A Research Retrospective of Innovation Inception and Success: The Technology-Push Demand-Pull Question

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WP #3767 March 1993
PROFIT #93-06

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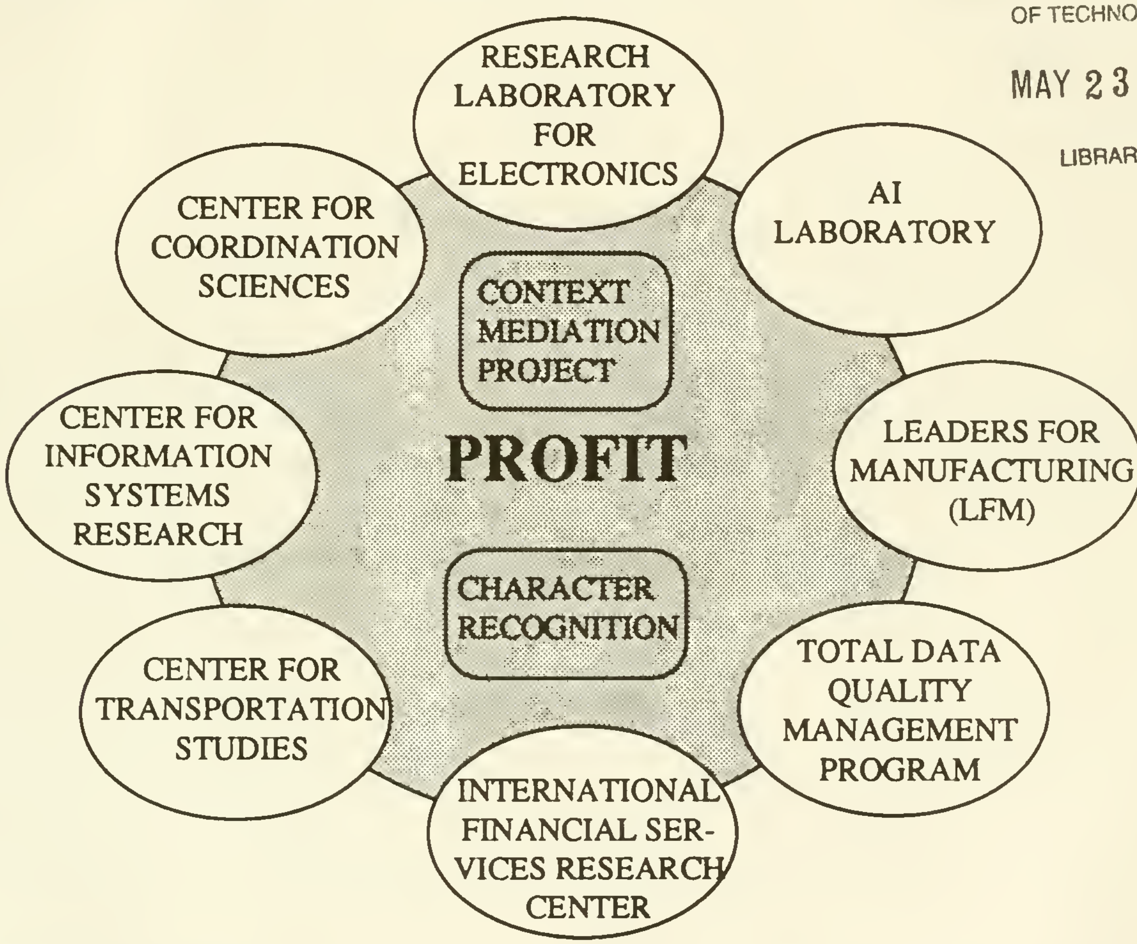

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March, 1993

(Forthcoming in the International Journal of Technology Management Vol. 9, No. 1, 1994)

The authors would like to acknowledge the insightful comments of Stephan Schrader

Abstract

Innovation researchers have frequently debated whether organizational innovation is driven by market demand or by technological shifts. The market demand school of thought suggests that organizations innovate based on market needs, whereas the technology proponents claim that change in technology is the primary driver of innovation. Collectively, empirical research studies on technological innovation are inconclusive regarding this technology-push demand-pull (TPDP) debate. Eight key studies relevant to this issue are examined for their methods, implications, and caveats, to establish a structured way of interpreting the various results. The philosophical underpinnings of market demand and technology factors as drivers of innovation are also examined.

This paper suggests that much of the contention between the demand pull and technology push findings is due to different research objectives, definitions, and models. The main conclusion is that there exists a clear relationship between the research models used in these studies and the outcomes observed, suggesting that differences in problem statement and research constructs may be causing the apparent incongruity in research findings. Organizational and national policy level issues are also examined in light of the finding that different levels of analysis lead to different results.

Key Words: technology push, demand pull, innovation, levels of analysis, research models, policy implications

1. INTRODUCTION

1.1 The technology push demand pull research question

The Technology Push-Demand Pull (TPDP) question constitutes a dialogue among innovation researchers about the underlying motivations and driving forces behind innovation. The push argument suggests that innovation is driven by science, which in turn drives technology and application. The pull argument suggests the opposite, that user demand is the primary factor and that markets, users and applications are, or should be, the key drivers of innovation. Implicit in a pure version of either side of the debate is a linear model of the innovation process with science at one end and markets or users at the other.

The question has ramification at many levels of inquiry ranging from understanding the source of inspiration for an individual inventor, to the establishment of economic policy and competitive strategy among companies and nations. The "answer", if any universal one exists, is that *many* factors influence the innovation process, and that only through bounding the question, and working within a tighter set of definitions and levels of analysis can meaningful distinctions be made.

Downs and Mohr [1976] suggest:

> *... previous research indicates that determinants important for one innovation are not necessarily important for others. Perhaps the most straight forward way of accounting for this empirical instability and theoretical confusion (in innovation) is to reject the notion that a unitary theory of innovation exists. ... The existence of empirically distinguishable categories of innovations and their associated models would help to explain why studies employing roughly the same predictors achieve widely varying R^2's and why the explanatory power of individual variables is unstable across them.*

Additionally, Langrish, *et al.* [1972], in a study frequently quoted for its support of demand pull write:

> *It makes us skeptical of attempts to define unique origins for particular innovations. Different workers select different 'origins' for given innovations. The point was forcibly brought home to us when we provided each other with given sets of facts and asked each other , 'What was the origin of this innovation?' or 'Where did the technical idea come from?' Even among ourselves, different answers were forthcoming. In view of this uncertainty, the concept of a 'time-lag' between a discovery or invention and its exploitation and innovation is a hazy one, ...*

Unfortunately, as is typical in the study of human organizations or social processes, there are serious obstacles to obtaining generalizable results. Not only are the underlying processes complex and inter-related, but they are in a sense unobservable; there is a "chicken and egg" quality to the TPDP issue. Confounding the problem is the fact that research goals of related studies are slightly different, so that even if a well catalogued set of innovation types were developed, cumulation of results would still be difficult due to the fragmentation of studies and to the inherent uniqueness in scientific projects. Allen [1984] suggests "*in science and technology, each piece of work is, by definition, unique. If the problem has been solved before, it is no longer research.*" And so, unfortunately for policy makers and managers there continues to be a lack of hard evidence at several different level of analysis.

This situation summarizes, to a large extent, the state of related research at this point; different studies concentrate on different facets of the question, sometimes due to different research goals, and sometimes due to unsubstantiated conclusions. In empirical studies at the firm or project level there appears commonality in results suggesting that market pull may be a more significant factor in the success of an innovation than technology push. Yet at both higher levels of analysis such as economic, and lower levels of analysis such as isolated case studies there are mixed results. If research results were more consistent, managerial and policy implications could become clearer.

1.2 Difficulties in Empirical Research

Much of the empirical research related to the topic lacks definitional rigor. For example, many of the demand pull studies compare successful and unsuccessful innovations and suggest that user needs are important to success [SAPPHO, Utterback]. This seems tautological, as it is unlikely that companies that are not sensitive to user needs could succeed, and whether the observed relationships are due to cause or effect is unclear.

The TPDP question might better be approached with user needs as a given and not an important variable to measure, or at least acknowledging the interaction between technology push and market pull. Issues such as the specificity of demand and the *a priori* definition of the target market are poorly addressed in existing research. Defining commercial success as a binary outcome variable misses some of the underlying subtleties in innovation. Sensitivity could be gained by using quantitative empirical research, such as by understanding *how much* of a success an innovation was. Firm level financial and accounting statistics can provide much of this information fairly objectively.

A common feature of much of the work in the area is a project-centric *ex post* analysis of those innovation projects which have reached some particular stage of the development process or had some level of impact on an industry's activity. This approach has some hidden biases and assumptions. In short, this approach ignores the possibility that products which failed might have been major successes had the market had more time to adapt to and eventually adopt the product. When a product is declared failed, there may be other factors than technical or market which caused it to fail, and products least likely to offer short term profitability (non market pull products) would be the first to get cut from an R&D budget in times of managerial or technical difficulty. Thus a strong bias exists in the definition of products along their success-failure dimension towards market oriented products.

Van de Ven and Poole [1989] remind us of the difficulty in doing an *ex post* analysis of products which are known to have failed or not: "*it is widely recognized that knowledge of the success or failure of an innovation invariably leads to bias.*" This might suggest that quantitative *ex post* data collection techniques such as those used in project SAPPHO may simply be an inadequate research model for the topic.

2. Survey of empirical work

This section includes a summary of the eight studies analyzed. The studies are broken out by their push versus pull orientation. For each of the push and the pull sides there are three empirically based papers. In addition, two meta-analyses of demand side research are included; one which refutes demand pull, and one which supports it. These meta-analyses are found in Mowery and Rosenberg, who go to great lengths to point out the underlying definitional and empirical weaknesses in the pull-side research, and Utterback, who aggregates the findings of previous empirical studies, confirming the importance of market demand.

2.1 Demand pull studies

The following studies are four of the major studies referred to as demand-pull studies. All are based on *ex post* data collection related to distinguishing characteristics of successful innovations, with Utterback's [1974] aggregate meta-analysis confirming the findings of the other three. All draw the conclusion that attention to market demand, or information from market sources, and not technical sources, was the major factor for the successful innovations.

2.1.1 Project SAPPHO 1974

Project SAPPHO is heavily cited as a demand pull supporting study, though its original intent was an empirical cataloging of the innovation process along many different dimensions. The research study includes detailed data collection of paired successful and unsuccessful innovations in the hope of eliminating mono-operation bias (i.e., studying successful innovations only). While the study demonstrates the importance of user focus in success, there is no evidence that technology push differentially affected failure or success, and thus the corresponding role of science in the innovation process is uninvestigated. Indeed the fact that paired comparisons were based on their competition for the same market [SAPPHO] might screen out the possibility of technology push even being correctly represented as a core concept in the study since true technology push, or scientifically novel innovation, would generally have poorly or undefined markets.

A comment made by the authors of the SAPPHO study based on the qualitative analysis of failures was that "*failure was frequently associated with neglect of relatively elementary rules of good management*" [p 276]. There are two interesting rival hypotheses that might follow from this observation. The first is that in times of managerial difficulty there may be upper management bias, when funding is limited, towards canceling funding of leading edge innovation more quickly than innovation for which a clearly defined market exists. SAPPHO authors only measure managerial competence at a higher level: that of "the innovating organization" (as opposed, for example, to the R&D and marketing organizations), though they conclude that basic mismanagement was a major problem for most failed innovations and suggest that there is no substitute for managers of high quality and ability. The second rival hypothesis, also caused by a bias in the sample, is that management of the R&D function is often handled by technology specialists who have little formal management training, placing a higher mismanagement based "mortality rate" on more advanced products.

The results do not indicate the lack of importance of technology. Rather, the data seems to argue for a balance between organizational competencies and firm level focus on the R&D-marketing interface for greater success. In data representing ten aggregate index variables, two of the leading four determinants of success are scientifically oriented. (These were: R&D strength and communications with outside scientific or technical contacts.) This would indicate that at the aggregate level, an R&D focus is at worst a close second behind a marketing focus in defining an innovation's success. Even though these two variables came in first and second in the overall relevance, little discussion is made of the importance of the interaction between the two in the innovation process.

2.1.2 Meyers and Marquis 1969

Results of this study are many, but the dimensions of innovation differentiation are of particular relevance. The study provides a strong record of the innovations within real organizations, and does so through interviews, so qualitative information backs up some of the quantitative data. However, this research is more a statement of fact, than a prescriptive list of conclusions. The authors themselves acknowledge that the research is descriptive and does not show causality.

The main finding in the study, and the reason it is cited as a pull supporting study is that in only twenty-one percent of the successful innovations was recognition of a technical opportunity a primary factor in the innovation. Market factors were reported as the primary factor in forty-five percent of the innovations and manufacturing in thirty percent indicating, according to the authors, that three-quarters of the innovations could be classified as responses to demand recognition. A direct managerial recommendation made by the authors is that R&D labs should pay attention to *needs for innovation* in addition to maintaining technical competencies. This is at best anecdotal evidence and not a very strong statement regarding larger issues of market pull.

2.1.3 Langrish 1972

The Langrish *et.al.*[1972] study was clearer in its definitions and samples. The authors attempt to overcome the empirical weakness in looking at only commercially successful innovations as the study claims "*success is not judged solely by financial criteria, ... that for some innovations, the financial returns may yet be in the future.*" The sample, however, is slightly weak along that dimension as the Queen's Awards (Britain) is given to those organizations which submitted their innovations for judgment, and organizations with no profit to show for an innovation would have less motivation to apply for such an award. Those organizations that do apply will likely be biased towards a heavier marketing or public relations focus. Most of the innovations sampled turn out to be financial successes.

The authors mirror the sentiments of several of the other demand pull supporters in that there is difficulty in going beyond descriptive studies, and that problems exist in making any claims of causation. More fundamentally, the authors note that it was through effective marketing - R&D interaction that project success was likely to come, and that project success was a meeting of a technical need. The authors credit the technology push in all of the cases in indirect ways, but one comment in particular illustrated a point: they suggest that because manufacturing could not exist without electricity, then only through the invention of electricity could innovation have come about, thus technology push in some sense by definition is always present.[1972] They also suggest one possible firm level definition by which it may be possible to tease apart technology push from demand pull: "*if a sales manager realizes that a product needs a particular new property, then the innovation is 'need pull' type.*"

2.1.4 Utterback 1974

Utterback states strongly that in 60 to 80 percent of the cases in his meta-analysis, market demand was the motivating force in the innovation. Although he qualifies this conclusion in the sense that very little research is available on the *adoption decisions* by firms, suggesting that firm biases may make *ex post* research questionable. Importantly, he states that the probability that a given firm will adopt an innovation is thought to be an increasing function of the proportion of firms already using the innovation, and naturally, the higher the risk factor the less likely the decision to adopt.

An interesting note in that this research is the lag time measured between an innovation's stimulating information being generated and the time it is used in an application is eight to fifteen years. This time period is critical for innovation studies as the time frames of the most innovations studied are unspecified. The result of this is that there is a pre-selection bias in the collection of research data towards successful market pull innovations which are able to get to market in shorter periods of time. The degree of fit between existing company and management processes and a new technology are cited as inhibitors to effective diffusion of technologies. Thus, push innovations are predestined to fail if there is not proper management attention placed in the effective dissemination of information related to the product. This is an element missing from the research. There seems to be little interest (or perhaps great difficulty) in measuring managerial commitment and competence with respect to an innovation.

2.2 Technology push studies

The following four sections each cover one representative study which supports the technology push concept.

2.2.1 Mowery & Rosenberg 1979

Mowery & Rosenberg [1979] were distressed by the uniformity of results of a number of empirical studies which showed that market-pull factors had significant influence over the innovation process. Their concern was that the preponderance of the market pull results would skew public policy making to favor continued disinvestment in basic research and development. Their primary goal was to critically evaluate the major studies that supported market pull results and show that these studies do not measure the same dependent variables. They state that "*our purpose is not to deny that market demand plays an indispensable role in the development of successful innovations. Rather, that the role of demand has been overextended and misinterpreted.*"

Their study is a meta-analysis of eight empirical studies that are most frequently cited as evidence for the demand pull argument. They suggest that every one of the demand pull studies suffers from the problem of confusing the infinite number of insatiable human wants with market demand and propose a more rigorous definition of demand pull to be a demonstrable shift in the demand curve faced by the firm. This meta-analysis has significance beyond that of casting doubts on the validity of the demand pull argument. It adds an entirely new level of analysis for innovation research in general, by suggesting that the effects observed at the firm level may not apply or be consistent with, effects observed at the industry or the national level. In other words, what is good for General Motors, may not be good for America or even the auto industry.

2.2.2 Freeman 1982

Mowery & Rosenberg stressed the importance of studying the TPDP question at a higher level of analysis than the firm alone, and this Freeman [1982] study is an example of such an analysis. The data collection is focused on more macro-economic issues such as changes in occupational levels in different industries instead of projects in specific firms. Besides macro-economic data, the study also uses qualitative data to support the findings. Freeman seems to have been influenced by Schumpeterian[1] thinking, and echoes the notion that without scientific progress, economic progress will grind to a halt.

The results of the Freeman study indicate that in the long term, a strong scientific base contributes to economic progress through the process of innovation. This study illustrates the complexity of the TPDP argument and the need for multi-method, multi-construct studies to examine issues related to technological innovation. Freeman acknowledges that many issues are still open by stating that "*this book reflects the relatively elementary state of our present knowledge. The generalizations are tentative because they have been insufficiently tested and corroborated by applied research.*"

2.2.3 Casey 1976

Casey [1976] traced the sequence of events from basic discovery and conception of a new, revolutionary sweetener to its commercialization. High fructose corn syrup was a radical innovation in the industrial sweetener business, since it made it possible for U.S. industrial consumers to obtain a less expensive domestic substitute for sucrose. The commercial payoff of this innovation was very high. Though this is a case history of a single innovation, the data collected was not restricted to a single firm. Instead, records from scientific journals and industry economic data from 1932 to 1972 were used to piece together a historical retrospective. In his summary Casey, unequivocally states that "*the innovation in high fructose corn syrup was not due to product focused research, but because of medically oriented biological studies in cell metabolism.*"

Besides being a ringing testimony for the technology push argument, the Casey study raises two important issues. First, to truly understand the effects of technology push, time seems to be an important factor. Casey looked at data from a variety of sources that was archived over forty years. The time factor could partly explain the preponderance of demand pull findings in the inherently shorter duration cross-sectional studies done at the firm project level, where current employees are asked to identify the largest innovations in recent years. Second, the research method and level of analysis influences the results. All the demand pull studies seem to done in organizational settings, whereas the technology push studies do not use firm level data.

2.2.4 Pavitt 1971

Pavitt's [1971] Organization for Economic Cooperation and Development (OECD) report is a macro-economic study, aimed at providing a basis for policy making at the governmental level. The study was in response to a request from the OECD council

[1] refers to the economic philosophy of J.A. Schumpeter, which is briefly outlined in section 3

to report on the factors and conditions for technological innovation. The goal was not to prove or disprove either of the TPDP arguments, but simply to gather data on technological innovation in the OECD countries and provide statistical analyses to help in their interpretation.

The report is divided into three parts that examine the role of industry, universities and government in the process of technological innovation. Though it is not an academic research study, this is an example of the examination an innovation issue at multiple levels, using a variety of measures and a mix of both quantitative analyses and qualitative data. This study suggests that incremental innovations in organizations are driven by market pull factors, while at national levels, basic research in universities, government laboratories and individual firms have impact on overall economic progress. The lesson, methodologically, is the continuing need for mixed methods and multi-level research.

2.3 Research validity issues

Of the four basic measures of research validities: construct, internal, external, and statistical, perhaps only the statistical validity component is rigorously satisfied in the research studies reviewed above. Causality is not shown and external validity is limited by the types of innovations or industries studied. Constructs are poorly defined; given the unobservability of the invention process, innovation and project activity are viewed as substitutes for invention. Attention to user needs, shifts in the technical environment, or patterns of information flow are used as proxies for sources of innovation. This leaves two issues not addressed. First, for information flows, it is unclear where information comes from? Second, user needs as a measure for market demand lacks definitional rigor.

As suggested by Mowery and Rosenberg, shifts in user needs and not current trends in industrial activity, should operationalize demand pull. There are implicit assumptions in all of the demand pull arguments that the existing industrial method is acceptable and thus may deserve emulation. Given slowed productivity growth and an increasingly competitive and changing world technologically, models of past corporate success may not apply well today. In summary, all authors are willing to state their preference for either market or technical factors, but leave to the reader the conceptual building of the relationship between market indicators and underlying changes in the technological base. They have demonstrated that both market need and technical capability are necessary conditions for innovation success, but have not demonstrated that either is alone a sufficient condition.

2.4 Summary of research models

The TPDP discussion is a complex one because of the inherent difficulty in defining constructs, making measurements, and the unavailability of data. Since it is not possible to conduct experiments, none of the studies can claim to have a causal framework for explanation of their hypothesis. Researchers have instead resorted to a variety of methodologies, in an effort to make some headway.

The Casey study was largely a historical retrospective of a particular innovation. The Langrish, SAPPHO and Meyers and Marquis studies were *ex post* analyses of projects at the organizational level of analysis. Only SAPPHO used matched pairs of successful and unsuccessful innovations for the study, while the other two studies conducted *ex post* statistical analyses of projects in a small number of industries. Both the Pavitt and Freeman studies show the usefulness of a multiple method approach. Pavitt used a combination of macro-economic analyses and qualitative information to study innovation at the industry and national levels while Freeman used historical retrospectives in conjunction with macro-economic analysis. Utterback and Mowery & Rosenberg conducted meta-analyses, but interestingly, Utterback did not convincingly raise the level of the discussion to the industry or national levels as did Mowery & Rosenberg. This might partially explain the opposite conclusions drawn in the two studies.

The following sections give a brief summary of the different research methodologies of studies referenced.

2.4.1 Ex post cross sectional project focus

An *ex post* project focused analysis deals exclusively with data from different completed projects in different organizations. In most of the *ex post* studies reviewed in this paper, structured interviews with project managers constitute the bulk of the data. Market factors such as commercial success and profit are innovation outcome measures. Typically, regression analysis of variables such as market success, profits, and time to market are run against independent variables such as project manager responses on questionnaire items.

The major advantage of this method is the large sample size and the consequent statistical validity of the results. The large sample size also makes it possible to explore a wide variety of independent variables and control for a number of factors such as maturity of the industry and the national economy. Another advantage is the possibility of obtaining data across many different industries, which can increase the external validity of the hypothesis.

The major disadvantage of this method is the inherent bias towards studying commercially successful innovations. Managers are unlikely to suggest that the successful innovation was driven more by the technical and scientific forces than by their own astute reading of market signals. Another problem is that the immediacy of the market information compared to scientific information is likely to skew responses from even the more objective managers are prone to cite market pull factors. Respondents are more aware of recent market-based information about the innovation than the earlier, slower scientific information. The *ex post* cross sectional study is inherently not suited for observation of slow, long term impacts, because cross-sectional data represents a single snap-shot in time. It is probably no coincidence that all the *ex post* cross sectional studies reviewed in this paper showed market pull factors to be more significant.

2.4.2 Case study: Innovation focused

A case study (or case history) is a systematic record of a specific innovation. Data is mainly qualitative and obtained through interviews, public records and archival data supplemented with simple statistical analyses like contingency tables. The objective is to present a more vivid picture of the innovation over a longer time horizon.

Case studies have the distinct advantage of providing rich details of the underlying process that is being observed. This is particularly useful in the TPDP research question, because of the slow and often subtle influences of science on the innovation process are difficult to observe with traditional cross sectional studies. The historical retrospective effectively "normalizes" for the difference in time-lags between the effects of the market and the effects of science.

The disadvantages are of course, the lack of generalizability of results and findings. However, since TPDP research still lacks causal frameworks, the insight developed from case histories can help in the development of better theory in this area.

2.4.3 Economic/National level statistical analysis

This type of study is based on rigorous statistical analyses of aggregate level data (i.e. data gathered at the industry or national level). The unit of analysis is not a project or an innovation but an entire industry or national economy. These studies have a distinct macro-economic focus.

The primary advantage of a study of this sort is the ability to observe and report on large scale effects and longer term diffusion patterns. Since, the level of analysis is above the firm or innovation level and based on reasonable sample sizes, the observations have reasonable external and statistical validity.

The disadvantage is that aggregate level statistics may not convey important firm level information, for example, national GNP figures do not convey the profitability of individual companies. Also, the reliability of aggregate data is often suspect, which is one reason that Pavitt in his OECD report included qualitative data in the interpretation of the results.

This methodology is valuable in TPDP research, since it can help determine whether firm level effects are observable at the industry and national levels. It also help policy makers decide on public investments that encourage technological innovation.

2.4.4 Meta Analysis

A meta-analysis is a critical overview or a quantitative aggregation of several different studies. The results of different studies are integrated and the generalizability of certain findings is investigated. A meta-analysis typically also addresses the deficiencies of research in the particular area and suggests the adoption of specific definitions of variables and constructs, so that the field as a whole can progress.

The advantage of a meta-analysis in examining the controversial TPDP question is in pulling together different studies in this area and observing consistency of results. Both Utterback and Mowery & Rosenberg have noted in their meta-analyses that different studies have very different definitions of constructs for demand and technology. Another important advantage of a meta-analysis, as shown by the Mowery & Rosenberg study, is that the results at a higher level of analysis can shed new light on the research question.

The disadvantage of this method of study is the reliance on secondary sources of data and the possibility of misinterpretation of constructs and results. However, both Utterback and Mowery & Rosenberg have been frequently cited for the thoroughness of their analyses and interpretations.

2.5 Constructs missing in existing research

Innovation variables which are poorly addressed in the current research models, yet were cited as important variables throughout the studies are:

(1) The time component (time from innovation inception to success or termination) as a variable in the analysis.

(2) Treatment of the innovation process as a "birth" process in which the eventual impact of a never "grown" innovation is unknown.

(3) The decision making of the inventors and the innovators themselves.

(4) How firms make optimal choices for innovation investment in both long and short term opportunities given resource constraints.

(5) Organizational processes, such as the interaction between strategy, R&D and marketing groups of a given firm as determinants.

(6) The dual nature of lead users as both users and innovators, which blurs the line between technology push and demand pull situations.

(7) The importance of the customers' ability to state their demand in the innovation process.

(8) The strategic motivations of the firm, as suggested by Schumpeterian destruction of existing capital through substitution, and the role of incumbency and competitive position.

(9) Effect of market environment (e.g., oligopolistic vs monopolistic) on innovation investment, including the role of complementary assets and defense of existing competencies.

(10) The relationship between different innovations diffusion patterns and innovation success.

(11) The importance of sample bias in research results.

The above list is not intended to suggest that all of these variables could somehow be embodied in a single research design. To the contrary, the whole reason for the lack of decisive knowledge about the TPDP issue lies in this inability to do perform multiple-methodology studies rigorously and completely. An alternative to the idea of creating a single cross-level analytic tool is the possibility that the multiple levels could be researched independently, as done in the eight studies reviewed. What has been missing, however, even in such single level studies is a focus on the internal mechanisms of the organization. There has been extensive focus on the innovation as a marketable entity, and much less focus on the organizational activities and competencies that bring them about.

Certainly a critical part making the research stronger in the field is in stronger definitions. The denunciation of the "other side's" research results does little to advance the understanding of innovation methodologies. There is needed a more rigorous distinction of levels of analysis, and such issues as distinguishing innovation from invention, science from technology, and market demand from a resourceful matching of capability with needs.

3. Philosophical underpinnings of the TPDP debate

Academic study of technical advance is a relatively recent phenomenon, beginning at about the end of World War II. However, the 18th century French mathematician and philosopher Leibnitz

[Rescher, 1978] is said to have conceived of science as an *economically* productive enterprise, dealing with "putting science on a businesslike basis." Later, in 1937, Adam Smith [1937] in *Wealth of Nations* acknowledged the role of technological and scientific advancement in economic progress. Smith saw major advances coming from men of independent means, seeking truth for its own sake and identified two ingredients that make technical advance an economic activity. The first is that scientific advances have economic value and the second is that they required the investment of time and money. He failed, however, to combine the two ingredients into an integrated theory.

3.1. Schumpeter's view: technology push

The classical economists continued to ignore this aspect of economic progress, choosing instead to view technology as a means of changing the factors of production, and technical advancement as serendipity (being at the right place, at the right time). It was Schumpeter, who in his three books, *The Theory of Economic Development* [1961], *Business Cycles* [1964], and *Capitalism, Socialism and Democracy* [1975] clearly articulated the active role of economic agents in innovation. The notion of innovation most commonly associated with Schumpeter is the idea that it is a "process of creative destruction"; he is a proponent of the technology push argument. In Schumpeter's view the pace and direction of innovation activity will be determined by the advances in the underlying scientific base.

The Schumpeterian view of technology push is corroborated by Phillips [1966] who places a major emphasis on the role of scientific knowledge in innovation based on studies of patents, competition and technical progress in selected manufacturing industries. The basic argument of this school is that a firm's research staff is the primary initiator of innovation. Advances in basic science are brought to the attention of the organization by the research staff for possible commercialization. The market has a relatively minor role in determining the pace and direction of innovation within the firm.

The evidence given in support of this argument are major breakthroughs such as lasers, paper copiers and microelectronics which were originally developed for relatively immature or undetermined markets. These remarkable innovations proceeded to have widespread use and turned out to be immensely profitable. The technology push hypothesis is further supported by Merton [1973] who showed the contemporaneous nature of many discoveries, suggesting (according to the Schumpeterian view) that certain discoveries are almost inevitable in the course of human development. Phillips [1971] later acknowledged the influence of market forces on innovation by incorporating a strong feedback loop from the market success (or failure) of innovations on future innovation activity in the firm. In other words, the firm changes its innovation partially in response to market signals. However, the fundamental belief in the primacy of basic science remains unaltered.

3.2. Schmookler's view : demand pull

Schmookler's [1966] studies on patented inventions across different industries showed that industries which had more patents were more oriented towards the market, supporting his demand pull hypothesis. The basic premise of the argument is that firms perceive profit opportunities in the market and innovate in order to maximize profit. Thus the market, and not the scientific base, becomes the prime mover of innovation. The Schmooklerian view extends the demand pull argument beyond the confines of a single organization to the macro-economic level as well, i.e, all innovations in the economy are demand driven. Many examples are provided to support this view. For example, AT&T is said to have developed the transistor in response to the need for smaller, more efficient switching systems. The demand pull studies by Meyers & Marquis and Langrish support Schmooklerian arguments that innovation is a response to profit opportunities.

The demand pull argument borders on being tautological. There is *little possibility of firms innovating in order to decrease profits*. Firms do innovate in order to reduce losses, but that too is rational profit-saving behavior. Schmookler's patent application studies have been questioned by Mowery & Rosenberg on the basis that most patents never reach the stage of commercial exploitation and furthermore that many commercial innovations are never patented. Another argument against the demand pull argument is that most inventions can be traced back far enough to some basic advance in scientific knowledge.

3.3 Is synthesis possible?

3.3.1 Different Research Uses Different Definitions

The definitions used in the TPDP spectrum across the push and pull sides are inconsistent and perhaps do not even address the same underlying concepts, making synthesis of results difficult. Technology push is defined as supported when shifts in underlying scientific activity evoke shifts in innovation activity. Demand pull, however, instead of being correspondingly represented by a shift in the demand curve, is considered supported when successful innovations are differentially more oriented towards fulfilling market demands than are unsuccessful innovations. This demonstrates market orientation only as a necessary, and not as a sufficient condition to success. Many of the studies draw conclusions beyond those which directly follow from the research results at hand. For example, market pull studies which show that successful innovations were driven by market need tells us nothing about any scientific precedence that may have enabled those innovations. Conversely, technology push studies of a correlational and economic nature can say little about organizational dynamics. Given that none of the research directly addresses cause and effect issues, conclusions are necessarily conjectural in nature. True experimentation is infeasible, and solid quasi-experimentation has not been done.

Both Freeman and Pavitt look at economic indicators, and both conclude that at national levels, over the long term, scientific discovery occurs in spurts, and fuels a number of more market oriented, commercial innovations. Cross-sectional innovation based studies, on the other hand, conclude consistently that the linkage between science and its application in technology is at most occasional. Based on these differences in findings, the two sides appear to be irreconcilable, but the differences in research methodology seem likely to explain the differences in empirical results.

Mowery and Rosenberg convincingly rebut the research supporting demand pull as based on poor constructs, tautological research models, and lack of experimental design. At the same time, the two varieties of technology push studies (case history and economic analysis) are also both unable to show causality, or make definitive policy recommendations. Case histories which examine the long term effects of a particular innovation have a built in bias in that it is only successful inventions that are studied, offering little help in the project selection and management process. Because of the difficulties in capturing project dynamics and human interactions in large scale data collection, aggregate measures are all that are available at this level of analysis. The importance of capturing organizational dynamics in the research measure is made apparent by the consistent statement by research authors that project member's capabilities and organizational interfaces are critical to project success.

Market and technical forces are frequently cast as opposite ends of a spectrum in the research literature; suggesting somehow that one or the other, but not both can be present in a given innovation project. It was repeated in all of the research conclusions that combining market need with technological capability was perhaps the single largest critical underlying factor, illustrating the need for a combined technology-market interaction for successful innovation. Unfortunately, the power of such interaction effects are lost in the binary comparisons of success and failure and labeling market or technical factors as stimulating an innovation, as done in cross sectional studies.

New market needs can, by definition, drive new solutions, but also many examples can be given for new discoveries driving new needs. Classic examples of technology push innovations, particularly in synthetic materials and microelectronics, serve as fitting examples of occasions in which scientific activity, initially aimed at some eventually unsuccessful application, enables countless other uses. Some of these technology push instances have become so ubiquitous as to be ignored for their scientific origins. For example, when IBM was creating the computer it was completely unable to predict the level of societal diffusion the computer would eventually reach, by many orders of magnitude underestimating the eventual market size and impact. The computer, which was the result of integration of many dimensions of scientific activity (in logic, solid state physics, etc.), taught people an entirely new way of managing and *wanting* information which, prior to the computer, would have been unthinkable. Such ubiquity of scientific "infrastructure" innovations, which include the electric power grid, the telephone, advanced transportation systems, etc., seemingly makes immaterial any arguments based on the particulars of a given firm level innovation.

If it is presumed that the different research methodologies are addressing the same issues, then it must be concluded that the research is simply too young to be of much value (due to conflicting results) and that the subject is not yet well understood. It may also be, however, that both sides of the research issue are correct within their respective domains and that the results are *complementary and not contradictory*. Because there is much research literature to back up both sides of the debate, this becomes the most appealing interpretation of the mixed results. The reason for the paradox may not be research flaws, but rather it may be in the specific issue being addressed. This suggests that the key to integrating findings is in understanding exactly which portions of the innovation processes the different research models pertain to.

3.3.2 Results Integration

Though the TPDP discussion has been cast as a debate, it's existence may actually reflect the simple inability to integrate apparently inconsistent results. It may be an artifact of looking at a complex social process from many levels of analysis, and trying to reduce it to a single, objective declaration. While each side acknowledges the other's merits and importance, there is little attempt to integrate the two models of activity into one. Until dynamic models encompassing both organizational and economic policy levels are created, synthesis must remain a fragmented process. No research to date has been able to resolve the apparent disagreement between the economic and the project level of analysis. Economic and organizational levels both have direct implications for the TPDP question, but clearly they answer different types of research questions, and thus can not be easily combined.

For true cumulation and comparison of results across studies, demand pull should be held to the same standards of definitional rigor as technology push. Where shifts in the scientific supply curve or input of scientific information defines technology push, shifts in the demand curve, not attention to customer needs, should be the criteria for defining an innovation as demand pull. All of the authors agree that value to the customer is critical, but technology push is operationalized as a discrete event such as scientific information stimulating an innovation, where market pull is more loosely defined.

An alluring model of innovation activity which might synthesize notions of technology push and demand pull is summarized in Mowery & Rosenberg [1979] in which they suggest that companies essentially exist as dynamic entities which are neither in pursuit of specifically technical nor specifically market opportunity, but rather are commonly in pursuit of increased returns through innovation . In this model, at any given time, companies sit at an equilibrium point, changing strategy in response to a changing environment, attempting to follow most likely avenues of profitability. An environmental shift can come from either technical or market opportunity, and a firm can benefit from either type. Again missing from this model are issues of organizational competencies and market conditions; these constructs are hidden the notion of opportunity. The policy implications may remain unclear, as the dynamic interaction between the structural orientation of the firm, and its dynamic linkage with the environment is unclear.

One thing comes clear for all the studies: in the short term, incremental innovations, which constitute the bulk of successful innovations, are launched into existing markets, or markets whose near term needs are well known; market demand is a clear requisite to success. In addition, it is found that, overall, market based successful innovations tended to be more incremental in nature than those technologically based, making them of proportionately less long term value.

The situation is murkier for cumulation of long term results associated with more radical innovations since market demand is a less well defined construct in this context. Most of the study's authors agree that there is some confusion surrounding the time-lag between scientific discovery and commercial application which confounds or potentially invalidates research data. For example, all studies which do an *ex post* analysis of successful and unsuccessful innovations have a built in bias against innovations which were aborted early in their development. This is a problem as there is no way to estimate the long term potential of those innovations, resulting in a bias against any innovation which does not have immediate market application.

Although the researchers on the two sides of the debate disagree as to their respective positions, there exists a unifying framework which allow for both results to coexist. As suggested in the previous paragraph, the crux of the difference between the two sides may lie in the micro versus macro level of analysis and the temporal dimension or time-lag issues between scientific discovery and commercial application. It may indeed be true that the majority of commercially successful innovations are market dependent or immediately inspired by market information, but this does not show that they were not founded upon some existing scientific base of knowledge. If this were the case, as is suggested by Casey, then both the science and the market forces would be critical in complementary fashion. Technology push innovations are fewer in number, but they may fuel a larger number of incremental innovations.

4. Theoretical and practical relevance

The TPDP debate has significant implications for managers of organizations as well as public policy makers. If the primacy of the market pull is established, organizations may need to rethink the nature and role of R&D efforts and increase their market orientation in order to catch market signals earlier. The financial fortunes of the firm depend on the firm's ability to innovate in response to the market; there would theoretically exist declining returns to purely scientific research.

On the other hand, if science is shown to be the prime mover of successful innovations, organizations would have to increase spending on long term R&D or at least have close ties to centers of fundamental research such as universities. At the national level, policy makers would have to actively encourage R&D in order to stimulate the economy, since scientific progress is the harbinger of economic progress.

Ultimately, the objective of the research is to guide policy direction, so as a benchmark, theory is inadequate until it can assist in decision making. Until research models are tested for their predictive power, however, they will remain more in the framework than the model category, offering merely novel ways of thinking about the issue without offering any concrete policy implications.

The following two sections discuss synthesized (but unproven) implications as specific to organization and industrial/national policy.

4.1 Implications for organizations

Importance of R&D

Though not stated explicitly by the demand pull studies, many major innovations are driven by science and technology. The current microelectronics revolution, superconductivity and biotechnology seem as likely to change existing markets or create new markets than to grow into current ones. These major innovations can have significant long term economic payoffs for individuals, firms, and nations. It is therefore, in the interest of at least some components of an economic system to continue investment in R&D, whether that be through investment by individual firms or at a more aggregate level such as consortia.

R&D Strategy depends on firm size

Since larger firms have more resources, they can invest in basic research in the interests of long term benefits. This is the classic Schumpeterian hypothesis on the advantage of large firms. The counter-argument to this hypothesis, however, is that large firms may have a disincentive to invest in radical innovation due to obsolescence of existing competencies. Large firms could still potentially gain first mover advantages by initiating major innovations and it may be in their best interests to continue investment in basic research based on a "deep pocket" competitive research advantage. Smaller firms on the other hand, may be more prone to maintain close ties with major research centers (e.g., universities, government laboratories) to leverage new scientific and technological breakthroughs.

Market focus may fuel incremental innovation

As Pavitt suggests, major scientific breakthroughs do not occur at regular intervals, so firms cannot afford to neglect incremental innovations which can be a potential source of steady revenues and profits. This implies that firms must continue to be receptive to market signals, which are a necessary condition for successful incremental innovations. This could mean closer ties between R&D and marketing within the organization and increased use of market research. The individual firm has to be capable of responding quickly with innovations that meet specific market needs, while simultaneously exploring basic research areas for potentially major innovations that can more significantly alter the market landscape.

Managing Innovation is important

Many of the TPDP studies (Pavitt, Langrish, SAPPHO) have found that managing the process of innovation is an important organizational function. Poor management practices can slow down the pace and quality of innovation, which can result in significant market losses. This is, however, not an easy task given the apparently conflicting demands for resources between basic research and marketing. As Mowery & Rosenberg suggest, individual firms need to be aware that they are in an equilibrium at any given point in time and need to respond effectively to both scientific and market opportunities.

4.2 Lessons learned and future research

Individually, each of the research studies advanced our understanding of innovation and the TPDP question in particular only incrementally. *Ex post* studies such as SAPPHO and Meyers & Marquis reiterated the market pull arguments. The case histories by Casey and Freeman provided longitudinal data on specific innovations, and the meta-analyses by Utterback and Mowery & Rosenberg came up with opposite results. Collectively, however, there were several important lessons learned from the TPDP research studies.

First, innovation can be studied at different levels of analysis; at the firm project level, single innovation level, and industry/national level. Results obtained at one level are often inconsistent with results at another. Second, there is a need for multi-construct, multi-method studies of innovation. This is particularly important since the research method employed tends to bias the results of the different studies. With the use of multiple methods and constructs, some of the inconsistency in observed results might be better understood.

First principles are hard both to define and to measure as related to innovation inception. Several of the papers reviewed here include a subjective assessment by the authors of the current state of the research in the area. Most suggest that in order to gain a fuller understanding, integrated models will be necessary which venture to tie organizational to economic activity towards managing the multi-faceted nature of the problem. Mowery and Rosenberg suggest that the research to date on the topic has been of a "black-box" orientation, in which the firm is analytically reduced to an innovation production function in which inputs are mysteriously transformed into outputs. This criticism could apply to all four of the research models, except perhaps the case history model but there again predictive capability is lost due lack of a causal research model.

The notion that the innovation process is tractable enough to study through retrospective techniques may be underestimating the underlying complexity. As suggested by Utterback [1974, p625], case studies may continue to be a source of ideas and hypotheses for further research, but they do not offer a better understanding of the innovation process. A more comprehensive empirical research model is needed which includes variables from individual to organizational and national levels.

5. Conclusion:

The fact that the major studies on the TPDP issue were completed in the 1970's raises the question as to whether they are applicable today. The 1950's and 1960's, for example, were a period of heavy investment in R&D, so innovation activity in the 1970's may have been skewed towards market oriented incremental innovations built on market foundations from previous scientific research. Changes in world markets and technological competition may have shifted the situation over time, calling for new studies to revisit innovation inception issues.

The TPDP research studies actually address many different issues, but share the common element of trying to understand the factors that determine innovation success. Though the issues are complex, it can be seen that answers to the TPDP research question seem to depend strongly on the research methodology and the level of analysis. The inability to perform experiments, coupled with the high cost of multiple methods makes research progress difficult. Meta-analyses and anecdotal evidence by experts in the field appear to be the most interesting firm level information available. The evidence is retrospective, correlational and potentially biased. This may likely continue to be the case until more comprehensive models or frameworks are developed. This needs to be kept in mind by both practitioners and researchers of technological innovation as the impact of innovation research on the innovation process is particularly important in competitive markets.

Comparing or integrating the TPDP research with the more general innovation literature is a difficult process. There are few frameworks, if any, that fall directly from the papers reviewed. If anything, these papers demonstrate the difficulty in obtaining empirical data in a complex domain. Where much of the innovation literature has clear managerial implications and impacts, such as increased communications among certain groups, TPDP research largely ignores the organizational dynamics, with little prescription for managerial action. The reader is left to draw concrete conclusions.

The complex interaction between markets and science are well summarized by quotes from two prominent individuals involved in what appear to be opposite ends of the TPDP spectrum [Shanklin, 1984]. Thomas Edison, the quintessential American inventor writes: "*First be sure a thing is wanted or needed, then go ahead.*" While Akio Morita, CEO of

SONY corporation, a highly consumer market oriented company states: "*Markets must be created, not surveyed*", with Sony's advertising slogan reading: "*Research Makes The Difference.*" Clearly both technology and markets play significant roles in defining the innovation process.

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SAPPHO updated - project SAPPHO phase II

1974

GOAL:

A systematic attempt to discover differences between successful and unsuccessful innovations.

RESEARCH METHODS, VARIABLES & SAMPLE SIZES:

Studies 43 paired successful and unsuccessful innovations quantitatively.

Follow up interview with 34 of the failed innovation's firms

122 questions per innovation

Compared successful innovations to unsuccessful innovations along several dimensions.

- degree of risk taken by organization
- strength of management of the organization
- structure of the organizations - organic vs mechanistic
- efficiency of marketing research and precise understanding of user need
- level of familiarity of the firm with technical problems and market problems
- strength of the development work concerned with the innovation
- effectiveness of the organizations communications network with outside technical and scientific communities
- level of pressure facing the organization and its innovation
- a measure of the marketing effort put out by the organization

Comparisons made on a trichotomized basis as to the differential across successful and unsuccessful firms. less than, equal to or greater than

Innovation success defined by net monetary gain, market share, and alignment with company strategy.

RESULTS AND CONCLUSIONS

- Successful innovators seen to have better understanding of user needs
- Successful innovators pay more attention to marketing and publicity
- Successful innovators work more efficiently, but not necessarily faster
- Successful innovators make more use of outside technical and scientific information
- For successful innovators, the responsible individual on the project was of greater seniority and had greater responsibility

Conclusion is that the factors which emerge as important to success are those related to user needs, and :

It is important to maintain interaction with customer.

No substitute for quality management.

Marketing/R&D interface important.

Quoted as a DEMAND PULL study

CAVEATS

- Market pull defined in terms of user needs
- The authors make no negative statements about the importance of technical and scientific input to the project, in fact scientific and technical contact was among the higher of the differentials between success and failure.
- Predominantly process innovations.

Marquis and Meyers

1969

GOAL:

A systematic study of how innovation is spawned, nurtured, financed, and managed into new business.

RESEARCH METHODS, VARIABLES & SAMPLES:

- Studies 567 innovations at 121 firms in 5 industries
- Stated as a novel study due to: wide range of innovation types, inclusion of adopted innovation.
- Uses extensive, semi-structured, retrospective interviews of people close to the innovation
- Innovations identified as most successful in several years - no strict definition of success, but commercial was most common result.
- Uses extensive statistical analysis
- Define innovation as the introduction by a firm of technical change in process or product.
- Studied: nature of innovations, primary factors in their initiation, information used in formulation and solution, and sources and channels of information.

RESULTS AND CONCLUSIONS

- Recognition of demand is a more frequent factor in innovation than recognition of technical potential.
- Adopted innovations contribute significantly to success.
- Ideas for innovation may be evoked by information inputs
- Most information which led to the solution of existing technical problems was widely available.

Quoted as a DEMAND PULL study

CAVEATS:

- Innovations were mostly minor - market forces greater
- Producer-goods industries only - housing, railroad and computers
- No classification of firms as high or low tech
- No measure of the impact of the innovation
- All innovations were successes,no "control" group

Langrish, Gibbons, Evans, and Jones
1972

GOAL:

To build up a fuller descriptive "natural history" of the innovation phenomenon through detailed accounts. In particular to relate the technological to organizational and other aspects.

RESEARCH METHODS, VARIABLES & SAMPLES:

- Used the British Queen's Award as the innovative sample
- In theory giving both financial returns and technical advancement opportunity to be included in the sample
- Various industries, mostly manufacturing
- 84 innovations total, mostly incremental
- Ex post surveys and extensive interviews of successful innovations
- Case history based
- Thorough data collection and verification
- Some of the innovations were expected to generate financial returns yet only in the future

RESULTS AND CONCLUSIONS:

- 35 % of innovations driven by discovery push, 65 % by need pull.
- Scientific input into the innovation process, through real, comes largely through indirect channels.
- No support for the key individual hypothesis (p 11)
- Simple linear models of innovation do not apply.
- There are multiple sources of information leading to innovation.
- Larger innovations were more on the technology push side.

Quoted as a DEMAND PULL study

CAVEATS:

- Innovations were self-selected for submittal to Queen's judges for award, possibly leading to a marketing-heavy sample of innovations
- Technology push rigorously defined as material to fill a graduate level science course - a rough measure.
- Need not distinguished from demand.

GOAL: Summarize "what we know" about the process of innovations by firms. How do characteristics of the environment affect the firm? What do we know about the acceptance of innovations in the market and about the creation of new firms based on technology.
RESEARCH METHODS, VARIABLES & SAMPLES: - Meta-analytic study of 17 previous empirically based innovation studies - Covering over 2000 innovations - Innovation seen as distinct from invention and dioscovery
RESULTS AND CONCLUSIONS: - 60 - 80 % of the innovations studied have been in response to market demands and user needs - Strong similarity between US and UK empirical findings - Architecture (geographic distance) plays a large part in the communications patterns among employees - A research need exists for understanding and measuring interfirm and interindustry activity in innovation - Author believes that market activity, as opposed to tax incentives or patent laws, will be the more critical factor in stimulating innovation - Definitive answers will require experiments in the field, but expense will necessarily leave control out of the hands of the experimenter.
CAVEATS: - Subject to tall of the same definitional and sample biases that the other market pull studies are only successful innovations, ex post, correlational, cross sectional studies - .(stated by the author) Problems are raised by the distinctly nonrepresentative nature of samples used.

Mowery & Rosenberg 1979
GOAL: -Critical analysis of empirical studies -Demonstrate the inconsistency of constructs -Propose a more rigorous definition of demand pull
RESEARCH METHODS, VARIABLES & SAMPLE SIZES: -Meta Analysis -Eight empirical studies analyzed -Analysis is a theoretical critique of the different studies
RESULTS AND CONCLUSIONS -There is no consistency between the studies on constructs -Human needs frequently interpreted as demand -Ex-post analyses and surveys bias the results -Some studies are not valid, since they study military procurement -Pull studies say very little about direction and pace of innovation -There is insufficient appreciation for the small, continually occurring technology changes -Demand pull assumes perfect market signalling -Shift in demand curve is proposed as definition of demand pull -The debate should be examined at the industry & national level -Simple linear models of innovation may no longer be appropriate -Innovation in firms is in a dynamic balance -Basic research affects commercial innovations in complex non-linear ways
CAVEATS -This is a purely theoretical argument -M&R do not prove technology push, only cast doubts on demand pull -The suggested construct for demand pull, cannot be easily measured

Freeman 1982
GOAL: -To stimulate "new thinking and research" in the area of economic and policy analysis
RESEARCH METHODS, VARIABLES & SAMPLE SIZES: -Historical analyses of a number of different innovations ranging from plastics to genetics -Data is gathered at the industry and national levels on R&D expenditures, number of researchers, number of patents etc. -Data on variables such as R&D expenses gathered across nations as well -Statistical analyses using contingency tables, regression etc. complemented with historical narrative of particular innovations and particular industries
RESULTS AND CONCLUSIONS -Long term scientific research contributes to commercial innovation -Technology develops in spurts and fuels a series of incremental innovations -A healthy mix of "pure" invention and application is needed -Strong in-house R&D needed for successful innovations -In absence of strong R&D, close ties are required with those conducting basic R&D -Larger scale producers have inherent advantages in innovation -Ties R&D to the notion of risk and suggests that fundamental research is always risky
CAVEATS -The studies are all correlational studies using different levels of data, there is a possibility of missing organizational level dynamics in the study -Prescriptions for organizations are based on industry and national level data -There is no coherency in mixing and matching qualitative data with statistical analyses

Casey 1976
GOALS: -Trace the evolution of the high fructose corn syrup from research to commercialization (1932 to 1972) -Learn more about the innovation process
RESEARCH METHODS, VARIABLES & SAMPLE SIZES: -Case history of a particular innovation -Sample size is obviously 1 -Data gathered from multiple sources: scientific journals, press reports, government and industry data
RESULTS AND CONCLUSIONS -Basic research is important to commercial innovation -Basic research should be done in-house -Sources of information can be from outside the industry -Long intervals separate major innovations in mature industries -Confluence of market & technological opportunity offers special rewards
CAVEATS -This is a case history, not a large sample study -The paper does not articulate the details of the data collected -The results are more like opinions of the researcher than results from analysis -Though this case history is said to support TP, the author himself says that "if early market research had shown, the potential, perhaps the results may have been different

Pavitt 1971:
GOAL: -Study of technological innovation in 20 OECD countries -Understand the impact of industry, government and universities on the innovation process -Provide an analysis which can be used for policy making
RESEARCH METHODS, VARIABLES & SAMPLE SIZES: -Combination of statistical analyses on econometric data, surveys and interviews -545 innovations over a 25 year period were studied in 13 different industries -Number of scientific abstracts and Nobel prized analyzed for 20 countries -Level of R&D expenditure over 25 years analyzed for 20 countries -Measures of GNP, per capita income, education levels, govt R&D etc were collected as used in regression analysis
RESULTS AND CONCLUSIONS -Incremental innovations are driven by market pull factors -Research activity varies across industries -Both large and small firms are innovative -Size of national markets is a weak indicator of innovation strength -University and govt. sponsored research contribute to innovation in firms -Government policies can change direction and pace of innovation
CAVEATS -Many of the variables have statistical and conceptual shortcomings -In some of the analyses, only USA data was used -It is not clear whether currency and inflation adjustments were made -Aggregate level data may not cast light on individual level constructs -The study was not based on any theoretical foundations