>Yes, Sig. Barrier</th>
<th>No Sig. Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (499 or less)</td>
<td>15 (8.3%)</td>
<td>3 (1.5%)</td>
<td>169 (90.0%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>14 (8.1%)</td>
<td>5 (3.3%)</td>
<td>142 (88.2%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Yes, Sig. Help</th>
<th>Yes, Sig. Barrier</th>
<th>No Sig. Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29 (8.5%)</td>
<td>8 (2.3%)</td>
<td>304 (89.1%)</td>
</tr>
</tbody>
</table>

Chi-square = .79 (df=2, p=.67)
Table 10b: Comments for Significant Nonfunding Government Influence on the Innovation Process

<table>
<thead>
<tr>
<th>Significant Influence?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, help</td>
<td>Equipment is used for pollution control to large extent.</td>
</tr>
<tr>
<td>Yes, barrier</td>
<td>Required burner for solvent vapor incineration, which required many permits.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>State encourages diversified agriculture.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Enthusiasm and contract funding.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Actively promoting technology transfer.</td>
</tr>
<tr>
<td>Yes, barrier</td>
<td>FDA required animal feeding studies.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>R &amp; D funding from DOE and subordinated debt</td>
</tr>
<tr>
<td>Yes, help</td>
<td>As a customer</td>
</tr>
<tr>
<td>No, help</td>
<td>Only need to meet specifications, codes, etc.</td>
</tr>
<tr>
<td>Yes, barrier</td>
<td>Export permits.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Product built to military specifications.</td>
</tr>
<tr>
<td>No influence</td>
<td>Assistance from the British government - audit.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Worked on developing for the U.S. Army.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Recommendations to resolve technical problems</td>
</tr>
<tr>
<td>Yes, barrier</td>
<td>Compliance with government regulations.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>A bid from USDA for this kind of (deleted) system led us to develop the (deleted) to be priced competitively with the competition.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Promoted the need and funding.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Design criteria.</td>
</tr>
<tr>
<td>Blank</td>
<td>FDA regulation under (deleted) followed in the marketing of product.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Technology was a spin-off of that used to fulfill EPA emission limits.</td>
</tr>
<tr>
<td>Yes, barrier</td>
<td>Product required to meet certain U.S.D.A. and F.D.A. regulations.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>License of NASA Patent</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Funding provided by DOE</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Mandated use of product in (emergency vehicle).</td>
</tr>
<tr>
<td>No influence</td>
<td>National Labs Photovoltaic Battery Project.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Recommend product to government contractors.</td>
</tr>
<tr>
<td>Yes, barrier</td>
<td>FDA identity approvals</td>
</tr>
<tr>
<td>Yes, barrier</td>
<td>FDA regulations class II Medical Device.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Device greatly endorsed by Bureau of Mines.</td>
</tr>
<tr>
<td>No influence</td>
<td>Hinder development by indecision (Chronic).</td>
</tr>
<tr>
<td>Yes, help</td>
<td>No regulations for emissions.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Patent only</td>
</tr>
<tr>
<td>Yes, help</td>
<td>NBS-NASA verified operating (deleted).</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Cooperation in testing product in USDA plants.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Research and early development done with government (deleted) money.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Requirement of Dairy Standards.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Packaging concepts.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>1. Wasted time with EPA 2. EPA made introduction difficult.</td>
</tr>
<tr>
<td>No influence</td>
<td>No government involvement.</td>
</tr>
<tr>
<td>Yes, help</td>
<td>Set (deleted) (standard).</td>
</tr>
</tbody>
</table>
Table Ila: Crosstabulation of Information Source and Firm Size Category for Development

<table>
<thead>
<tr>
<th>Firm Size (499 or less)</th>
<th>External</th>
<th>Internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>114 (66.3%)</td>
<td>58 (33.7%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>105 (66%)</td>
<td>54 (34%)</td>
</tr>
</tbody>
</table>

Pearson's r = -.002, sig. = .48 (n.s.)

Table IIb: Crosstabulation of Information Source and Firm Size Category for Production

<table>
<thead>
<tr>
<th>Firm Size (499 or less)</th>
<th>External</th>
<th>Internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>70 (47.0%)</td>
<td>79 (53.1%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>54 (38.0%)</td>
<td>88 (62.0%)</td>
</tr>
</tbody>
</table>

Pearson's r = .0905, n = .0618

Table IIc: Crosstabulation of Information Source and Firm Size Category for Marketing

<table>
<thead>
<tr>
<th>Firm Size (499 or less)</th>
<th>External</th>
<th>Internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>129 (77.7%)</td>
<td>37 (22.3%)</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>121 (79.1%)</td>
<td>32 (20.9%)</td>
</tr>
</tbody>
</table>

Pearson's r = -.01667, sig. = .3834
<table>
<thead>
<tr>
<th>Proposition</th>
<th>Outcome of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Small firms are more likely to introduce radical technological innovations unless the radically new product requires excessive resources.</td>
<td>1. Supported with qualifying condition: Larger firms are significantly more likely to introduce radical innovations—regardless of relative cost. Pearson's r = -.24 (p &lt; .01) for award status and firm size category. Small firms are significantly more likely to report initial cost problems r = -.26 (p &lt; .01), and debt service problems, r = -.12 (p &lt; .01).</td>
</tr>
<tr>
<td>2. An innovation champion is more necessary for innovating in larger firms; in small firms that have innovation champions they are likely to be at higher levels in the organizational structure than in large organizations.</td>
<td>2. Strongly supported. Larger organizations are significantly more likely to have had a champion for the innovation case investigated; Pearson's r = -.12 (p &lt; .02); and smaller firms are significantly more likely to have innovation champions at top and middle management levels in the organization. Pearson's r = -.29 (p &lt; .01); Kendall's tau c = -.27 (p &lt; .01)</td>
</tr>
<tr>
<td>3. Larger firms are more likely to be innovative in mature industries (Stage III) than small firms. (Utterback &amp; Abernathy model)</td>
<td>3. Moderate support. For four of the seven industries with sufficient data (all assumed to be relatively mature), larger firms received proportionately more awards than smaller firms. For two industries, this relationship was statistically significant; machinery, Kendall's tau b = -.31 (p &lt; .01); and instruments, Kendall's tau b = -.36 (p &lt; .01). Larger firms have significant process innovations (r = -.12, p &lt; .02).</td>
</tr>
<tr>
<td>4. Larger firms are more likely to be aided in innovating by public funds than smaller firms, but when smaller firms receive public funds, the proportion of assistance is greater.</td>
<td>4. Moderate support. There is a statistically significant, but practically small tendency for larger firms to report a greater proportion of government funds used in innovating; Kendall's tau c = .13 (p &lt; .05); but only 27 firms report using any government funds for the case studied.</td>
</tr>
<tr>
<td>5. Regulatory compliance is relatively more difficult for smaller firms, hindering innovation, but this may lead to higher concentration of specialists that ultimately encourages small firm innovativeness.</td>
<td>5. Not supported. Chi-square=0.79 (df=2, n.s.)</td>
</tr>
<tr>
<td>6. Small firms are more likely to utilize external, and especially government sources of information in innovating.</td>
<td>6. Weak support: for production information only, small firms tend to favor external information sources (r = .09, p = .06, n.s.).</td>
</tr>
</tbody>
</table>
Table 13: Crosstabulation of Firm Size Category by Customer Influence on Design or Invention of the New Product

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>Customer, Design</th>
<th>Customer, Specific Design</th>
<th>Customer, Gen. Recom.</th>
<th>Little or No Customer Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (499 or less)</td>
<td>2 (1.0%)</td>
<td>11 (6.2%)</td>
<td>44 (24.9%)</td>
<td>177 (52.7%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>120 (67.8%)</td>
<td></td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>2 (1.3%)</td>
<td>12 (4.5%)</td>
<td>58 (36.5%)</td>
<td>159 (47.3%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>87 (54.7%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>336 (100%)</td>
</tr>
</tbody>
</table>

\[ r = -0.11 \ (p < 0.03) \]
\[ \tau_c = -0.13 \ (p < 0.02) \]
Table 14: Summary of Multiple Regression to Predict new Product Success Scale (n=348)

<table>
<thead>
<tr>
<th>Predictor Entered</th>
<th>Zero-Order @ Correlation</th>
<th>Regression Equation F</th>
<th>Cumulative $R^2$</th>
<th>Beta for Final Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overbudget requests (1=yes, 0=no)</td>
<td>-.18*</td>
<td>11.2*</td>
<td>.03</td>
<td>.028</td>
</tr>
<tr>
<td>2. Degree to which new product incorporates new technology (1=14 in the world)</td>
<td>-.13*</td>
<td>8.6*</td>
<td>.05</td>
<td>.042</td>
</tr>
<tr>
<td>3. Continuing Cost (1=yes, 0=no)</td>
<td>-.12**</td>
<td>6.7*</td>
<td>.06</td>
<td>.047</td>
</tr>
<tr>
<td>4. Award Status (1=yes, 2=no)</td>
<td>-.09</td>
<td>5.5*</td>
<td>.06</td>
<td>.048</td>
</tr>
</tbody>
</table>

@Two-tailed test  
*Because of coding directions, the absence of these two cost problems promotes new product success.

Next (5th predictor), to enter is number of employees (beta= -.043, n.s.) but valid variance ($R^2$) begins to decrease on 5th step.
APPENDICES:

<table>
<thead>
<tr>
<th>INSTRUMENT</th>
<th>PÁGINA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CROSSTABULATION OF YEAR SOLD BY FIRM SIZE CATEGORY</td>
<td>A-7</td>
</tr>
<tr>
<td>RELIABILITY ANALYSIS FOR NEW PRODUCT INNOVATION SUCCESS SCALE</td>
<td>A-8</td>
</tr>
<tr>
<td>DESCRIPTIVE STATISTICS AND CORRELATION MATRIX FOR REGRESSION SUMMARY IN TABLE 14</td>
<td>A-9</td>
</tr>
<tr>
<td>LISTING OF 380 CASES</td>
<td>A-10</td>
</tr>
</tbody>
</table>

Part I

VERIFICATION OF PUBLISHED INFORMATION. (Please circle the number corresponding to the appropriate responses or fill in information as needed).

1. According to published information, your firm first offered the following new product for sale in 19: ________________________________
   and won the following award: ________________________________

   a) Is this information correct? Yes ... (skip to Q. 2) .......... 1
      No .................. 2
      Don't know .......... 8

   b) If this information is incorrect or incomplete, please correct it here:
      The new product was ________________________________ and offered for sale in 19: __________; and won the following award ________________________________

2. a) At the time of the introduction of this new product, published sources indicated that your organization (total enterprise) had the following number of full-time, year-round employees:

      Approximately_________________________ employees.

      Is this information correct? Yes ... (skip to Q. 3) .......... 1
      No .................. 2

   b) What was the correct number of full-time, year-round employees for your organization (total enterprise) at the time the new product was offered for sale?

      Approximately_________________________ employees.

3. a) At the time of market introduction, published sources indicate that one of the following (circled) best describes the organizational unit or firm that originated this new product:

      Closely held corporation, partnership, or sole proprietorship .......... 1
      Publicly held corporation (shares traded on an exchange) .......... 2
      Government owned or controlled firm or organization .......... 3
      Division of a corporation ........................................ 4
      Subsidiary of a corporation ...................................... 5
      Other (please describe ) ........................................ 6

   b) Is this information accurate? Yes ... (skip to Q. 4) .......... 1
      No .................. 2

   c) Please fill in the number from question 3a above that corresponds to the best description of the organizational unit that originated the new product:

      Organizational Unit: ...  ...  ...
Part 2 INFORMATION TO BE KEPT CONFIDENTIAL.

4. a) Does your firm have a Research and Development (R&D) department?
   Yes ........................................
   No ........................................ (skip to Q. 5) ........................................

b) What is the total number of full-time employees located in this department?
   Approximately ___________________ employees.

5. Has any of the technology underlying the new product a result of the firm's
   R&D or new product development activity and effort (formally organized or not)?
   Yes ........................................ 1
   No ........................................ 2

6. What percent of the total cost of bringing the new product to market (e.g., R&D,
   capital investment, tooling, production and marketing) came from the following
   sources?

   Division, plant or funds from this location ..............................................
   Corporate or total firm funds ..............................................
   Joint venture with other firms ..............................................
   Government funds ..............................................
   External investment capital ..............................................
   Other (please describe) ..............................................

   % of total funding

7. If government funds were used at all in the development, production, or market-
   ing of the new product, what was the primary source of government funds?

   Grant ........................................ 1
   Contract (other than military) ........................................ 2
   Military contract, Grant, or Cooperative agreement ........................................ 3
   Cooperative agreement ........................................ 4
   Loan of government personnel ........................................ 5
   Use of government lab ........................................ 6
   Other (please name) ........................................ 7

8. a) Were any of the following problems encountered in obtaining adequate funding
   for the development?

   Expense vs. capital budget ........................................ 1
   Lag in funding ........................................ 2
   Timing in funding ........................................ 3
   Obtaining total amount ........................................ 4
   Other (please name) ........................................ 5

   Debt service (high interest rate) ........................................ 5
   Initial cost ........................................ 6
   Continuing cost ........................................ 7
   Over-budget requests ........................................ 8
   Other (please name) ........................................ 9

b) Of these problems, what was the most significant funding barrier? Fill in the
   number from Q. 8a that corresponds to the answer.

   Most significant problem: ___________________.
9. a) Did the government (federal, state, or local) have any significant influence on the development, production, or marketing of this new product other than funding?

   Yes, significant barrier .......................... 1
   Yes, significant help .............................. 2
   No significant influence (skip to Q. 10) .......... 3

b) Please briefly describe the specific nature of this significant government influence.

10. a) Was the new product a technical success (We define technical success as achievement of technical performance required in the project specification)?

   Yes .................................................. 1
   Too soon to tell ........................................ 2
   No .......................................................... 3
   Don't know .............................................. 8

b) Was technical success achieved at or very near budgeted cost?

   Yes .................................................. 1
   Too soon to tell ........................................ 2
   No .......................................................... 3
   Don't know .............................................. 8

c) Was technical success achieved during the required time period?

   Yes .................................................. 1
   Too soon to tell ........................................ 2
   No .......................................................... 3
   Don't know .............................................. 8

11. a) Overall, was the new product a commercial success (met commercial success expectations)?

   Yes .................................................. 1
   Too soon to tell ........................................ 2
   No .......................................................... 3
   Don't know .............................................. 8

b) Was market share attained by the new product above, about the same as or below expectations?

   Market share above expectations ...................... 1
   Market share about the same as expectations .......... 2
   Market share below expectations ......................... 3
   Too soon to tell ........................................ 4
   Don't know .............................................. 8

c) Which one of the following statements best describes the return on investment (ROI) for the new product to date?

   Below total costs ...................................... 1
   About equal to operating costs ......................... 2
   About equal to total costs ................................ 3
   Moderately above total costs ............................ 4
   A good multiple of investment ............................ 5
   Too soon to tell ........................................ 6
   Don't know .............................................. 8
12. What is the primary market for the product?

Industrial ................ 1 Government (not military) ........ 3
Consumer .................. 2 Military ..................... 4
Other (please name ___________________________) ................

13. Which of the following statements best describes your new product? (circle only one.)

Our firm was first in the world to introduce the product ................ 1
Our firm was the first in the U.S. to introduce the product ............. 2
Our firm was the first in the industry to introduce the product .......... 3
Our firm was the second or third in our industry to introduce the new product ........................................ 4

14. a) If this new product is only one of many you produce, was it one of the most costly to introduce (e.g., R&D, production, marketing)?

Yes ........................................ 1
No ........................................ 2
It was our only product ................. 3
Don't know ................................ 8

b) Is the new product still one of the most costly to produce?

Yes ........................................ 1
No ........................................ 2
It still is our only product ............... 3
Don't know ................................ 8

c) Was the new product the first in what became a broad line?

Yes ........................................
No ........................................ 2

14. d) Was the new product imitated by any of your competitors?

Yes ........................................ 1
Too soon to tell .......................... 2
No ........................................ 3

15. Compared with other products that try to satisfy the same customer need, which of the following best describes the new product's unit selling price when it was first offered for sale? (circle only one.)

Less than 50% of the price of the other product(s) ..................... 1
Between 50% and 5% less than the others ............................. 2
About the same selling price ........................................ 3
Between 5% and 50% more than the others ............................. 4
Prices at more than 50% above the others ........................... 5
There were no comparable products at the time of introduction ....... 9

16. At the time of introduction, did this new product incorporate technology that was a significant break from past knowledge, technology, or practice in the industry? (circle only one.)

The most significant breakthrough in the industry for many years ...... 1
A very significant break with the past, but not the most significant 7
It represents an improvement on past technology—not a breakthrough 4
The new product is a modest improvement on current practice ........ 4
The product is similar to competitors offerings with some different features 5
The product is the same or almost the same as our competitors ......... 6
Don't know ................................ 8
17. a) In order to develop, produce, and/or market this new product, were significant new skills acquired by your firm, either by hiring new personnel or training existing personnel?

   Yes ........................................ 1
   No ........................................ (skip to Q. 18) .... 2
   Don't know .................................. 8

b) Please list the new skills or job titles added during development.

18. a) To what extent were significant (new to the industry) processing technologies necessary in order to produce the new product when it was introduced?

   At least one significant new (to the industry) process technology was required .............. 1
   Some process modifications were necessary, nothing major ............. 2
   No process changes required for introduction (skip to Q. 19) .......... 3

b) Please describe the new process technology briefly, in general (nonproprietary) terms, that was required for the introduction of the new product. 
(e.g., Vendor supplied).

19. a) What was the primary stimulus for the original investment in R&D or product development? (circle only one.)

   Exploited a major technological strength of the firm (skip to 20) ........ 1
   Need to improve quality, cost, or time in production ..................... 2
   A specific customer demand or suggestions ................................ 3
   Regulatory or legal requirement ............................................. 4
   Other (please specify) ................................................................ 5
   No R&D funds were committed ................................................. 6
   Don't know ............................................................................ 8

b) If a specific customer demand or suggestions were the primary stimulus for the original investment in R&D for development, which of the following statements best describes this? (circle only one.)

   Customer(s) dissatisfied with our existing product ................................ 1
   Customer(s) dissatisfied with competitor's product ......................... 2
   Competitor's success with product we don't sell ............................. 3
   Customer(s) satisfaction with a related product we sell .................... 4
   A substantial increase in demand for the new product idea .............. 5
   Customer(s) problem became acute, in urgent need of solution .......... 6
   Other (please name) .................................................................... 7

20. Did a customer(s) contribute to the actual design or invention of the new product? (circle only one.)

   Customer(s) designed the new product and asked us to produce it .......... 1
   Customer(s) made specific design suggestions that were later incorporated into the new product ........................................... 2
   Customer(s) made general suggestions or comments that stimulated our design process .................................................. 3
   Customer(s) had little or no influence on the actual design of the new product ..................................................... 4
   Don't know ............................................................................... 8
21. a) During the development of the new product, did one individual in the firm assume the sponsorship of the project so that it became a reality?

Yes, there was a "champion" for the new product ................. 1
No, no one person was a strong advocate ............... (skip to Q. 22) ... 2
Don't know .................................................. 8

b) What was the person's title at the time of the development?

22. Was the new product based on technology developed by your firm, adopted from another source, or developed collaboratively with another firm?

Originated by this firm .................. 1
Adopted from another source .............. 2
Developed collaboratively with another firm 3
Other (please specify) .................. 4
Don't know .................................................. 8

23. From the following list of information sources, please indicate which were the most important sources of information for the development, production, and marketing of the new product (Fill in the numbers next to the function, as appropriate).

<table>
<thead>
<tr>
<th>Information Source</th>
<th>Important for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Trade shows</td>
<td>a) Development</td>
</tr>
<tr>
<td>2. Suppliers</td>
<td>b) Production</td>
</tr>
<tr>
<td>3. Articles in trade publications</td>
<td>c) Marketing</td>
</tr>
<tr>
<td>4. Competitors</td>
<td></td>
</tr>
<tr>
<td>5. Customers</td>
<td></td>
</tr>
<tr>
<td>6. Government, other than military</td>
<td></td>
</tr>
<tr>
<td>7. Military (U.S. Government)</td>
<td></td>
</tr>
<tr>
<td>8. In-house information</td>
<td></td>
</tr>
<tr>
<td>9. Trade associations, other than trade shows</td>
<td></td>
</tr>
<tr>
<td>10. Consultants</td>
<td></td>
</tr>
<tr>
<td>11. Licensor</td>
<td></td>
</tr>
<tr>
<td>12. Joint venture partner</td>
<td></td>
</tr>
<tr>
<td>13. Foreign source</td>
<td></td>
</tr>
<tr>
<td>14. Other (please name)</td>
<td></td>
</tr>
</tbody>
</table>

24. Finally, in case we need to contact you to clarify any answers, what is your name, title, and telephone number where you can be reached?

Name ........................................................................
Title ......................................................................
Telephone number (area code) ____________________________

THANK YOU FOR YOUR COOPERATION

If you have any questions, please call Dr. John Ettlie, collect, (312) 321-7803, or leave a message at (312) 321-7783 and the call will be returned.

Please return survey in the stamped envelope provided, thank you.
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>30</td>
<td>31</td>
<td>63</td>
<td>19</td>
<td>199</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm Size</td>
<td>(0.5%)</td>
<td>(0.5%)</td>
<td>(0.5%)</td>
<td>(1.0)</td>
<td>(1.5)</td>
<td>(0.5)</td>
<td>(1.0)</td>
<td>(1.0)</td>
<td>(2.0)</td>
<td>(5.5)</td>
<td>(15.1)</td>
<td>(15.6)</td>
<td>(31.7)</td>
<td>(9.5%)</td>
<td>(53.6%)</td>
<td>199</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
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Chi-Square = 23.21 (p= .0570)
Kendall's Tau c = - .03496 (p= .2754)
Pearson's r = .05313 (p= .1537)
**TABLE A-2: RELIABILITY ANALYSIS FOR NEW PRODUCT INNOVATION SUCCESS SCALE**

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<tr>
<th>Item</th>
<th>TECHSUCC</th>
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<th>TECHTIME</th>
<th>CONSUC</th>
<th>MKTSR</th>
<th>ROI</th>
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<th>CASES</th>
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**Correlation Matrix**

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# OF CASES = 240

**Statistics**

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**Item-Total Statistics**

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**Recode Information**

TECHSUCC, TECHUUG, TECHTIME, CONSUC (1:3:1:4:3)
ROI (8:6:5:4:3:2)

**Reliability Coefficients**

**Alpha** = 0.61599

**Standardized Item Alpha** = 0.66081

**Correlated Item Alphas**

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**Recode Information**

TECHSUCC, TECHUUG, TECHTIME, CONSUC (1:3:1:4:3)
ROI (8:6:5:4:3:2)
Table A-3: Descriptive Statistics and Correlation Matrix for Regression Summary in Table 14 (n=348)

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Correlation Matrix

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* p .01 (two-tailed test, r=.12202, n=348)
** p .05 (two-tailed test, r=.1061, n=348)

Missing data recoded: for technical success, within budget, on time and overall commercial success, code=2 "too soon to tell" for missing. For market share, same. For R01, code=4, "too soon to tell."
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