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Marketing and Technology: A Strategic Coalignment

The authors present a case for integrating technology and marketing strategy as key elements that affect corporate success in rapidly changing environments. After describing the implications of technological change for firm behavior, the authors propose a framework for developing a technology strategy and introduce the technology portfolio. The technology portfolio serves both as a model for technological resource allocation and as an aid in choosing an optimal set of technologies from a set of feasible alternatives.

THE business environment of the recent past has been characterized by turbulence (e.g., Drucker 1980), resulting in often sudden reassessments of the growth prospects of entire industries as well as dramatic upheavals in the relative positions of firms within an industry (Harris, Shaw, and Sommers 1981). The causes of such turbulence are both numerous and interdependent, but it is by now apparent that a major engine of the unprecedented instability is technology or, more precisely, the emergence of rapidly changing technologies into the environment. Though it has been ignored in most traditional considerations of economic or managerial behavior, technology is no longer taken for granted and has risen to the forefront in debates on world and national economic policy and on the future of specific industries and markets.

Clearly the long-run competitive position, if not the fundamental financial performance, of most individual firms depends on how well they learn to manage and increase their technological asset bases. However, despite studies suggesting that most senior executives expect their organizations' future growth and profits to come largely from new-technology-based products (e.g., Booz, Allen & Hamilton 1981), technology strategy and its relationship to marketing strategy have not been given explicit formal consideration.

In this article, we examine the issues associated with the management of technology and highlight some of the key factors involved in integrating technological considerations into the overall strategic marketing plan. Our focus is on the larger multiproduct, multitechnology firms, whose corporate identity and purpose are not synonymous with a single technology, no matter how new.

We begin with a brief general discussion of the problems in defining and identifying technology as an economic good, then describe the implications of technological change for firm behavior. We next present a framework for developing a technology strategy, propose an analytic model for choosing an optimal set of technologies from a set of feasible alternatives, and highlight key issues in the technological decision nexus. Finally, we outline a framework for technological resource allocation, the technology portfolio.

Our purpose is not to present a blueprint describ-

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ing in detail the mechanics of developing and implementing a specific technology strategy, but rather to suggest a conceptual overview for generally thinking about technology in the context of corporate decision making. Such an approach is intended to help managers understand the scope of both the problems and opportunities involved in formulating technology strategy, as well as to stimulate academic researchers to undertake both theoretical and empirical investigations of the issues raised. Our current effort should be viewed as the first stage in our long-term research agenda on the impact of technology on corporate behavior.

The Nature of Technology

Technology can be defined broadly as "know-how," more specifically (with respect to a firm), as the information required to produce and/or sell a product or service. Though technology is typically an exogenous variable in classical economic theory, the definition offered here reflects the emerging tradition within economics of viewing technology, in general, as that which changes the firm's production function (Mansfield 1966) and, in particular, as the stock of relevant knowledge that allows new techniques to be derived (Nelson, Peck, and Kalachek 1967).

Three components, or sources, of know-how can be identified: product technology (the set of ideas embodied in the product), process technology (the set of ideas involved in the manufacture of the product or the steps necessary to combine new materials to produce a finished product), and management technology (the set of management procedures associated with selling the product and administration of the business unit). The definition we use distinguishes technology from new products *per se*. Products are the embodiment or manifestations of know-how; therefore, from the current perspective, the management of technology poses a set of issues and problems distinct from those associated with the new product development and introduction process.[1]

Technology also should be distinguished, at least conceptually, from the more general notion of knowledge itself, though the boundary between the two is often fuzzy. For our purposes, technology, unlike all knowledge, is intended for "use," a definition that echoes the distinction sometimes made in the sociological literature between utilitarian and more general "knowledge" (e.g., Bell 1973; Merton 1957). Perhaps more appropriately, technology should be seen as a proper subset of knowledge and hence many of the difficulties encountered in attempts to define knowledge as a measurable resource (Machlup 1962) also arise in our efforts to understand technology. Such concerns are increasingly important if we are to take seriously the study, development, and application of technology strategy, where both managerial objective functions and academic hypothesis-testing presuppose the ability to measure precisely the phenomenon under investigation.

Knowledge as a Commodity: Implications for Technology as an Asset

For many years the industrialized world has been shifting from a labor- and capital-intensive to a knowledge- or information-based economy (Machlup 1962; Porat 1974). As a result, knowledge has become a primary commodity (i.e., economic good) within the economy and knowledge capitalized as know-how, or technology, has become a major asset of most firms. Following the emerging literature on the "economics of information," we note that among the characteristics associated with a typical economic good are scarcity, divisibility, appropriability, a demand function that corresponds to a price and value, and a supply/production function that exhibits no increasing returns to scale (e.g., Porat 1976). The regular functioning of normal markets depends on goods satisfying these attributes of typical commodities.

Knowledge as a commodity, however, seems to "violate" all these properties in most cases (Arrow 1962; Stiglitz 1975). As a result, the markets for know-how tend to be rather inefficient (Arrow 1962) and the particular institutional arrangements for the transfer of technology between firms reflect the practical experience of managers in attempting to overcome the theoretical difficulties in treating technology as a normal commodity. We only pose the problem at this point, but note that though technology comprises an increasing proportion of a firm's resource base, attempts to develop a comprehensive technology strategy can be successful only to the extent that progress is made in measuring and valuing technology as an asset available for exchange.

Technological Change and Implications for Firm Behavior

In the presence of a fixed state of knowledge or know-how that both firms and consumers take as given, corporate and market behavior evolves according to normal economic and business criteria and technology is invisible. Technology becomes of concern only when

[1]Early in the technology life cycle (Ford and Ryan 1981), new products and new technologies are essentially isomorphic and issues associated with the management of new products are often identical to those involving the management of technology. A major portion of the literature on new product development (e.g., Glazer and Montgomery 1980), however, pertains to the introduction of new products based on present technology and the concerns raised are typically different from those addressed here.

the technological environment is no longer stable. In this sense, the management of technology is really concerned with the management of technological change, and technology strategy begins with an understanding of the effects of changing technology on the strategic and operational decisions of the firm. Because the most recent wave of technological change is as dramatic as any in history (including fundamental transitions in worldwide communications and information processing), the implications for firm decision making are perhaps more pervasive now than at any other time and involve numerous key areas of corporate strategy and structure: changing product life cycles, changing definition of market segments, changing definitions of industries/new sources of competition, changing employee relations, and increased globalization of markets. Table 1 summarizes some of the effects of these developments on corporate behavior. (For a more thorough discussion, see Capon and Glazer 1986).

The overall impact of the individual consequences of changing technology, combined with the interaction of technology with other political and socioeconomic forces, is that traditional opportunities for corporate growth are closing (Roberts 1980). The once-typical pattern of systematic expansion outward from a basis of strength in a set of product markets is a luxury few firms still possess. Markets and products are less proprietary and entry barriers that firms have relied on to protect their positions are coming down.

Perhaps most significantly, as the fixed technologies and stable product-market structures give way to rapidly changing ones, technology itself becomes less proprietary. A firm's know-how more quickly becomes everyone's and possession is less important than access and use. In such a world, sustainable long-term corporate growth comes increasingly from a policy based on the broadest possible valuation of, and continual development and exploitation of, a firm's technology; in other words, from an integrated technology strategy.

Firms that choose to approach the technological frontier place themselves at risk, for technology research, development, and exploitation are by definition uncertain. However, though remaining in familiar product-market situations reduces current uncertainty and may ensure current profits, the advoidance of technological risk today may lead to considerable market risk tomorrow. Companies that do not learn to use and profit from their know-how may well find they

TABLE 1
Impact of Technological Change

Changing Product Life Cycles
Changing product technology → shorter product life cycles
Changing process and management technology → shorter product life cycles (if technology is shared by many competitors)
→ longer product life cycles (if technology reduces costs and results in market expansion)
Increased riskiness of high volume/low cost market share strategies
Need for increased coordination between R&D and marketing
Changing Definition of Market Segments
Less segment stability
Increased segment fragmentation
Focus on target marketing
Importance of market sensitivity and understanding consumer needs
Changing Definitions of Industries/New Sources of Competition
Shifts in traditional product market boundaries
Increased importance of competitive intelligence
Fights over which competitor's "rules" govern industry
Need for corporate definition or "mission" both sufficiently broad/general and focused/specific
Changing Employee Relations/Organizational Restructuring
Increased emphasis on decentralized decision making
Expanded levels of employee participation at all levels
Elimination of layers of management/barriers to direct flow of communication
Focus on what employees "know," not what they "do"
Changing Government Relations
Deregulation (often after period of regulation following introduction of new technology)
Increased Globalization of Markets
Emergence of "global village," resulting in both expanded markets and new sources of competition
Choice between global market share strategy and differential targeting of segments
Implications for national industrial policy

have failed to extract returns from their most valuable asset. In the following sections we propose a model for the systematic evaluation and management of the firm's technological resources as a first step toward developing an integrated corporate marketing-technology strategy.

A Framework for Technology Strategy

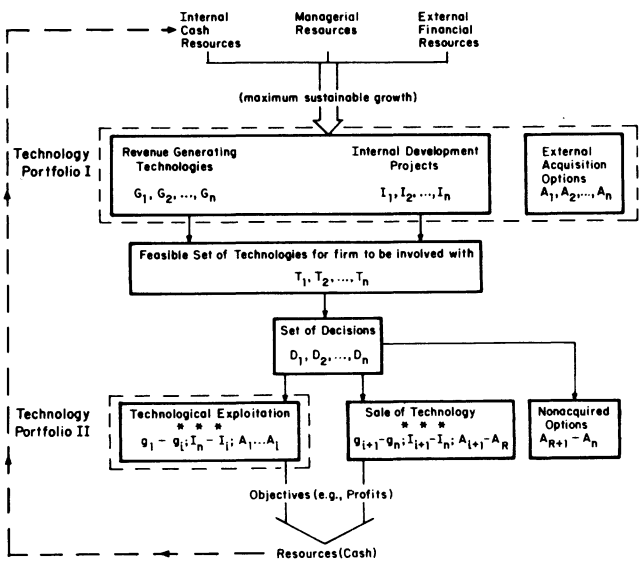
The essence of a coherent technology strategy is that the firm

- comes to view technology itself as an asset,
- sets as a goal the maximizing of returns to that asset,
- views the total technological asset base as a set—or portfolio—of discrete yet interdependent (at least in terms of cash flow) technologies, whose constituent elements change over time as technologies enter and exit the portfolio and may require different strategies and resources.

The firm's problem is to allocate resources among the portfolio elements to maximize some long-run total return function.

Figure 1 is a schematic framework for technology strategy (see Larréché and Srinivasan 1981 for a similar framework for product portfolios). For a given set of financial and managerial resources, the firm applies a set of technology decision variables—for example, internal development, external acquisition, independent manufacture and marketing, joint venture—to its feasible set of technologies, its current technologies plus external options, so as to maximize some objective function (e.g., discounted profits).[2,3]

FIGURE 1
A Framework for Technology Strategy



Formally, let

$D = \{d_1, d_2, \ldots, d_m\}$ be a set of decision variables and

$T = \{t_1, t_2, \ldots, t_n\}$ be a set of technologies

where $d_i t_j$ refers to applying the i^{th} decision to the j^{th} technology. $\pi(d_i t_j)$ and $c(d_i t_j)$ are the profit and cost functions, respectively, associated with the decision/technology pair. The firm's problem then is: maximize, over $\{d_i t_j\}$, $\pi(d_1 t_1, d_1 t_2, \ldots, d_m t_n)$ subject to $c(d_1 t_1, d_1 t_2, \ldots, d_m t_n) \leqq R$, where R is the set of available resources.

The proposed framework raises four issues of importance to the corporation in developing a technology strategy. First, what are the constituent elements of the firm's current technological portfolio? This is the problem of technology identification. Second, how should the firm add to its technological portfolio? Third, how should the firm commercialize and obtain returns to its portfolio? Fourth, how, in a general way, should the firm manage its developing technology asset base so that individual technologies are not treated in isolation but as interdependent elements that constitute an integrated, coherent strategy?

Technology Identification

In many organizations, largely as a result of the problems associated with defining knowledge as an economic good, the identification of technological assets tends to be somewhat limited. However, the starting point for a technology strategy is the accumulation of a technology inventory; specific areas of know-how must be identified in order to find those having marketable value. After careful analysis, the firm may decide that many technological opportunities should remain unexploited, but in the early stages of technology identification the broadest possible perspective is desirable, particularly for firms unfamiliar with the process. The goal is to instill within the organization an appreciation for the potentially vast, yet untapped, set

[2] "Managerial resources" typically are not included in sustainable growth models, largely because of the difficulties involved in quantifying the relevant variables. Nevertheless, in keeping with the framework developed here, managerial resources (i.e., know-how) are a major asset of the firm and therefore integral to the long-term growth rate. (For an early discussion of the need to consider managerial resources in the context of corporate growth, see Penrose 1955).

[3] An important component of external financial resources, in the context of technology, is federal sponsorship and subsidy of research and development projects conducted by the private sector (e.g., Bozeman, Crow, and Link 1984).

of resources that are available to be turned into assets of real value.

As noted before, technology can be categorized as either product, process, or management technology. Product technology (e.g., the microprocessor on which a personal computer is based, Coca-Cola's syrup formula) receives most attention in discussion of technology. Product technologies are typically easy to identify and the options for their exploitation are usually understood (even if many firms fail to take full advantage of them). Product technologies tend to remain underidentified and underexploited when they are either old technologies that have been superseded or are new technologies arising from research and development but for which no immediate use by the firm has been planned (e.g., the float glass process, developed and patented by Pilkington Brothers, the British glass manufacturer, was based on a set of ideas originally formulated at PPG). In both instances, too narrow a view of the role of technology within the firm's business blinds the organization to opportunities for identifying and exploiting an otherwise unvalued asset (e.g., selling an old technology into a less developed foreign market, as DuPont has done with cellophane).

Process technology may be easy to define, but often is difficult to identify as having real value to markets outside the firm. The procedures for marketing the technology are likely to be very different from those with which the firm is familiar. For example, whereas Norton has significant experience in selling grinding wheels to industry around the world, the sale of its process technology to a customer such as an Eastern Block state trading agency posed a host of new problems.[4]

Management technology is often difficult to define and categorize and, because of the inherent difficulties in measurement, is not easy to identify as having marketable value. Management technology incorporates both organizational (manufacturing, marketing, etc.) and managerial (planning, controlling) functions (Chandler 1977). Because these activities are typically the "glue" that holds the firm together, management technology may be taken for granted. It becomes apparent only through a careful and systematic understanding of the procedures and operations that have made the firm successful, such as inventory control systems, communication and information processing systems (Booz, Allen & Hamilton 1980, 1983), marketing research capabilities, and decision support systems (Buzzell 1985). The most opportune time to identify a firm's set of management technologies may be during the study of firm strengths and weaknesses as part of the situation analysis undertaken in the preparation of a strategic plan.

For service industries, where the definitional boundaries are inherently fuzzy, a distinction must be made between the actual provision of a service and the possession of proprietary information or know-how (i.e., management technology) that enables the firm to provide the service. We note that a service is typically an intangible product based on skills or techniques that are not in themselves imparted to the customer. Technology, in contrast, involves skills or techniques that can be imparted to a customer for his or her own uses (Ford and Ryan 1977). A hotel management chain (e.g., Westin) thus provides a service as part of its normal business if it contracts to manage a hotel owned by someone else. However, the set of skills possessed by Westin that enables it to manage hotels is part of Westin's management technology. If this know-how were imparted to another firm in the form of a consulting contract whereby Westin teaches its client to manage hotels, Westin would be marketing its management technology. An additional source of definitional uncertainty in the service sector is exemplified by airlines' reservations systems (American's Sabre and United's Apollo) which, depending on the context, can be viewed either as management technology or as a "process" technology that contributes to the provision of the primary service—air travel. Perhaps because the boundaries between their basic businesses and the underlying technologies are not clear, service firms tend to show greater awareness of the marketable value of their management technologies than do manufacturing organizations.

Though technology identification begins with an internal investigation, once the process is underway external acquisition becomes a means of building the firm's technology portfolio. In the next section we discuss the issues involved in building a technology inventory from both internal and external sources. The emphasis in this section is on product technology, for which the decision between internal development and external acquisition is typically an important one. However, the points noted can be applied also to process and management technologies which, though usually developed in-house, can be acquired from external sources within the expanded framework for technology strategy proposed here.

Technology Additions

Development risk is the key dimension in the choice of a method for enhancing the technology portfolio. Risk capital is necessary to develop technology. The firm's options range from independent research and development by the firm (high technological risk) to acquisition of a fully functioning technology (technology *per se* or organization unit) from another firm

[4]See the case study, Norton Company, ICH 9-581-046.

(low technological risk).[5] We term this the "make/buy decision." Between the polar extremes are R&D performed by the firm's joint venture subsidiary, R&D partnerships, acquisition of partially developed technology, funding of university scientists with agreements about output of the research, and other options. Whether the firm adopts a predominantly internal development strategy or an external acquisition strategy depends on many factors such as firm strengths and weaknesses, organizational culture, and competitive/environmental pressure (Table 2).

Though corporations may have many reasons for acquiring technology, rarely are technology purchases a substitute for technical competence in the acquiring company (Oliver 1982); rather, a well-planned policy of external acquisition affords technology strategy options that a "go-it-alone" attitude would preclude. In return for the greater flexibility associated with external acquisition, the firm does give up a portion of the total returns to technology that could be realized through internal development. The balance between internal development and external acquisition thus ultimately hinges on a risk/reward tradeoff.

Once the technology acquisition decision has been made, several methods of implementation are available. The two most common are (1) purchase of the rights to use the technology from another firm, either for a fixed payment (lump sum or installment) or for some combination of fixed and variable payments, and (2) license.[6] Other options are purchasing the technology outright or acquiring a fully functioning revenue-generating unit of another firm; the most extreme case is purchase of the other firm itself.

TABLE 2
Enhancing the Technology Portfolio: Reasons for Internal Development or External Acquisition

Internal Development
Expense: internal R&D is cheaper than external acquisition
Technological distance: R&D area is close to current corporate skills
Learning: firm wishes to gain expertise in a particular technology
Secrecy: firm wishes to keep its technological thrust confidential
"Not invented here" (NIH) syndrome: firm culture fosters belief that the only good technology is developed internally
External Acquisition
Avoid reinventing the wheel: technology already developed saves time and effort
Achieve faster growth: cannot reach growth objectives from internal development
Complex technology needs: firm does not have all the skills to develop its future desired portfolio
Aggressive posture: firm has an aggressive self-image to protect
Risk reduction: firm lets others take big risks before participating
Competitive threat: need to keep up with competitor whose new technology threatens
Increase returns to manufacturing investment: obtain technology for products that can be made on present equipment
Increase returns to marketing investment: obtain technology for products that can use present brand names, distributor channels, and so forth

Technological Commercialization

Marketing risk is the key dimension involved in commercialization of the fruits of technology. Marketing risk spans the range from full independent commercialization of a technology by the firm (high marketing risk) to either sale or complete licensing of a technology, or divestiture of an organization unit (low marketing risk). We term this the "make/sell decision." Between the polar extremes are joint ventures and various combinations of independent commercialization and technology licensing. As with technology addition, many factors contribute to the firm's choice of options for technology commercialization.

The option most frequently addressed in the marketing literature involves independent manufacture and commercialization by the firm (e.g., Wasson 1974). A single product technology can be viewed as a key input underlying the functioning of a number of end-use products and services, and most firms devote significant resources to developing and bringing new products and services to market. Perhaps the most important new product issue related to a firm's technology strategy is the timing of entry into a new market. Several different entry strategies (first to market, follow the leader, application engineering, "me-too") have been discussed elsewhere (Ansoff and Stewart 1967). Their relative attractiveness is determined by the interaction of life-cycle stages with the firm's strengths and weaknesses in light of competitive pressures. We would add that the implications of a particular entry strategy, judged at the level of a specific technology-based product, might be different when evaluated at the broader level of technology (including process and

[5]Firms make acquisitions for many reasons (e.g., reaching growth objectives, removing competition from the market, tax minimization, securing supply and/or distribution) in addition to obtaining technology. Regardless of the primary motivation for purchase, the firm typically adds new technology to its portfolio. Failure to be fully aware of the implications of technology addition, which include the necessity of understanding the technological dimensions of the acquisition and the associated culture within the unit, may lead to less than optimally successful acquisitions (e.g., the potential problems for IBM in its purchase of Rolm and for DuPont in its purchase of CONOCO).

[6]See Capon and Glazer (1986) for a detailed discussion of implementation issues involved in structuring technology deals.

management technology) where a wider range of options (including buying and selling of technology itself) is possible.

A key alternative option is the direct sale of technology or know-how. Under this option, technology *per se* is sold directly for use by a customer firm rather than being just an input to the firm's production and sale of its own end products. The firm's product, process, and management technologies thus become end products themselves. Contributing factors that might lead the firm to adopt this strategy are noted in Table 3.

A final option, which combines the other two, is to commercialize independently and sell the rights to use the technology. Factors contributing to the firm's decision to employ this option are highlighted in Table 4.

The foregoing discussion concerns mostly product technology. For process and management technology, which the firm typically employs in its ongoing operations, the independent commercialization versus sale distinction is essentially meaningless. The respective technologies are in themselves the end products and the issue becomes whether this know-how should be marketed. The important consideration here is to recognize that the technology (process and management) is indeed a marketable asset.

Should the firm decide to obtain direct returns to technology, either as the only strategy or in combination with independent commercialization, the key marketing issues are distribution and pricing.[7] However, the failure of technology to satisfy many of the properties associated with a typical economic commodity (notably scarcity, appropriability, and divisibility), as well as the inherent difficulties in measuring a unit of know-how, pose serious practical problems for the firm in actual distribution and pricing decisions.

[7]Advertising and promotion are unlikely to be relevant marketing mix elements except as a means of identifying potential acquirers.

TABLE 3
Reasons for Selling Technology

Mission mismatch: the technology does not fit with the firm's corporate mission
Access to capital: firm has insufficient financial resources to exploit the technology
Market window of opportunity: firm may be unable to exploit the technology sufficiently quickly
Insufficient size: the potential business is smaller than expected
Resources needed elsewhere: pressing financial requirements elsewhere in the firm
Unprofitable: the business cannot be made profitable by the firm
Technological irrelevance: the firm has a new technology that supersedes the one for sale
Strategic imperative: allowing other firms access is the most appropriate strategic action (e.g., franchising)

TABLE 4
Reasons for Simultaneously Exploiting and Selling Technology

Differences among segments: firm has skills for some market segments but not others (e.g., consumer vs. industrial)
Shared market development: a competitor can share the expense of market development
Profit pressure: certain short-term returns may outweigh potential long-term profits
Disincentive for competitive invention: competitor firms will not both use the technology and attempt to invent around patents
Industry culture: reciprocity in offering patent access is standard practice in the industry
Second source requirements: major industrial buyers often will not adopt a new product unless alternative sources are available
Government fiat: government may insist that technological secrets be shared
Forestalling competitive technology: offering technology to competitors may encourage industry standardization on the firm's technology
Access to international markets: certain markets (e.g., Eastern European and LDC markets) may be effectively closed to the firm without technology sale
Foreign market risk reduction: local partners can limit the firm's exposure in foreign markets

Distribution. The normal notions of product marketing, which imply a stockpile of the commodity from which a measurable amount can be delivered at a specified time and place, do not readily apply to technology. Rather, distribution of technology is analogous to information flow within a communication channel. To protect the value of the asset being communicated, however, technology channels are likely to be rather short, usually involving direct sales (Ford and Ryan 1977). Key distribution problems in technology sale and licensing are field-of-use restrictions—market segment decisions based on geography, end-use application, and other segmentation variables—and licensee decisions. The firm must set criteria for licensees (market access, technological and other managerial skills, commitment, etc.), identify licensees, and decide on the appropriate balance between exclusive (monopoly) and totally nonexclusive access. (See Capon and Glazer 1986 for a detailed discussion of the issues involved.)

Pricing. In normative terms, technology, like all goods and services, should be priced according to its value in the marketplace. However, an inherent difficulty in pricing technology is that generally the value of information to a customer can be known only at

the time it is revealed—at which point it loses all further value. (In many instances, the value of an underlying technology can be inferred from a consideration of the value of the results derived from an application of the technology, where the customer can be shown the results of how the technology is applied. This is particularly true for technology involving a legal monopoly in the form of a patent.)

Despite the difficulties in the valuation process, there are some general questions the technology owner should ask in attempting to gauge the potential value to a buyer in formulating a licensee agreement (Table 5). For a given technology, many of the answers will be invariant across all potential acquirers; in other situations, individual buyers may value the technology differently. For example, a new technology may have little value to a market leader with similar technologies, whereas to a small company with few technological resources it may provide the wedge needed to secure improved market position and thus be more highly valued. Therefore the pricing decision is tied closely to the selection of which, and how many, firms should be allowed access to the technology.

The subject of royalties and the mechanics of actually setting licensing fees has been well covered elsewhere; here we highlight only the broader issues. The major decision is between minimum (fixed payments regardless of degree of use) and earned (based on some volume of use measure) royalties and basically concerns the tradeoff between risk and return; it parallels the decision of whether to sell a technology or exploit its products. A payment structure favoring high minimum royalties ensures that the owner gets some payment for the technology (in the absence of business failure or legal challenge). Further, the discipline of paying minimum royalties is apt to encourage the technology acquirer to invest the resources necessary to obtain a return on its minimum royalty investment. Minimum royalties paid over time are likely to encourage continued efforts by a licensee, whereas short-period minimum royalties may be treated as a sunk cost if enthusiasm for the technology wanes.

TABLE 5
Questions for Identifying the "Value" of Technology

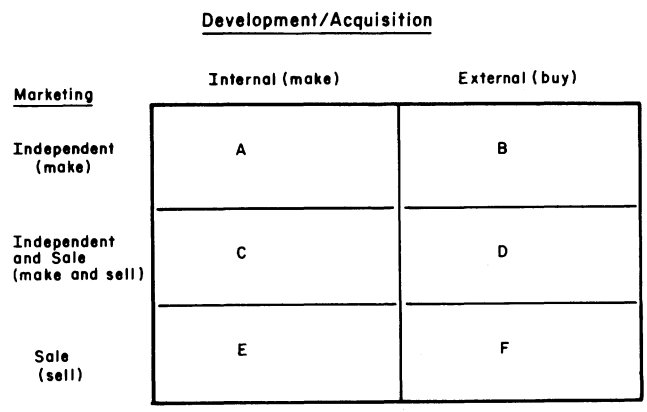
Does the technology represent a genuine breakthrough or is it a relatively minor improvement over some current product, process, or management technology?
Does the technology create a real and sustainable advantage for the acquirer? Is it in the nature of a long-term benefit or a shorter lead-time advantage?
Does the technology eliminate a disadvantage or hedge against a possible disadvantage?
Could the potential acquirer develop the technology independently and, if so, what would be the cost?
If a process technology, does it provide the only route to producing the product or are others available and, if so, what are the relative costs?
If a product technology, does it provide a unique set of customer benefits or are alternative products available?
Are alternative products (processes) likely to be available in the near future?
Can the technology be legally protected for those given contractual access to it?
If there are patents, are they strong enough to withstand court challenges?
Are the patents broad enough to cover alternative approaches likely to be followed by competitive firms? or
Can the technological secrets be maintained by firms having contractual access (e.g., by "reverse engineering" in the case of product technology)?

The Technological Decision Nexus

In the preceding two sections we develop the argument that the full range of strategic technology questions for the firm involves decisions related to both the building and commercializing of its technology; we represent these questions as the technological decision nexus, Figure 2.

As a practical matter, most firms traditionally have operated in cell A, internal development and independent commercialization of technology. However, we argue that firms should investigate the full range of options, not as mere reactions to environmental imperatives, but rather as part of a well-planned *proactive* strategy for building their technological asset bases and for achieving profitable returns from those assets. Figure 2 thus suggests an expanded definition of the marketing of technology to include the full range of options through which a firm *exchanges* both tech-

FIGURE 2
The Technological Decision Nexus



nology and the fruits of technology with its environment.

Firms should plan for both the internal development (cells A, C, E) and acquisition (cells B, D, F) of technology and give consideration to the three options for achieving returns: independent commercialization (cells A, B), sale (cells E, F), and a combination of the two (cells B, D), rather than just independent commercialization. In this context two special cases should be noted, technology brokerage and joint ventures.

Technology brokerage. This option for firms is represented by cell F—the buy/sell decision. In this case the firm contributes little added value in research, development, or exploitation but acts essentially as a broker between technology originators and marketers.

A number of circumstances may lead firms into brokerage operations. In some cases the firm may acquire title to a technology intending to exploit it, but later may decide that its sale is more desirable. Precipitating internal factors include reductions in resources available for exploitation and managerial changes leading to shifts in product and process policy. A key external factor is the unexpected closing of a market window of opportunity, usually after competitive activity.

In other cases, the firm consciously pursues a brokerage strategy and never holds the technology in its own inventory. Rather, it capitalizes on specialized knowledge of recent technological developments (perhaps related to its own products and processes), together with intimate knowledge of customer requirements in particular markets. Despite an unwillingness for direct involvement, the firm may nonetheless be well placed to bring together those buyers and sellers best able to take advantage of the opportunity. The increase of agents acting exclusively as technology middlemen has been well documented (Ford and Ryan 1977), particularly in international technology transfer. However, intensification of the technological environment, involving shorter product life cycles, segment fragmentation, and globalization of markets, should increase technology buy/sell (brokerage) activity by firms for which it is not the primary line of business.

Joint ventures. In the context of the "pure" strategies highlighted in Figure 2, joint ventures are "hybrid" strategies in which the firm shares its ("make") technology development and/or exploitation activity (and the risks and returns) with a partner firm. Of critical importance for the firm is choice of partner; in general the selection process involves matching strengths and weaknesses to give the combined entity a competitive advantage greater than that of either firm undertaking the project alone (Hlavacek, Dovey, and Biondo 1977).[8] For maximum payoff it is important that the joint venture partners complement each other's strengths (or compensate liabilities) and do not merely duplicate resources or abilities. Prototypical joint ventures are between small innovative firms with new technology and large firms with strong marketing capability, end-user reputation, and financial resources (e.g., Polaroid's investment in small high technology companies; Wayne 1985).[9] However, in an increasingly turbulent environment, where knowledge of both specialized markets and technologies is essential, firms of widely different sizes and backgrounds should be expected to consider joint ventures.

Management of the Technology Asset Base: The Technology Portfolio

The framework of technology strategy in Figure 1 suggests that optimizing the total return on technological assets is essentially a problem of resource allocation. Implicit in this formulation is the notion that the set of technologies in a firm's inventory constitutes a portfolio in which actions taken for one technology have implications for others, particularly in terms of the flow of resources. Different technologies require and/or generate different resource patterns, depending on both their relative positions along the development-exploitation continuum and their degree of differential advantage in competitive activity.

In this section we introduce a model of the firm's technology portfolio, the "content" corollary of the ubiquitous product portfolio (Day 1977). The product portfolio is a guide to allocation of the firm's resources based on business strength and industry attractiveness (commonly operationalized as relative market share and market growth), but it has no advice for the types of technologies (and associated products) with which the firm should be involved and is thus content-free or technology-neutral. Indeed, many of the normative implications of the typical growth/share matrix, such as the advantages of experience-curve strategies, require the assumption of a fixed or constant technology (Abernathy and Wayne 1974). The technology portfolio thus extends the product portfolio by providing the firm a tool for evaluating the particular mix of technologies in its asset base and

[8]In some cases, particularly with R&D consortia, joint ventures are undertaken because development costs are too great for an individual firm (e.g., Rolls Royce and Pratt & Whitney's joint development of aero-engines).

[9]In such cases care must be taken lest systems and procedures of the large firm undermine the entrepreneurial spirit in the smaller partner firm.

analyzing how they complement one another as part of the overall corporate strategy.

Portfolio Parameters

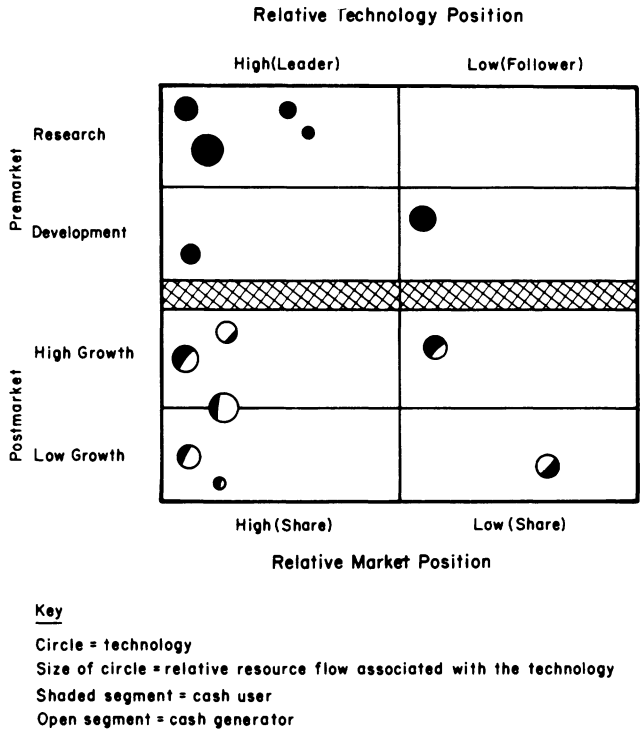
Figure 3 is one formulation of the technology portfolio. It is an eight-cell matrix that builds on the four-cell growth/share product portfolio matrix, though the entries are technologies rather than products. The vertical axis is a time dimension, incorporating both technology and product life cycles (Ford and Ryan 1981), that is divided into two intervals reflecting the *pre-* and *postmarket* phases of technology exploitation. Each of these phases is subdivided, premarket into research and development stages of technology generation and postmarket into the familiar high and low growth stages of the product life cycle. Taken as a whole, this axis traces the flow of a technology through its life cycle from its inception as a basic research idea to its decline in the low growth stage of market exploitation.

The horizontal axis captures the relative business strength or competitive position of the firm and is understood best in terms of the pre- and postmarket phases. In the postmarket phase the (lower) horizontal axis captures relative market share as embodied in the product portfolio. In the premarket phase the (upper) horizontal axis applies to relative technology strength and indicates the extent to which the firm is a leader or follower in the research and/or development of given technologies.

Each entry (circle) in the matrix represents a technology, the size of the circle reflecting the relative resource flow associated with that technology. The circle is divided into two regions, a shaded portion indicating cash use and a clear portion indicating cash generation. The relative areas of the two regions suggest whether the technology is a net cash user or a net cash provider. (By definition, all technologies in the upper, premarket, half of the matrix are cash users and the circles therefore are shaded.)

For a multitechnology firm, the matrix provides a "snapshot" at a point in time of how its resources are distributed across its mix of technologies and where those technologies stand in both development/market exploitation and competitive strength. The portfolio can be used to suggest how technology- versus marketing-intensive a given firm is in its strategy; each firm has a unique portfolio portrait corresponding to its individual corporate strengths and organizational culture. Though the normative implications of the technology portfolio for optimal resource allocation across technologies is a subject for future research, a well-managed firm's set of technologies should be balanced in the matrix in terms of both distribution and size. In particular, heavy concentrations of (large) circles in any single part of the matrix imply that the firm's total flow of resources probably will be difficult to sustain. Figure 4 shows three hypothetical portfolios and their implications for corporate performance.

FIGURE 3
The Technology Portfolio

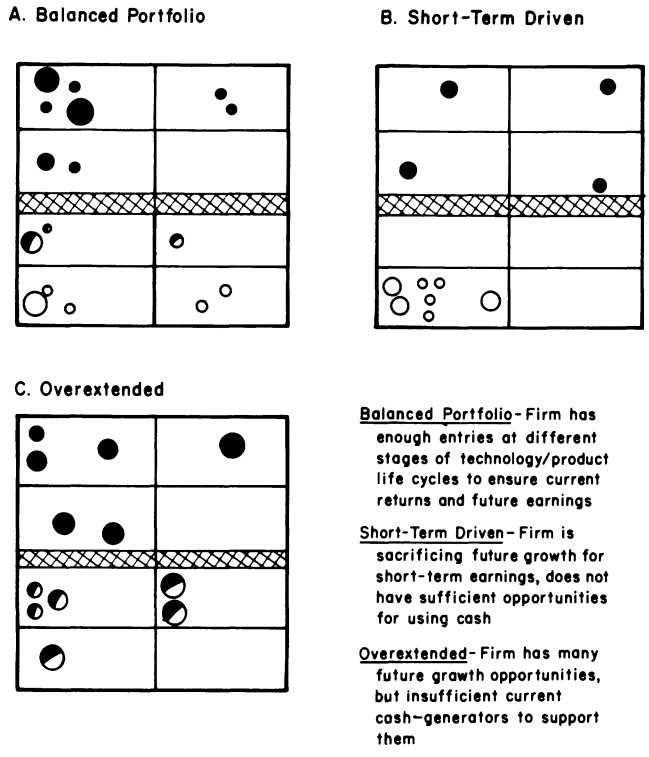


Technology and Product Portfolios

There is no relationship between the upper part of the technology portfolio and the product portfolio. Though the parameters of the lower half of the technology portfolio are similar to those of the product portfolio, there is not a direct correspondence between the two. Rather, entries in the technology portfolio are technologies and entries in the product portfolio are products. Each single entry in the technology portfolio has its own corresponding product portfolio; each product portfolio has several entries reflecting the products derived from that technology (Figure 5). Because the products derived from a single technology are likely to differ in terms of competitive position and market segment growth, a single position in the technology portfolio gives rise to multiple entries in the product portfolio. The single entry in the technology portfolio is thus a weighted average of the associated product portfolio and consequently the technology portfolio generalizes the product portfolio as a planning tool.

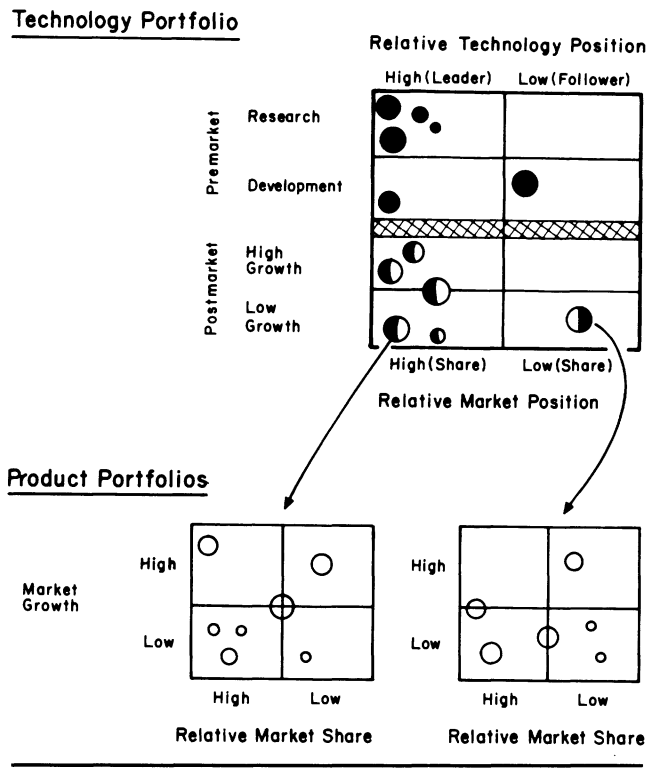
In this respect, the formulation of the technology portfolio presented here differs from a similar concept developed by Booz, Allen & Hamilton (Harris, Shaw,

FIGURE 4
Typical Technology Portfolios[a]



[a]Axes labeled as in Figure 3.

FIGURE 5
Relationship Between Technology and Product Portfolios



and Sommers 1981). The Booz, Allen & Hamilton approach relies on a separate four-cell technology matrix (whose axes are relative technology position and technology importance) that mirrors the traditional product portfolio matrix. Each entry in the technology matrix has a corresponding (though not necessarily the same) position in the product matrix. The technology and product portfolios thus provide different perspectives on the same set of corporate activities and the firm's objective is to ensure that the two portfolios are compatible as well as consistent with overall strategy. In our formulation, because both technologies and the products derived from them are integrated into a single perspective, the resource allocation process can be considered within an essentially dynamic framework. Clearly the two approaches are compatible and each is appropriate, depending on the desired application.

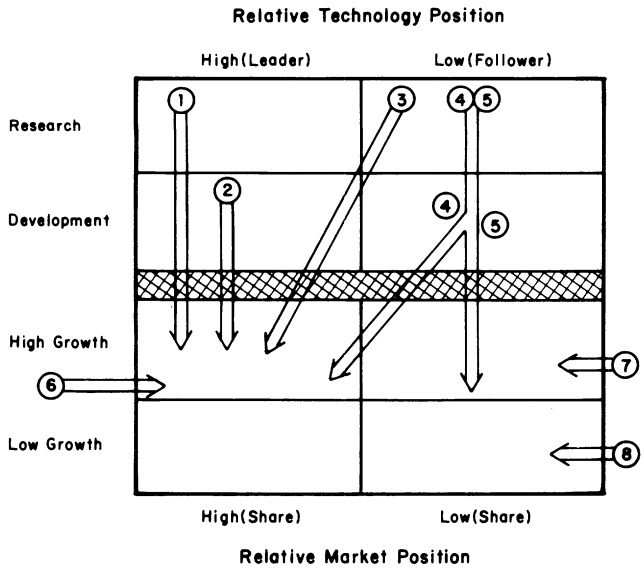
Large diversified corporations commonly conduct product portfolio analysis at two levels within the firm, at a division/SBU level where the entries are individual product-market segments and at the corporate level where the entries are individual divisions or SBUs represented as weighted averages of market growth rates and relative market shares (Capon, Farley, and Hulbert 1986). To the extent that the corporate organization is based on technologies, such a corporate portfolio approximates the technology portfolio as described here. However, to the extent that a firm's organization is not based on technology, the product and "technology" portfolios would overlap; sorting them out is a major strategic issue.

Implications for Entry Strategy

The inherently dynamic aspect of the portfolio concept as discussed here has interesting implications for the evaluation of strategic entry decisions. The portfolio in Figure 3 is basically static—a "snapshot" of the firm's technology at a single point in time—but a series of portfolios developed over time would trace the flow of technologies and provide a view of the dynamics of technology evolution. Though many dynamic scenarios are possible, certain patterns are both descriptively more plausible and normatively most effective. We suggest a few such patterns that reflect the prototypical entry strategies firms use to bring technologies into the marketplace.

Figure 6 depicts several common entry strategies. Strategy 1 is that of the pioneer, a technological research and development leader that is also first to the market with products based on new technologies. Strategies 2 and 3 are those of market pioneers that have technology-development skills but weaker (or no) research abilities. In strategy 2 the firm acquires tech-

FIGURE 6
Typical Market Entry Strategies



Legend

1. Technological leader: first-to-market
2. Technological acquirer: first-to-market
3. Research follower, strong developer: first-to-market
4. Technological follower: strong marketing thrust
5. Technological follower: weak marketing thrust
6. Minimal technology: acquire leadership positions early
7. Minimal technology: acquire follower position early
8. Minimal technology: acquire follower position late

nology from elsewhere but is very active in its development; in strategy 3 the firm is a follower in research but recovers through strong development capability.

Strategies 4 and 5 are those of marketing-intensive firms that maintain a technological R&D posture. In both cases the firms lag in technological ability, but attempt to gain early market leadership positions through strong marketing efforts. The primary difference between the strategies is empirical. In strategy 4 the firm's marketing prowess is strong enough to overcome the technological disadvantage and it enters the market as a leader. In strategy 5 its marketing abilities are insufficient and the firm enters as a follower. Note that, whereas in the product portfolio certain regions are normatively undesirable (e.g., "dogs"), in the upper portion of the technology portfolio any region may have potential strategic value.

The other patterns (strategies 6, 7, and 8) are those of firms with minimal technological R&D capabilities that acquire developed technology from others and then rely exclusively on marketing. Strategies 6 and 7 differ empirically and raise the question, "To what extent does marketing ability alone enable a firm to enter a market early and become a leader?" Strategy 8 reflects the (increasingly common) phenomenon of the firm that enters late in the life cycle, when the product technology is standardized and the market has stabilized, aiming to become the low cost producer, perhaps by initiating a new experience curve with new process technology.[10] This combination of laggard product technology and innovator process technology is but one example of many that suggest technology portfolio analysis and its relationship to corporate strategy is a highly complex matter and a rich subject for further investigation.

Conclusion and Directions for Future Research

We argue that a coherent approach to the coalignment of marketing and technology encompasses:

- explicit consideration of the effects of technological change on the ongoing strategic and operational decisions of the firm,
- adoption of a more comprehensive definition of technology (incorporating product, process, and management know-how) as a real asset from which the firm should seek to extract the maximum return,
- evaluation of a wide range of options for developing and acquiring technology, as well as for marketing technologies in the firm's inventory,
- utilization of the technology portfolio as an organizing tool that can help the firm both to evaluate the current technological portfolio and to plan the optimal allocation of resources and strategic marketing decisions for future technology scenarios.

In developing what we call a "framework" for technology strategy, we provide a conceptual overview of some relevant areas for study. Though we imply that the framework outlined is both normatively desirable and descriptive of those firms doing a good job of managing technology, our discussion is not a formal theoretical or empirical investigation in itself. A major goal of our effort is to initiate such a research program by highlighting the key issues that should be addressed. In particular, each of the major areas discussed raises a series of research questions and hypotheses about what firms should do in the management of technology (the theoretical/normative dimension), what they actually do (the empirical/de-

[10]Porter (1985) makes the important point that advances in process technology may lead to the development of superior products manufactured with higher tolerances.

scriptive dimension), and how they do it (the processes they use).

The technology portfolio concept suggests future research (1) at the normative level on the implications of particular portfolio patterns (i.e., distribution of technologies across the various cells in the matrix) for the firm's strategic behavior and resource allocation decisions and (2) at the empirical level on the effect of different dynamic entry strategies on ultimate performance. Of crucial importance if the technology portfolio is to be operationalized is the development of reliable and valid measures of "technology share."

The implications of technological change for firm behavior have been addressed in several studies (e.g., the Qualls, Olshavsky, and Michaels 1981 study on shorter product life cycles). What is needed, however, is further empirical research documenting both the precise role of changing technology in precipitating the observed effects (shorter product life cycles, increased fragmentation of markets, etc.) and the strategic and tactical responses of firms across industries that differ in level of technological change. If, for example, new-technology-intensive industries are indeed characterized by smaller, more heterogeneous segments, do these industries tend to be less concentrated (i.e., fewer firms with large market shares) than industries with slower technological growth rates? Similarly, are there, as hypothesized, observed differences in patterns of decision making and organizational structure among firms in industries that differ in terms of technological change?

A prerequisite to such a research stream on the effects of technological change is the development of adequate measures of the degree of technological change that are comparable across a wide range of situations. Similarly, research into the actual decisions firms make about their technology inventories must be preceded by the development of a meaningful series of measures for categorizing and specifying a firm's set of technologies. The ability to measure technology is the essence of the technology identification problem, in particular for the "intangible" management technologies, in light of the problems inherent in defining know-how as an economic commodity.

Once a battery of appropriate measures has been created, an important group of hypotheses can be formulated for the range of decision variables the firm can use to develop and market its technology. In general, four sets of questions can be asked.

1. Under what conditions does the firm tend to choose one option over another (say, the internal development/external acquisition decision)?
2. What empirical generalizations can be drawn about the relative importance of the factors leading to a given decision (e.g., avoiding "reinventing the wheel" vs. achieving faster growth vs. reducing risk in the case of external acquisition; expense vs. secrecy vs. technological distance in the case of internal development)?
3. How successful are the various decisions (develop/acquire; commercialize and/or sell) and what are the relative levels of performance (market share, profitability, etc.) associated with different decisions across different industries and different levels of technological growth?
4. What are the structural characteristics of firms (relative market share, size, financial structure, etc.) as well as industry-specific factors that correlate with the various technology decision options and levels of performance associated with given decisions?

When taken as a whole, these questions should lead to a set of hypotheses about the situational variables, or interaction effects, that describe technologically oriented marketing decision making within firms. When applied to a sufficiently large set of cross-sectional data across firms, industries, and levels of technological change, the resulting analyses should yield a profile of the particular environmental forces and firm-specific characteristics that tend to lead to given behaviors and outcomes. Such a profile can provide a series of norms or benchmarks against which any individual firm can assess its own position and make decisions about the interface between its marketing and technology strategy.

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