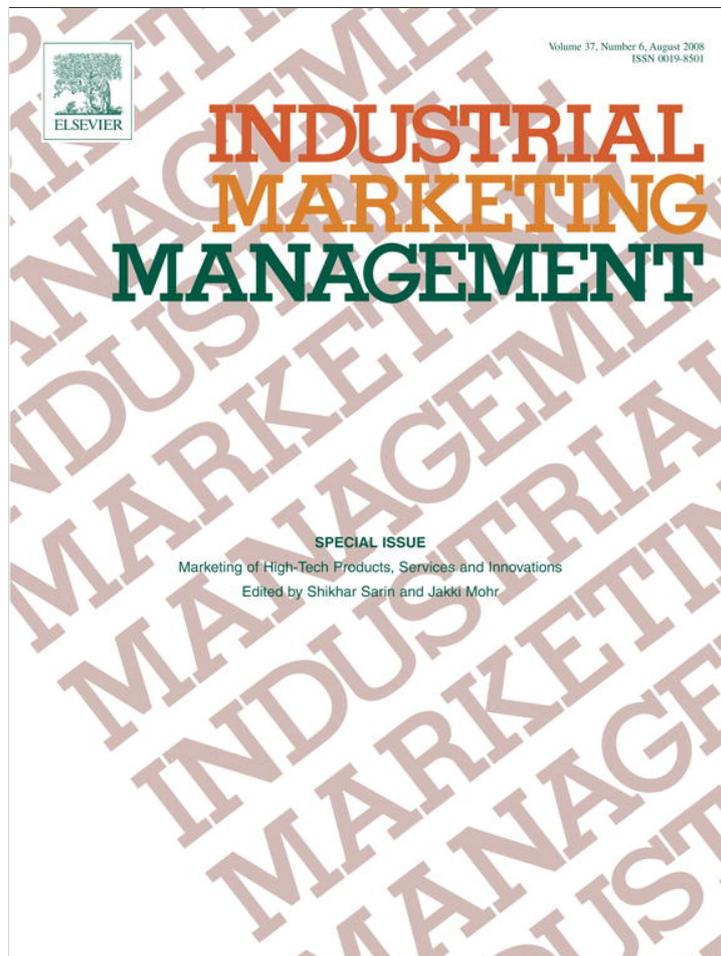


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Important research questions in technology and innovation

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1. Introduction

Consumers today have a better standard of living than consumers had a decade ago and much better off than consumers had a hundred years ago. That improvement is due to technological innovation. The landscape of firms in high tech markets steadily changes. Firms that stand still face the danger of decline and extinction. Firms that innovate grow to dominate their markets. The force that facilitates this change is technological innovation. Today, as in prior eras, the wealth of nations is driven not so much by their possession of raw materials, but by how they or the firms within their borders translate those resources into superior products and services through technological innovation. Thus, technological innovation is a critical driver of the improvement in consumers' living standards, the survival, growth, and success of firms, and the wealth of nations. Understanding innovation is of great importance because of its huge impact at these three levels of consumers, firms, and nations.

Researchers in a vast number of disciplines have studied various aspects of technological innovation. However, those in marketing have a unique advantage. Adopting a consumer orientation helps in understanding technological evolution because all innovations ultimately aim to produce better products for consumer welfare. Thus researchers in marketing have a unique vantage point in researching and understanding this phenomenon. This essay aims to point out some important research questions in technological innovation from a marketing perspective.

2. How do technologies evolve?

A commonly observed phenomenon in innovation is that one technology seems to replace another. For example today, digital photography is replacing film photography and online air reservation is replacing travel agencies. In printing, ink-jet and laser technologies replaced dot matrix printing, but both are steadily improving in performance. Which one will win or will thermal printing replace both? Will fuel cells or Lithium-ion batteries win the new technological race in the automobile engine market? A change in technology involves huge costs of equipment, training, and management for firms. More importantly, transitions in technologies often cause the demise of or at least the tripping up of giant incumbents. Thus, predicting the path of technological evolution can be a great advantage for an incumbent or entrant. How do technologies evolve?

Foster (1986) proposed a simple theory to explain technological evolution. He suggested that technological performance on some key dimension, as a function of research, effort evolved along an S-shaped

curve. Curves for rival technologies crossed once. So, a good strategy was to switch from an old technology on the mature or upper flat of its S-curve to a new technology on the upward or growth trajectory of its S-curve. Unfortunately, Sood and Tellis (2005) showed that this simple model is rarely if not never true. Technologies evolve along step functions, with multiple crossings, and huge spikes in performance after periods of long dormancy. How does one predict the path of this evolution given this messy real world? What theory or model can throw light on the phenomenon? Is the pace of technological evolution increasing? If so, where is this heading? These are unanswered questions with billion dollar implications for the firms locked in combat on rival technologies.

3. Why do great firms fail?

Given how important innovation is for the survival and success of firms, one would expect that they would invest massive amounts of time, equipment, and personnel into research for innovation. The largest firms in each market would have the most resources for this task. Hence, they would be the most successful at innovation and would grow to dominate the next technological platform. As such, wealth would lead to greater wealth. However, history reveals that large, wealthy firms frequently fail (Chandy and Tellis, 2000). Indeed, great market leaders in one generation sometimes do not even survive the next generation. For example, leadership in the personnel computer market moved from Altair, to Tandy, to Apple, to IBM, to Compaq, to Dell, to HP (Tellis & Golder 1996, 2001). Why does prior strength not lead to continued strength?

Researchers have put forth a number of theories for why great firms fail. Schumpeter (1942) at least initially attributed failure to the disadvantages of large size. Foster (1986) attributed the failure of firms to the emergence of a new technology and the commitment of old dominant firms to the old technology. Failure occurred when the new technology crossed the old technology in performance. Continuing on the technological explanation, Utterback (1994) attributed failure to the type of technology. Failure occurred not merely if a new technology merged, but if the new technology was competence-enhancing rather than competence destroying. Christensen (1997) went a step further and attributed failure to the single-minded focus of established firms on meeting needs of the mass market of customers served by the old technology. That focus blinded them to the emergence of a new technology that was inferior to the old technology on the primary dimension of performance but superior on some secondary dimension that satisfied only a niche market. Failure occurred, when the new technology surpassed the performance of the old technology even on the primary dimension. Chandy and Tellis (1998) attributed failure to the internal culture of the firm. A firm with

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a culture, which focuses on the future, is not risk-averse, and is willing to cannibalize past successful products, is more likely to embrace innovations and stay ahead of the game.

Which of these theories best explains the failure of firms? They have not been tested strictly against each other in a rigorous field experiment or empirical study. The jury is still out.

4. Should firms make or buy innovations?

In developing the Boeing 787 Dreamliner, Boeing decided to outsource the manufacture and even research of about 70% of the plane to firms all over the world (Kotha & Nolan, 2005). This included outsourcing parts of the wings, that Boeing considered the most important parts or “crown jewels” of the aircraft. In the past Boeing reserved manufacture of the wings to internal divisions only. Moreover, Boeing outsourced such manufacture even though it was well known that some of the firms building these parts had aspirations to grow into manufacturing entire planes themselves. Was Boeing nurturing the competitors of tomorrow? Would these suppliers one day grow to threaten if not displace its dominance of the airplane manufacturing business?

For decades P&G developed its new products entirely within its laboratories. It adopted a policy of ignoring and rejecting anything that was “not invented here.” Recently, P&G, decided to abandon its policy of developing all new products internally to developing at least 50% of its products from the outside (Huston & Sakkab, 2002). This policy has come to be called open innovation (Chesbrough, 2004). It involves the sourcing of new ideas and innovation from the outside or outsourcing even R&D to outside firms.

Whether a firm should make or buy its supplies has been a perennial strategy issue. One theory enlightening the solution has been that of transactions costs. A firm should make when the transactions costs of buying from the outside exceed the costs of acquiring the expertise to make on the inside (Walker & Weber, 1984). However, the examples above illustrate a far more complex set of problems and opportunities that firms face in the global economy today. Products today are so complex and centers of excellence so distributed all over the world, that a firm would be unwise to completely ignore good innovations and expertise on the outside (Rigby & Zook, 2002). What is the core technology, if any, that a firm should reserve for internal development? When should a firm go outside for ideas and when stay inside? In which country should a firm locate its R&D and how recruit and organize its talent for this task?

If a firm has chosen to make its innovation, some other important issues arise. How should a firm organize to be innovative? Should it use a functional or divisional structure? If the latter, should it resort to cooperating divisions, competing divisions, spinouts, or spinoffs? These are important issues that merit research.

5. What drives takeoff of innovations?

Researchers have long known that the sales of a new product follow an S-shaped curve (Bass, 1969). Following the early work of Bass, numerous models have been developed to capture the shape of this curve and predict its pattern (Chandrasekaran & Tellis, 2007). However, recently, researchers have shown that the early flat portion of the curve prior to takeoff is long while the first turning point or takeoff is sharper than previously believed. The Bass (1969) model and most of its extensions are not suitable for predicting takeoff, because they need data past the maturity to get reliable estimates of the model. Golder and Tellis (1997) developed a hazard model to estimate takeoff and showed that price played an important role in takeoff. Agarwal and Bayus (2002) argued that product innovations were an important determinant of takeoff. Another factor that could affect takeoff is cascades or hype (Golder and Tellis, 2004). However, Tellis, Stremersch and Yin (2003) and Chandrasekaran and Tellis (in press) showed that culture and national identities were other important determinants of

takeoff, especially in the diffusion of innovations across nations. If differences among countries are sharp and persistent, it may help to resolve the choice between a waterfall or sprinkler strategy for the global launch of a new product.

Takeoff is a very important event in the history of an innovation. Failure to predict its occurrence could lead to premature withdrawal of a new product, over commitment to a failed innovation, or failure to exploit an unexpected takeoff. Which of the potential drivers of takeoff are the most important? How can managers control takeoff? Should they use a sprinkler or waterfall strategy? If the latter, in which country should they first launch an innovation? We need answers to these questions because of the critical importance of the phenomenon.

6. What causes a trough in new product sales?

In his book *Crossing the Chasm*, Moore (1991) highlighted the problem of a sudden and substantial drop or trough in sales of a new product, after a period of rapid growth. He attributed the trough to the gap between innovators who have adopted a new product and the mass market that is still not convinced about it. Goldenberg, Libai and Muller (2002) found that the trough occurred in 52% of 32 consumer electronic products in the US. They showed that a lack of communication between the innovators and the mass market could lead to such a trough. However, other researchers have pointed out that besides chasms between segments, the trough could be caused by a number of other factors including technological inertia, negative cascades, economic recessions, and slow repurchases by early adopters (Chandrasekaran & Tellis, 2008).

While the trough is a relatively new and under-researched phenomenon in marketing, it is a very important one. Firms that ramp up production and marketing in expectation of continued sales could be rudely surprised by any such sudden setback. Other firms may think that the trough is the beginning of maturity or even decline and may discontinue investments in the product. What is the prevalence of troughs among new products? When and why is it most likely to occur? Which of the above explanations is responsible for causing a trough? Because of the importance of this topic, answers to these issues have important implications for managers and researchers.

7. Is network or quality more important for success?

A not uncommon phenomenon in the age of high technology or internet products is that a single brand has an overwhelming market share. For example, Intel, iPod, iTunes, Microsoft Windows, Microsoft Office, eBay, Facebook, Amazon, all seem to dominate their respective markets. Also, in some cases, dominance occurs quite fast. Why does this phenomenon occur? Analysts attribute it to direct or indirect network effects. Direct or user based network effects occur when the benefit from a product increases with the number of other users of the same product. eBay is more useful as an auction site the more people use it. Microsoft Word's usefulness to consumers increases as more consumers use the same program. Indirect network effects occur when the benefit of a product increases with the number of accessories that run with or on it. For example, iPod is more useful as iTunes links with more music labels. Sony Playstation is more useful the more games are developed to run on it.

Some economists have argued that in the presence of network effects, a brand that gets an early lead, either because of entering the market early or through some accident, may end up with the highest market share (Church & Gandal, 1993; Farrell & Saloner, 1985; Katz & Shapiro, 1985). This phenomenon is sometimes called path dependence, because the market share path of the brand depends on some early accident (Besen & Farrell, 1994). The argument goes, that network effects or path dependence could be so strong that an inferior brand could dominate its market and even lock out superior quality or lower priced alternatives.

Some researchers have argued the case for networks effects and path dependence is overstated (Liebowitz & Margolis, 1999; Tellis,

Niraj, & Yin, *in press*). However, we are still faced with the persistent dominance of brands that have known to have many flaws (e.g. Windows). What are the real causes of market success and dominance of innovations for high tech and internet products? Are network effects more important than quality for such products? How do such networks develop and what control do managers have over them? Do inferior brands really win out through accidents of history? Answers to these questions have important implications for managers and public policy makers.

8. Should hardware or software come first?

Two products related by indirect network effects create another problem for managers and policy makers. Which should come first? Such linked products often have a hardware component and a software component. For example, the PC (hardware) is more useful as the number of programs (software) run off it increases. More generally, the hardware may be considered a heavy investment category while the software may be considered a light investment category.

The presence of indirect network effects raises a chicken-and-egg problem (Caillaud & Jullien, 2003; Gandal, 1994; Gupta, Jain, & Sawhney, 1999). Should firms invest in the hardware or the software first? Hardware manufacturers argue that without programs, consumers will not buy the hardware. Software manufacturers argue that without hardware to play on, the software is meaningless. This dilemma is what delayed and still delays the launch of HDTV or the easy spread of ethanol or electric cars in the US. In the latter cases, the link is between cars and the network of refueling stations. Some analysts argue that the issue has no solution like the proverbial chicken-and-egg problem. However, solutions could come from many sources including commitment, level of investment, or regulation (Stremersch et al., 2007). How prevalent is the problem of first investment for such linked products? Should hardware or software come first? Under which conditions? When if ever and how should government intervene to break the impasses between hardware and software suppliers, for the benefit of consumers? Research to answer these questions can serve multiple publics.

9. Does innovation or advertising create great brands?

Intel, Samsung, Apple. All these are unquestionably great brand names, with high market share, strong name recognition, and a great reputation for quality. But how did they get to be so? Advertisers have long argued that brands are created by careful and sustained advertising through decades (Aaker, 1991). However, evidence for such claims has often been anecdotal. Moreover, such anecdotes do not control for important other factors that could contribute to market share, reputation, and success. For example, while Intel, Samsung, and Apple have had outstanding advertising campaigns, they have also had outstanding innovations (Tellis, 2005). So, researchers still need to address some important questions: what role does advertising and innovation play in the development of great brands? Does one come before the other, is one more important than the other, or is success an interaction of the two? What are the dynamics of the development of brand names and reputations over time?

10. What is the payoff to innovation?

The normal way that managers invest for innovation is by comparing the investment costs against the future market revenues from an innovation. However, the payoff from innovations is often in the distant and uncertain future. Not only must managers discount the profits from future time periods but they must also factor in the uncertainties from ever earning those revenues. Some analysts suggest turning to the stock market to assess how the market values investments in innovations. The logic from doing so is that the market is efficient so that the stock price reflects current and discounted future cash flows that would accrue to

the firm given the all information available at the time. Any abnormal return in the stock price (beyond the normal for the whole market) on some announcement of innovation would reflect the value of that innovation at the time of the announcement.

A few studies have shown that the market does indeed show “abnormal returns” to certain events in the life cycle of developing and commercializing an innovation (Chaney, Devinney, & Winer, 1991). Nevertheless, these findings raise a host of important issues (Sood & Tellis, *in press*). What is the right metric and approach for evaluating the returns to an innovation? If one should focus on abnormal returns, what are the abnormal returns to various stages of an innovation, such as initiation, development, and commercialization? What are the total returns to all stages and events in the life of an innovation? Do investments in innovation ultimately payoff in terms of total returns? Answers to these questions are of critical importance in determining the value of investments in innovation and advising managers and investors about strategies they should adopt.

11. What drives the wealth of nations?

A question that has long intrigued researchers is what drives the wealth of nations and what role has innovation to play in it? Indeed, many disciplines have addressed this question and have come up with quite varied answers. One obvious candidate seems to be raw materials, which many people assume to be the most important cause of wealth. Along these lines, at least one recent author has argued that geography plays a critical role in enabling the harnessing of crops and animals for the development of prosperity (Diamond, 1999). However, could lack of raw materials, agricultural, or animal resources lead people to be innovative, while abundance of these resources lead people to be lazy? Some authors have argued that a key driver of wealth is a particular religion, which makes those believers more materialistic, industrious, and innovative than believers in other religions (Weber, 1930). Other authors have argued that climate plays a critical role in fostering a work ethic of innovation and industriousness (Parker, 2000). Still other authors have argued for the importance of social and political systems (such as patent law) that have given individuals the incentives to be innovative (Landes, 1999). Economists have argued for the role of regulation, investment in R&D, and education of the work force (Furman, Porter, & Stern, 2002). In contrast to these perspectives, a recent study argues that culture is the most important determinant of a country's innovativeness (Tellis, Chandy, & Prabhu, *in press*).

An overview of history shows that no country or civilization has been permanently dominant or wealthy. Wealth has not led to greater wealth and success, as at least some of the above explanations would lead one to conclude. Rather history has been witness to the perennial rise and fall of civilizations. Thus any explanation of this complex but important problem needs to take into account the failure of any one nation to remain innovative and wealthy permanently. Moreover, even within a nation, clusters of innovativeness (e.g. Silicon Valley) rise and fall with time. The answer to this problem is not merely of historical importance. It informs public and government policy and firm strategy today. Key research question are the following. What causes nations to be innovative? Is it climate, geography, culture, religion, economics, or politics? Does the innovativeness of a country affect the innovativeness of firms within it? Or does the innovativeness of a country rest on the innovation of its firms? Are there innovative clusters within countries? If so, what drives that phenomenon and how can it be replicated? Is the location of a firm's research department merely one of operational efficiency or does it affect the innovativeness of the department and the firm?

12. Conclusion

Technological innovation is an important force in markets today. It critically affects the fortunes of consumers, firms, and nations. Despite

research across many disciplines, many important questions remain unanswered. The goal of this essay is to identify some of these questions, indicate what research has preceded those questions, and trigger interest in findings answers to the persistent questions.

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