IESE Business School
University of Navarra

Working Paper
WP no 221
October, 1991

POSITIONING STRATEGIES AND PROSPECTS FOR SUCCESS IN EMERGING HIGH-TECHNOLOGY FIRMS: THE CASE OF U.S. BIOTECHNOLOGY

Joaquim Vilà

IESE Business School – University of Navarra
Avda. Pearson, 21 – 08034 Barcelona, Spain. Tel.: (+34) 93 253 42 00 Fax: (+34) 93 253 43 43
Camino del Cerro del Águila, 3 (Ctra. de Castilla, km 5,180) – 28023 Madrid, Spain. Tel.: (+34) 91 357 08 09 Fax: (+34) 91 357 29 13

POSITIONING STRATEGIES AND PROSPECTS FOR SUCCESS IN EMERGING HIGH-TECHNOLOGY FIRMS: THE CASE OF U.S. BIOTECHNOLOGY

Joaquim Vilà*

Abstract

This study estimates the relative contribution of a number of factors to the prospects for success of newly created firms in the emerging stage of biotechnology. The focus is on an empirical analysis of the relative role of positioning strategy (i.e. how a firm, chooses to build its competitive position over time) as a factor contributing to the strength of a firm's position for future success. Our theoretical viewpoint follows an asset-based view of the firm. The research is based on a sample of 80 new U.S. biotechnology firms created between 1971 and 1984. The contributions are primarily two: First, strategy in emerging high-technology firms does make a difference to firms' prospects for success. Second, timing of strategic choice (not just content) is a critical factor in identifying strategy-performance relationships in rapidly changing environments.

* Professor, General Management, IESE

POSITIONING STRATEGIES AND PROSPECTS FOR SUCCESS IN EMERGING HIGH-TECHNOLOGY FIRMS: THE CASE OF U.S. BIOTECHNOLOGY[1]

Determinants of Performance in Emerging High-Technology Firms

A central issue in the strategic management literature is the interplay between strategy, environment and performance. The nature of the relationship is inherently dynamic, demanding that research is guided to longitudinal studies in specific types of contexts. Our focus here is on factors which may help to understand why emerging high-technology firms differ in their prospects for success in the environment following a technological discontinuity.

The emergence of new technology is a powerful force with significant strategic implications. Radical technological change triggers a period of technological and market turbulence as traditional entry barriers are overcome and established competitive positions upset. Radical innovations dismantle old economic systems and replace them with new industrial regimes (Schumpeter, 1950). Radical change in technology-based industries calls for a redefinition of critical skills, resources and relationships (Aberriathy and Clark, 1985) and, consequently, sets the basis on which competitive positions and firm advantages are to be founded. Tushman and Anderson (1986) coined the description of such technological change as competence-destroying in nature. Their study reveals that the competitive conditions following such a discontinuity are so fundamentally different from those prevailing before the technological breakthrough that the skills and knowledge base required to operate the core technology shift, and assets built around the old technology are rendered obsolete. As a result of this turbulent environment, new firms created in high-technology fields face a set of peculiar challenges which are very different from those relevant to established firms or new ventures created in established industries.

A number of major challenges characteristic of firms created during the emerging stage of a new technology have already been advanced in former research: high technical and commercial uncertainty following a technological discontinuity (Tushman and Anderson, 1986), resource scarcity in high-growth firms (Hambrick and Crozier, 1985), limited access to complementary resources (Teece, 1987), and intensive competitive pressure faced by small high-technology firms (Shan, 1987). For the specific context of the emerging biotechnology field, Robert Fildes (1990) identified a set of internal and external challenges confronted by newly created biotechnology firms.

---

[1] The author gratefully acknowledges the helpful comments from William. F. Hamilton, Harbir Singh and Paul Allison at the University of Pennsylvania. This research was supported in part by the Reginald Jones Center for Management Policy, Strategy and Organization at the University of Pennsylvania.

Research on strategy in high-technology fields also demands a characterization of performance which recognizes the peculiar nature of these emerging environments. Several authors have pointed out that new businesses operating in high-technology markets tend to have negative early success (Stuart and Abetti, 1987). Yet, the distinctive character of emerging technical fields suggests that approaches to performance based on past financial accomplishments may not be adequate to estimate the future potential for success of emerging high-technology firms. Several factors contribute to the weakness of traditional performance measures. During the initial stage of industry evolution, a limited number of products reach market introduction. Also, a few products which still are several years away from market introduction will become major breakthroughs and replace existing products. In addition, the revenues of the newly created firms tend to be primarily based on R&D contracts and interest income rather than on product sales. Consequently, it would be misleading to assess future performance on the basis of traditional measures of profitability or market gains.

Characterizations of performance based on attributes which reflect the strength of a firm's asset position are better suited than traditional approaches to correctly discriminating future performance for emerging high-technology firms. This approach is very much in line with the presumption, from an asset-based view of the firm, that "the potential profitability of a firm is determined by its level of asset stocks" (Dierickx and Cool, 1989), which are the foundation of a firm's competitive position. Therefore, a premise of this study is that a major management goal in emerging high-technology firms is to build an asset position for future success. Thus, we equate performance at the end of the pre-commercialization stage of a new technology with the strength of the competitive position at that time, and this is supposed to be associated with subsequent performance levels once this technology dominates some established industry.

A review of former studies suggests that an *asset-based view of the firm* (Rumelt, 1984; Winter, 1987, among others) is indeed more appropriate than other theoretical approaches in strategic management (such as industrial organization, population ecology) in the study of strategy performance relationships in emerging fields (Vilà, 1991). As mentioned with regard to the previous principle, the strength of an emerging firm's position during the pre-commercialization stage of a new technology is expected to be a primary determinant of the firm's future success. Positioning for success results from at least three sets of factors: first, the starting position from which start-up firms were initially created (i.e. resources and skills brought to the ventures); second, factors external to firms which enhance or constrain their ability to profit from innovation; and finally, strategic choices which, mediating the effect of the former two factors, are directly guided to building a competitive position to successfully introduce innovations from the new technology.

Positioning Strategies in Emerging High-Technology Firms

Positioning a firm for future success involves directing its asset position to best match the expected opportunities and demands of future environments. In the specific context of an emerging technology, the process of building position may be conceived as encompassing, over time, three related, but conceptually different, processes: accumulating relevant assets, gaining advantage over competitors and matching environmental demands.

Positioning as an asset accumulation process means that asset management over time should be consistent with a firm's desired composition of resources, skills and relationships, in our case to create the necessary competence to effectively compete during the commercialization stage of

the new technology evolution. Positioning as a process of building advantage entails a comparative assessment of the asset position vis-à-vis its competitors. Relevant to this process will be both how a firm protects its position from imitation, as well as how it progresses relative to competitors' efforts in building their own capabilities. Positioning as a problem of fit simply follows from the widely proclaimed need for continued adaptation to new circumstances and relates to how the firm meets expected opportunities and threats. Fit is a property of the interaction between asset configuration and contextual forces.

In establishing and exploiting corporate assets in the emergent stage of technological evolution, firms confront a number of *strategic choices* (Hamilton, 1990; Hamilton, Vilà and Dibner, 1990). This empirical study employs three basic dimensions of strategic choice to characterize the strategies of emerging high-technology firms as they attempt to build a position in the environment of a new technology: giving priority to various innovation activities; the degree of externalization of these activities; and the timing of these strategic choices.

The first dimension of strategic choice, *relative emphasis on innovation activities*, tries to capture the relative importance ascribed to different activities within the innovation chain: research, development, manufacturing and marketing. As the new technology approaches commercialization, managers have to decide where to build corporate competence along the innovation chain. The tradeoff here is whether to keep focusing on what the firm is best at (e.g. product development as the current basis of technical competence) or, rather, building the new capabilities needed to commercialize the firm's innovations (e.g. complementary assets such as manufacturing and marketing capabilities) presumably a very costly endeavor unrelated to the initial strengths of the firm.

The second dimension of strategic choice, *external orientation*, tries to capture the extent to which managers externally allocate those activities which are considered important to the firm. The critical distinction here is between the different strategic behavior of managers who delegate activities considered of low importance to the firm to external agents and those who choose to rely on external relations to conduct activities perceived as important to the firm. The latter kind of manager typically will place high importance on downstream activities and, when facing a limitation of financial and operational resources, will prefer to develop them with the help of external collaboration rather than leave them insufficiently attended. Several motivations have been proposed in the literature on interfirm relations. Of special interest here is that some forms of external activity are selected to get access to the transferable capital stock of knowledge and skills the partners may lack (Polanyi, 1967; Kogut, 1988) and to create and keep options open for future full-scale commitment if desired (Hamilton, 1985).

Decisions in each of the former dimensions are expected to change substantially over time as technologies, markets and competitive positions evolve. Thus, the third dimension of strategic choice considered here is the timing associated with innovation activities and external alliances. *Timing* of strategic choices is especially important given the inherently dynamic nature of conditions following a technological discontinuity. The temporal location of these choices may be a critical factor in meeting changing opportunities and threats in a timely fashion. Building an internal innovation chain quickly may have the advantage of accessing downstream resources available in the environment, facing less competition in establishing market relations and benefiting from early customer reactions to initial products.

Alternative Factors Influencing Prospects for Success

In addition to different positioning choices, prospects for success are also the result of other internal and external influences. This study presumes that key success factors lie in the interface between changes in the field and changes in the firms themselves. Thus, the model used here confronts the contribution of strategy with alternative factors stemming from the initial conditions prevailing at the time the start-up firm was founded, and forces from the technological and competitive environment. The model includes the following environmental and firm-specific factors:

Entry time. Early entry confers some special advantages given the inherently dynamic nature of opportunities following a technological discontinuity. First movers will enjoy advantageous asset positions over late entrants to the extent that to speed up asset accumulation entails efficiency losses (Dierickx and Cool, 1990). In addition, first movers may enjoy advantages associated with better chances of securing key assets and occupying privileged positions in the environment (e.g., patent positions, advantageous partnerships, customer loyalty to first market introductions, etc.). On the other hand, it may be argued that early movers may incur some initial inefficiencies due to high uncertainty in asset management decisions. Yet, we presume that in rapidly changing fields the advantages outweigh the disadvantages.

Initial external conditions: Number of competitors. Emerging high-technology fields will attract a growing number of competing firms as the commercial potential of the new technology unfolds. If the resource carrying capacity of the environment stays constant over time, firm density will correlate with new venture propensity to die. Yet, a key distinguishing characteristic of emerging high-technology fields is the growing support of firms exploiting novel technical opportunities. New resources brought into the field will reduce the perceived competition for resources by emerging firms. While new firms do compete for resources, it may be that external support to the field is a critical moderating factor in the relationship between the number of competitors and the prospects of success of emerging firms. Even though the number of firms participating in the new technology is expected to increase over time, we propose that, unlike established industries, the number of competitors in an emerging field *per se* is not an independent determinant of firms' success or failure.

Initial firm-specific factors. The initial levels of a firm's asset endowment will determine the number and scope of technical projects being pursed, which, in turn, should be associated with chances of firm success. Also, a firm's ability to attract new critical assets is a reflection of its unique portfolio of resources, skills and relationships. In addition, according to the principle of asset mass efficiency, the initial level of an asset stock significantly facilitates the ease of further accumulation of the same type of stock (Dierickx and Cool, 1990). Therefore, emerging firms created with initially high levels of critical assets (in our case, financial and knowledge-based assets) should be better positioned for future success.

Current external factors: Technology and the market. In addition to initial conditions and firm-specific attributes, we also control for the effect of technologies and markets selected by firms. In a period of technological ferment, alternative technologies vie for supremacy (Anderson, 1988). Technologies and markets differ in the potential they have for profitability and the challenges they pose to firms. Decisions to focus on a given technology and target a specific market convey a great number of contextual influences on firm success. We control these parameters and therefore capture important aspects of threats and opportunities related to each specific external domain.

Time since initial stock offering. As a final mediating factor between positioning strategies and the resulting position strength, we include in our analysis the time span a new firm has been publicly trading stock. Even though conceptually it can be argued that financing strategy is a dimension of the overall positioning strategy, our model relates positioning choices to commitments along the innovation chain. Going public broadens a firm's financing choice set by expanding its possibilities to access new resources. The decision to go public is probably the most important resolution of the tradeoff between securing the necessary resources to finance growth and the desire to retain ownership and control over time.

Model Specification

We specify the following form in order to assess the contribution to prospects of success of a number of selected factors relative to how emerging high-technology firms try to build a competitive position in the environment of a new technology:

Prospects for success of an emerging high-technology firm depend on: firmage, firm's initial asset levels, number of competitors at the time the firm was founded, patterns of positioning choices over time, time span accessing financial stock markets, technology and market conditions at the pre-commercialization stage, error term).

i.e., the likelihood that an emerging firm will be successful during the commercialization phase of a new technology depends on the initial asset position and competitive conditions at the time the firm was founded, choices related to how the firm decides to build and exploit asset positions over time, and contextual conditions relative to the firm's technology-market domain.

Methodology

Measurement of Performance and Success Factors

Performance in emerging high-technology firms operating in the emerging stage of a new technology is better characterized on the basis of attributes which reflect the strength of the firms' asset positions (for example, its technological and financial position) than through traditional financial measures of performance.

The use of position for success as a proxy for the overall organizational performance has several advantages. First, it is expected to be more stable than traditional indicators used in established fields (e.g., market value or profits) which are either not available or subject to high volatility. Second, its measurement is not limited to publicly traded firms, as some market-based measures. Prospects of success encompass several aspects of organizational performance which are not possible to obtain with one-dimensional measures of performance (financial, technical, social, personal, etc.). Finally, other discrete measures of organizational outcome tend to be weaker informants of firm performance unless additional information is used, like surviving vs. discontinued, independent vs. acquired firms, etc. This measurement scheme as currently developed has the major limitation of being subjectively estimated.

Empirically, the concept of prospects for success was measured by an expert panel through a subjective assessment of the strength of the firm's position for success by the mid-1990s.

Success was defined as achieving traditional standards of profitability and growth. Position for success was measured in a Likert scale ranging from 1=very poorly positioned to 5=very well positioned for success. Experts could respond that they were unable to evaluate any given firm.

We computed the average of expert assessments for each firm.[2] To facilitate interpretation of the multivariate analysis results, the average prospect for success was rescaled to range from 10 to 100. Such a linear transformation will not affect significant levels in a multiple regression, yet it allows the interpretation of regression coefficients as changes in the propensity to be successful. Five discontinued firms were assigned a zero level of prospects for success.

Patterns of Strategic Choice in Emerging Firms

Empirical analyses of patterns of strategy evolution in emerging firms have been limited to date. In part, this may reflect the early stage of development of research on emerging high technology firms as well as the infrequent occurrence of technological discontinuities. Some preliminary evidence on the existence of distinctly different patterns of strategic choices in biotechnology firms is provided in Hamilton, Vilà and Dibner, (1990). Using the three dimensions of positioning strategy mentioned above (innovation focus, external orientation and timing of choices) and using standard cluster analysis techniques, this study identified four distinctive patterns of strategic choice over time among 88 U.S. emerging biotechnology firms founded prior to 1984.[3]

As shown in Figure 1, three of the groups (Groups 1, 2 and 3) started from similar positions, with relatively high emphasis on R&D activities (i.e. relatively low emphasis on production and marketing). These firms also began with comparable levels of external orientation. Two of the groups (Groups 1 and 3) increased both their external orientation and relative emphasis on production and marketing activities by similar amounts, but differed significantly in their timing. Group 2 revealed increased emphasis on manufacturing and marketing activities comparable to Groups 1 and 2, with no overall change in external orientation, while Group 4 showed little change in either R&D intensity or external orientation over time.

An important point here is the role of timing as the key factor which distinguishes the strategies of Groups 1 and 3. These groups started from similar positions during the first year, and expect to end in equally similar positions in the next few years (both positions tested as being not significantly different).

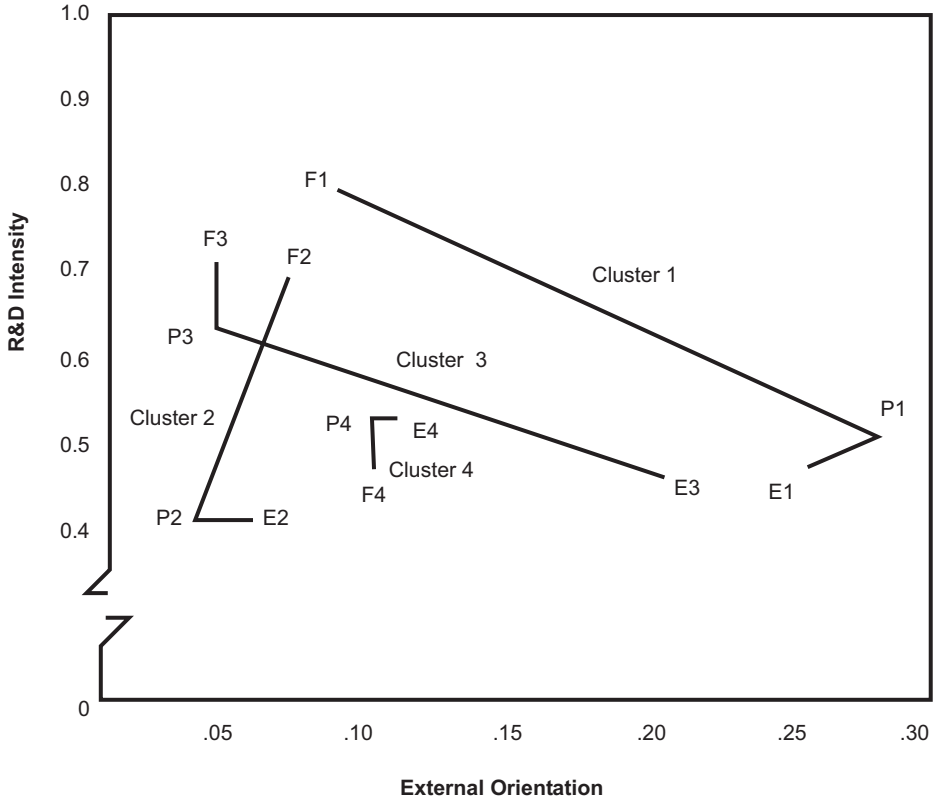
---

[2] More accurate than the equally-weighted average assessment would have been a weighted average using the parameters obtained by estimating a factor-component structural equation model of performance measurement contrasting objective indicators and the subjective assessments of experts. Yet, this project is still in progress at this point. Given that expert assessments are very highly correlated, the resolution probably has low effects on the results.

[3] This study used a disjointed clustering K-means method to identify the strategy patterns. Both the methodology and results are further discussed in greater detail in Hamilton, Vilà and Dibner, 1989.

Figure 1

Patterns of Strategic Choice in Emerging Firms



Fi: Values for First Year
Pi: Values at the Time of the Company Questionnaire (1987)
Ei: Values Expected in Five Years

Source: Hamilton, Vilà and Dibner (1989, 1990).

Positioning strategies reflected by the clusters can be characterized under four different types of patterns of strategic choice over time:

Pattern 1: *Technology driven, externally oriented – early mover.* Firms in this group began building a position of clear focus on strong science and technology as the source of future commercializable products. Within the pre-commercialization stage of the new technology, however, these firms substantially increased their emphasis on downstream manufacturing and marketing capabilities. This shift in emphasis on innovation-chain activities was simultaneously accompanied by a rise in external orientation. Internal capabilities in technological development were typically coupled with the manufacturing and marketing strengths of established firms. As the field enters into the commercialization stage and these firms significantly accomplish their goal of building downstream capabilities in-house, they are progressively reducing their previous dependence on external collaborations.

Pattern 2: *Technology driven, internally oriented – early mover.* Like those in cluster 1, firms in this group placed a relatively high initial emphasis on R&D activities and pursued an early shift in priorities toward downstream manufacturing and marketing activities. However, external alliances did not play an important role in building operational capabilities for these firms.

Pattern 3: *Technology driven, externally oriented – late mover.* This group of firms followed a strategy that closely resembled that of pattern 1, but differed importantly in timing. Firms in this cluster remained both highly focused on R&D activities and internally oriented from the time of their inception until the time the field approached the commercialization stage. However, as the stage of new technology field enters into the commercialization phase, these firms expect to increase the emphasis on both downstream and external activities.

Pattern 4: *Market driven, internally oriented, no change over time.* Among emerging firms, an important number were found to give as much priority to manufacturing and marketing activities as to R&D activities and, at the same time, they place limited importance on external alliances in their pursuit to position in this environment. Furthermore, these firms present only minor shifts in their strategic priorities over time. This may be expected of market-driven firms with initial asset positions that can be relatively easily to translate into well-defined products, tapping early market opportunities, in contrast to those technology-driven firms whose initial innovative efforts are more focused on exploiting the long-term potential of the new technology without clearly identified commercial applications.

The number of firms included in each group is presented in Table 1. This study provides support for the existence of different positioning strategies among emerging firms trying to exploit a technological discontinuity. Moreover, the three dimensions of strategic choice, which address the theoretical issue of how new firms are building a position in an emerging field, have proved to be useful in differentiating among biotechnology firm positioning choices.

Table 1

Number of Emerging Biotechnology Firms in Each Strategy Pattern

Patterns of Strategic Choice	Number of Firms
1: Technology driven, externally oriented – early mover	12
2: Technology driven, internally oriented – early mover	23
3: Technology driven, externally oriented – late mover	17
4: Market driven, internally oriented, no change over time	36

The identification of significant differences along these dimensions should be useful not only to track the evolution of the positioning strategies of these firms, but also to explore empirically their relationship with prospects for emerging firm success in a subsequent chapter. Table 2 describes how all variables were measured. An expanded description of the measurement schemes used for independent variables is included in Appendix 2.

Data Collection

Emerging U.S. biotechnology firms constitute the target population for this study. Three basic data sources were designed to collect data for this research: an early questionnaire on company and strategy attributes (spring 1987); a second questionnaire on firm prospects for success (spring 1990); and a longitudinal data base containing major biotechnology events since the mid-1970s, to track the evolution of firms and the biotechnology field.

We obtained 158 initial responses from the survey on company attributes and management choices sent to senior executives of 320 U.S. biotechnology firms. 85% of these questionnaires were completed by a senior officer of the responding biotechnology firm. Nevertheless, 24 companies could not be considered emerging biotechnology firms since either their foundation preceded the first successful scientific experiments that mark the start of the field, or they did not operate any of the core technologies constituting biotechnology. Our workable sample of 134 dedicated biotechnology firms operating in early 1987 represents a rate of response above 40%. During the analysis, five firms did not provide enough information to allow classification, and were removed from the sample. A section of the questionnaire reported selected strategy attributes, including ratings of key firm activities and priorities at three different points in time: during the first year of the firm's operation, at the time of the survey (January 1987) and expected for five years in the future. The survey had been previously tested with a small sample of firms. No serious problems of non-respondent bias were evident.

The second questionnaire collected assessments on firm prospects for success from a panel of experts. This questionnaire was pre-tested with a panel of five independent experts during the summer of 1989. The survey was mailed in April 1990 to a panel of 40 experts, consisting of professional people in selected positions in leading organizations and institutions related to the biotechnology field. A core section asked the experts to provide an assessment of how well-positioned for success the firms on a list of selected biotechnology firms were. As mentioned, success was defined by achieving traditional levels of growth and profitability by the mid-1990s. Experts were given the possibility of not responding for those firms for which they could not provide a qualified opinion. We received twenty expert responses, consisting of executives from emerging and established firms, financial investment and venture capital companies, a director of a major consulting firm and the editor of a leading biotechnology business publication.

Sample

We selected 79 emerging biotechnology firms as the sample for our study. The definition of an emerging firm presumes that the firm is free to make independent strategic choices and bears the risk of those choices. A number of firms had to be removed from the analysis for a number of reasons. First, given that subsidiaries of other firms cannot be considered freestanding companies, twelve such firms were excluded from further consideration to avoid possible strategic and operational interdependence. Also, to capture differences in strategic choices over time and reduce the possibility that these differences were not due to the timing of data collection, 26 firms founded after 1983 were excluded from the analysis reported here to minimize start-up effects. Table 3 presents a summary of respondent firm characteristics. Subsequent research suggests that multiple cases of leading and lagging firms as well as most relevant organizational features found in the population were present in the sample.

Table 2

Operational Definitions and Measurement Schemes of Variables

Variable	Measurement
Dependent Variable	
Prospects for Success	Average rate from 20 expert assessments of how well positioned the firm is for future success.
Independent Variables	
Positioning Strategy	Three dummy variables to identify four patterns:
Pattern 1: Technology driven, externally oriented – early mover.	
Pattern 2: Technology driven, internally oriented – early mover.	
Pattern 3: Technology driven, externally oriented – late mover.	
Pattern 4: Market driven, internally oriented, no change over time.	
Firm Age	Age of the firm at the beginning of 1990, in years.
Initial Conditions	
Initial Financing	Total financing (in $U.S.) at the end of the first year.
Initial Number of PhDs	Number of scientific/technical staff with doctorate degree at the end of the first year.
Initial Number of Competitors	Number of firms with primary focus in the same market as the focal firm.
Firm-Specific Control Variable	
Time Since Initial Stock Offering	Number of years that the firm had been publicly trading stock by April 1990.
External Control Variables	
Current External Conditions	
Technology Focus	Dummy variables for the core technologies: rDNA=1 if recombinant DNA is the current primary technology of the firm, 0 otherwise. MAB=1 if monoclonal antibodies are the current primary technology of the firm, 0 otherwise.
Market Focus	Dummy variables for the current target markets (therapeutics, diagnostics, animal agriculture, plant agriculture, chemicals/food, short-term and long-term markets).
Technology/Market Domain	Interaction variables (dummies) as product terms of primary technology and primary market.

Empirical Analysis

The empirical research estimates the relationship among concepts (positioning strategies and other success factors in emerging high-technology firms) in the context of biotechnology, which altogether has not received much attention in former strategy research. For this reason, we used multiple regressions (version 5 of the SAS statistical package) which could provide a valid test determinant of prospects for success.

To operationalize the concept of relevant environment, we used two alternative measurement schemes: sub-model A includes dummies to capture the separate effects (main effects) of having a given core technology (e.g., recombinant DNA or monoclonal antibodies) as the primary focus, and other dummies for targeted markets (e.g., therapeutics or plant agriculture). A second version, under sub-model B, estimates the effect of selecting combinations of technology and markets (e.g., targeting therapeutics with recombinant DNA).

Table 3

Characteristics of the Emerging Biotechnology Firms (as of spring 1987)

Characteristic	Number of Firms	Mean Value
Year of Firm Foundation		1980
1971-1975	5	
1976-1980	26	
1981- 1983	48	
Size (# Employees at 1/87)		76
Less than 30	38	
30-100	21	
More than 100	20	
Ownership Status		
Public	29	
Private	50	
Primary Technology Focus		
Recombinant DNA	23	
Monoclonal Antibodies	17	
Bioprocess	14	
Cell and Tissue Culture	14	
Other Complementary Techniques*	11	
Primary Market Focus:		
Therapeutics	22	
Diagnostics	15	
Chemicals	6	
Plant Agriculture	9	
Animal Agriculture	5	
Other**	22	

(*) Includes sequencing, synthesis, liposomes and microelectronics for biotechnology equipment.
(**) Includes food processing, energy and biomass conversion, bioelectronics, equipment, waste treatment and marine biotechnology, among others.

Since our dependent variable is obtained through subjective responses from a panel of experts, it is pertinent to assess the reliability of the prospects for success measure with a method evaluating the internal consistency of expert responses. Using the popular estimate of Cronbach's alpha, we obtained a very high reliability estimate (0.98). The implication is that we can assume a minimum threat to the validity of the results due to measurement error of the dependent variable. There seems to be a high degree of agreement among experts on the likelihood of success of the firms included in our sample.

We also checked the main assumptions on which regression is based. The residual plots did not show any indication of a curved pattern that could suggest the existence of serious

nonlinearity. A threat of erroneous interpretation due to complete multicollinearity seems not to exist; when each independent variable was regressed on the other variables, R-squared was very low in all cases except between firm age and number of competitors. This should not be a problem since firms of different ages compete for different kinds of resources. We did not detect the potential existence of heteroscedasticity when we plotted residual values against predicted values. Also, as discussed above, our target variable (prospects for success of emerging high-technology firms) seems to be quite robust against random variation in its measurement.

Results

All models examined are highly significant ($p<0.001$), suggesting that independent variables have power in predicting the dependent variable. Adjusted R-squared statistics are 35% for model A and 41% for model B,[4] attesting to the power of these models in explaining differences in prospects for success.

Table 4 presents the results of our estimated models. Since we use dummies to identify cluster membership, only three of the patterns identified in former research are necessary in the regression, and the results have to be interpreted as differences relative to the omitted category. Given the substantively different approach to building position reflected by pattern 4 (market driven, internally oriented and nominal changes over time) as compared to the other strategy paths, we selected this pattern as the baseline category to which to compare the differential performance of alternative positioning strategies.

Differences in the effect of distinct patterns of strategic choice on prospects for success are observed. Pattern 2 (Technology driven, internally oriented, early mover), and pattern 1 (Technology driven, externally oriented, early mover) seem to lead to a superior position relative to the omitted pattern (Market driven, internally oriented and nominal changes over time), even though the effect is not equally strong in the different sub-models. Following pattern 3 (Technology driven, externally oriented, late mover) has a slightly detrimental, but not strong, effect compared to not changing priorities over time (the choice set represented by pattern 4).

This finding suggests that emerging firms that first encompass the full range of innovation activities (patterns 1 and 2) turn out be better positioned for future success. The specific test that the coefficients of pattern 1 and pattern 2 in model B do not significantly outperform pattern 4 is rejected at $p=0.028$. A test for the hypothesis that differences in performance between patterns 1 and 3 do not exist is rejected at $p=0.021$. Firms reducing the degree of external orientation following their earlier use of strategic collaboration (pattern 1) are expected to outperform firms that increase external orientation after an initial period of internal focus (pattern 3).

The results in this model also provide a clear support for the claim of an age effect on superior position for success. We find consistent and strong support for the proposition that firms which enter this new technology field earlier are more likely to build a stronger position for future success. Also, first year financing emerges as a relevant factor, even though the value of its coefficients and significance levels are only marginally strong.

---

[4] Some variations of the models reported here were used ignoring outliers clearly separated from our strategy patterns. Adjusted R-squared rose to 0.56. These results are not included here for simplification.

The number of years a firm has had access to capital markets is strongly related to a superior position for future success. The strength of influence is consistent across all three models. On the other hand, neither the number of organizational members with advanced degrees nor the number of competitors appear as relevant factors in differentiating positions for success.

Finally, differences in the effects of environments selected by firms seem to exist. Yet, in general, the strength of relationships are not sufficiently significant and should be interpreted only as an initial illustration of the diversity of contextual influences. The effects of technology and market environments are more evident when we combine technology and market to define the firm's relevant domain (model B) than when we treat them separately (model A). Model A suggests that firms with a primary focus on the core techniques constituting biotechnology (recombinant DNA and monoclonal antibodies) as opposed to complementary technologies (such as bioprocess, cell culture, etc., which we use as the omitted category in the analysis) are better positioned for future success, with focus on rDNA being moderately significant.

In addition, prospects for success also depend on the market domain targeted by firms. Some firms direct their efforts towards markets where products lag commercial introduction relative to other areas (in our case, animal and plant agriculture, chemicals and food, and the aggregate category of long term markets). As expected, these firms saw the total contribution of market selection as an impediment to reaching profitability and growth by the mid-1990s. Yet only the effect of animal agriculture is significant. The negative prospects for success of firms targeting diagnostics may be due to the fact that most new biotechnology products in this market segment have to compete with the traditional products of large established firms, and this particular segment does not provide significant opportunities to isolate firm assets from competitor imitability.

Model B suggests that specific combinations of technology and market are more important in explaining prospects for success than the effect of each separate factor. Firms positioning themselves in therapeutics with the use of rDNA are significantly better positioned for success in the near future. We report here only the total effect of interaction terms formed with categorical variables; however, we performed an extended analysis including main as well as net effects of some interaction variables with significant results for interaction terms (Vilà, 1991). The initial strength of the interaction term strongly suggests that the effect of market on performance depends on the technology that the firm chooses to develop, and vice versa; that the effect of a firm's core technology on performance depends on the market to which it is directed. We will return to this point below.

To assess the relative contribution of each factor to prospects for success, we ran a standardized regression analysis on model B (which includes interaction terms only for technology/market domains) to estimate the independent contributions of the success factors.[5] The standardized coefficients in Table 5 represent the total contribution of each factor to prospects for success, that is, the contribution directly attributed to each variable plus the indirect effect as a result of moderating the relationship between other factors and performance (therefore, these coefficients do not represent net contributions).

[5] The dummy variables in model B were included in the standardized regression analysis with the use of a new variable defined as the linear combination of dummies in model B with their corresponding non-standardized coefficients.

Table 4

Dependent Variable: Prospects for Success
Positioning Strategies as Patterns of Strategic Choices

Variable	Model A	Model B
Intercept	-15.71	-17.55
Firm Age	3.41**	3.51***
Initial Conditions		
First Year Number of PhDs	0.11	0.06
First Year Financing	1.40*	1.41*
First Year Number of Competitors	0.07	0.16
Patterns of Strategic Choices†		
1: Technology driven, externally oriented, early mover	12.37	12.54*
2: Technology driven, internally oriented, early mover	11.93**	10.52*
3: Technology driven, externally oriented, late mover	-2.21	-5.28
Time Since IPO Date	1.51*	1.61**
A: Current Technology Focus†		
Recombinant DNA	10.09*	
Monoclonal Antibodies	8.23	
A*: Current Market Focus†*	5.74	
Therapeutics	-7.61	
Diagnostics		
Animal Agriculture	-14.37	
Plant Agriculture	1.76	
Chemicals/ Food	-6.23	
Models A and B:		
Short Term Markets	9.43	13.08
Long Term Markets	-4.02	-2.80
B: Current Technology/Market Domains†		
Therapeutics with rDNA		21.03***
Diagnostics with MAB		-3.92
Animal Agriculture with rDNA		9.73
Plant Agriculture with rDNA		11.51
Chemicals/Food with rDNA		-9.43
Adjusted R-squared	0.35	0.41
Overall p value	0.0002	0.0001

Note: (1) Sample size=79; (2) * p < 0.10; **p < 0.05, ***p < 0.01; (3) † Dummy variables.

The results suggest that most factors in our theoretical model are relevant determinants of the likelihood of success in emerging biotechnology firms. Our central construct, positioning strategy, appears to be an important determinant of prospects for success in emerging high-technology firms. Also, the technology/market domain a firm selects to position into, and the timing of entry into the field are found to be relevant factors in the resulting strength of firm position for future success. In similar terms, first year financing and the time span a firm has been accessing capital markets also represent factors which significantly add to a firm's position for success.

Our results in the standardized regression analysis, in line with prior models, show that strategy in emerging firms does make a difference in explaining prospects for success. The influence of positioning strategy still holds when we control for the effect of alternative explanations of firm success. Three independent tests for whether the total contribution of each factor; positioning strategy, firm age, and current technology/market domain, are not significantly different from zero (Ho: Bi = 0) are rejected at p=0.0014, p=0.0024 and p=0.0001 respectively. In sum, this research sheds light on factors influencing the prospects for success in emerging high-technology firms.

Table 5

Standardized Regression Analysis Results
Relative Contributions to Prospects for Success

Variable	Parameter Estimate	Standardized Estimate
Intercept	-17.24 (12.59)	0
Firm Age	3.48** (1.11)	0.34
First Year Number of PhDs	0.05 (0.40)	0.01
First Year Financing	1.40** (0.65)	0.2
First Year Number of Competitors	0.16 (0.17)	0.09
Time Since IPO Date	1.61** (0.63)	0.24
Patterns of Strategic Choices	1.01*** (0.30)	0.29
Current Technology/Market Domains	1.01*** (0.22)	0.39
Adjusted R-squared	0.47	
Overall p value	0.0001	

Notes: (1) Sample size=79; (2) * p < 0.10, ** p < 0.05, *** p < 0.01; (3) Standard errors within parentheses.

Discussion of Results

This empirical study provides some preliminary insights into the strategy-performance relationships for emerging high-technology firms created during the initial stage of evolution of an emerging technology. A former study by Hamilton, Vilà and Dibner (1990) showed the existence of substantively and statistically different strategies among newly created firms seeking to exploit a technological discontinuity. This study extends the identification of different positioning strategies by relating them to differences in expected performance.

The empirical results provide initial support for the emerging strategy perspective focusing on an asset-based view of the firm. The finding of a significant relationship between firm choices about how to build asset position in the rapidly changing environment of biotechnology, and potential for future success, constitutes an important contribution from the asset-based perspective. From the empirical results, the concept of positioning strategy comes forth as a relevant factor determining prospects for success. We focused on a confined aspect of strategy,

that of asset positioning over time. By so doing, we set a number of decisions of vital significance apart from our proxy for positioning strategy, such as the decision to enter the field, the decision to go public, and market and technology selection. Even with this narrow definition, the positioning strategy concept stands up as one of the primary determinants of prospects for success.

Some issues related to alternative factors influencing performance also deserve some discussion. The construct "Time since IPO" turned out to be a very significant determinant of success. It may be possible that the strong effect of the variable is due to the expected higher visibility of public firms and presumably better knowledge by experts rather than the actual effect of access to capital markets. It is not possible to separate the effect of both factors in the present research design and, therefore, we have been cautious to downplay the implications of this variable. The initial purpose of introducing this variable was, anyway, to control for alternative explanations of firm performance.

This study does not find support for an ecological proposition of a competitor density effect on firms' prospects for success in emerging high-technology fields. In these specific environments, the progressive support to the field as it develops may dominate the number of competitors in the effect of rivalry on prospects for success. Earlier theoretical discussion pointed out that emerging high-technology fields will attract a growing support for firms exploiting novel technical opportunities as the potential of the new technology unfolds. Therefore, competition for resources has to be assessed in the light of both the number of firms and trends in resource support to the field. While new firms do compete for resources, external support to the field is a critical moderating factor in the relationship between the number of competitors and the prospects of success of emerging firms. Supporting this logic, the effect of number of competitors at the time a firm was created has been found not to be a significant influence on a firm's prospects for success.

Some limitations should be taken into account in interpreting the results. First, we derived our model from a complex set of interrelationships among changes in the field, in strategy and in the firms, but only tested part of them. Some important concepts were necessarily left out of the analysis. Additional independent variables could influence the estimated parameters, the most important being a firm's early technical success, its stage of technological advance, field resource support during the first year of its operation, and technology-based competitors.

Second, the measurement of performance is not a discrete objective measure. It is only a subjective assessment of potential for future success. As has been discussed, traditional measures of performance are not adequate during the emerging stage of a new technology. We use strength of the position for success as a surrogate of performance, until objective performance indicators become available. However, we think that there is value in our measure since managers and analysts in the field continuously track the performance of biotechnology firms even in the absence of traditional performance measures. The surprisingly high inter-expert agreement (Cronbach's alpha=0.98) suggests strong enough reliability to encourage its use.

Third, it may be argued that the model does not cover all directions of causality prevailing in the true phenomenon it is intended to capture. For example, early financing amassed in venture firms may be the result of expected prospects of future success as much as increased early financing enhances the chances of future performance. To overcome these limitations it is necessary to expand the current model beyond the exploratory purpose of this study. This will be accomplished in future research as theoretical and empirical knowledge on emerging high-technology fields accumulates.

Contributions

The study shows that an array of factors influence the strategy-performance relationship in emerging high-technology firms. The results allow a contrast between the relative importance of competing views on the issue of why emerging firms differ in performance. It identifies patterns of strategic choice as a key factor explaining prospects for success for biotechnology firms (at a point when this new technology field is about to enter the stage of full commercialization of a large number of novel products for the first time).

We believe this research constitutes a pioneer study of the role of key success factors in newly created firms using a new technology with the potential to revolutionize many established industries. The contributions are primarily two: First, strategy in emerging high-technology firms does make a difference in firms' prospects for success. Second, timing of strategic choice (not just content) is a critical factor in identifying strategy-performance relationships in rapidly changing environments.

Appendix 1

A Brief Introduction to the Biotechnology Field

Scientific discoveries in the 1950s and 1960s led to the development of the two basic techniques in biotechnology: recombinant DNA and monoclonal antibodies. Broadly defined, biotechnology is based on the use of living organisms to produce commercial products. Biological processes and organisms have been used throughout history in baking, brewing and agriculture. However, modern biotechnology techniques represent a major technological discontinuity in the evolution of biological and biochemical sciences. These advances are creating countless opportunities for commercial impacts in many established industries: pharmaceuticals (in both therapeutics and diagnostics), animal and plant agriculture, chemicals (specialty and commodities) and other industrial sectors (food processing, energy, waste management, mining, and bioelectronics).

Even when the evidence supporting the claim that biotechnology constitutes a case of technological discontinuity is limited, several issues seem to confirm this presumption. The number of pending biotechnology applications for animal agriculture surged to 65 in April 1989, from about a dozen a year before. Before the advent of biotechnology, annual new introductions of pharmaceutical products in the United States had declined from 400 in the 1955-57 period to only 18 in 1974. Nearly all of these drugs represented marginal improvements on products already in the market. Yet in the next two years several dozen new pharmaceutical products are going to be introduced, only from techniques associated with modem biotechnology. Also, the commercialization of the recombinant and antibody pharmaceutical lines is expected to push a number of new biotechnology firms into the ranks of major pharmaceutical corporations, a feat not achieved in more than three decades.

To date, only about a dozen rDNA products have received government approval for marketing in the United States. However, even the most conservative estimates predict widespread products and process applications in existing and new commercial sectors.

The most dynamic participants in the emerging stage of this new technology are the new independent ventures created by scientific talents with the support of venture capitalists and corporate investors. Between 1971 and 1990 more than 500 new firms were founded in the United States alone to exploit some biotechnology-related technique. In 1987, the average U.S. biotechnology firm was six years old, had fewer than 100 employees, and operated at a loss (Dibner and Osterhaus, 1987).

These emerging firms have typically combined entrepreneurial teams with a vision of commercial applications that excited the investment community in the early 1980s. The resulting infusion of funds and new firms has vastly increased the level of biotechnology activity. It has also greatly increased the pressures on many emerging firms to deliver commercial products and processes to the market. It is expected that different emerging firms seek to position themselves for innovation and commercial success in different ways in the midst of rapid technological and market evolution. The present study examines the role that positioning choices play in creating a competitive position in the highly competitive environment of the biotechnology field.

Several characteristics make the biotechnology field interesting for our study:

1. The revolutionary nature of the technological change.
2. The wide range of established industries likely to be affected by the new technology.
3. The rich variety of strategies being pursued by emerging firms.
4. The temporal proximity of significant events and information from major players.

Appendix 2

Measurement Schemes of Independent Variables

Firm age. Given that only the year of founding was available for all firms, firm age is measured by the number of years since the firm was founded, as an integer number using 1990 as the reference point. This variable was obtained through the 1987 company questionnaire.

Initial financing of the firm. Firms reported the total amount of financial resources in dollars available at the end of their first year. A period of a year from inception is normally used by new ventures to negotiate the terms of initial financial backing with venture capitalists and other investors. Financial information was obtained through primary sources from firms responding to the 1987 survey.

Initial number of PhDs in the firm. We use the number of scientific/technical staff with doctoral degrees in the firm by the end of the first year as an operational definition of the firm's initial knowledge base. The personnel composition of biotechnology firms was also obtained through the company questionnaire.

Initial number of competitors. We operationalize the concept as the number of firms sharing the same market as the primary commercial focus. Primary market focus could be collected though the company questionnaire, major field directories and the *Genetic Engineering News Guides to Biotechnology Firms* for 397 new firms active in the U.S. biotechnology field in 1987. We decided not to use technology focus to define competition, since this information was not available for a large number of these firms.

Positioning strategic choices: The concept of positioning was defined as a set of strategic choices related to where to build capabilities along the innovation chain and how to do so. We use two dimensions of strategic choice: relative emphasis on selected innovation activities and external orientation, and measure them for two points in time: during the first year of firm operations and at a late pre-commercialization stage of the biotechnology field (more specifically in the spring of 1987, when the company questionnaire was collected). The first dimension of strategic choice, relative emphasis on innovation activities, tries to capture the relative importance given to different activities along the innovation chain in going from the laboratory to the market: research, development, manufacturing and marketing. A measure of *relative emphasis on research and development* was operationalized from the 1987 company questionnaire. Four items for each time period measured the importance assigned to the four innovation activities on a 5-point scale, with 1=low importance and 5=high importance. The relative emphasis on R&D for each period was measured as:

Relative emphasis on R&D activities = $(r_R + r_D) / (r_R + r_D + r_p + r_M)$

(at each point in time) R=research, D=development, P=manufacturing, and M=marketing.

r_i = importance assigned to activity i.

The second dimension of strategic choice, *external orientation*, refers to the extent to which managers rely on external collaborations in the conduct of those activities which are considered important to the firm. This measure was also obtained from the company questionnaire. Four items for three time periods measured, as a percentage, the degree to which each innovation activity was allocated externally to the firm. The external proportions were weighted by the importance ratings assigned to the respective innovation activities. The external orientation was operationalized as:

Appendix 2 (continued)

External orientation = $(r_R * e_R + r_D * e_D + r_p * e_p + r_M * e_M) / 2000$

(at each point in time) ei= % of activity i external to the firm

The upper bound of external orientation was computed as 4 (number of activities) * 5 (highest rating for importance) * 100 (highest percentage of external activity) = 2000.

This operational definition will presumably capture the critical distinction between a management team that delegates activities considered of low importance to the firm to external agents (low score in external orientation as a result of low importance assigned to innovation activities) and those who choose to rely on external activities because they perceive the activities to be important to the firm (high scores derived from highly relevant activities). Both concepts are more broadly discussed in Hamilton, Vilà and Dibner (1990).

Time since initial stock offering. We include in our analysis the period of time a firm has been publicly trading stock. The financing strategy of emerging firms is a dimension of positioning strategy which is not specifically addressed in this research, even though it is expected to play an important role in firm performance. Going public broadens a firm's financing choice set by expanding the possibilities of accessing to the resources. Since IPO dates were available in months and years in our data base, we measured time since IPO in fractional years. We took April 1990 as the reference point. Private firms at that time were assigned a value of zero.

Technology and market focus. We include in our models dummy variables to control for the effect of technologies and markets. Both were measured from the company questionnaire and therefore refer to the 1987 company focus.

Technology focus. We created dummy variables for recombinant DNA (rDNA) and monoclonal antibody (MBA) technologies as a primary focus. Other techniques, such as bioprocess (fermentation, large-scale purification, process monitoring control, lab-scale purification and separation and enzymology), cell and tissue culture and a number of complementary technologies are not central to the definition of biotechnology and constitute our omitted category in the regression analysis.

Market focus. Each of the major markets currently pursued by firms is included in the analysis (therapeutics, diagnostics, animal and plant agriculture, chemicals/food). In addition, minor markets were grouped according to the expected timing of product introduction. We have a dummy variable for long term markets (bioelectronics, biomaterials, mining, and energy) and another dummy variable for short term markets (products for the research market such as biological, plus reagents, drug delivery systems, equipment and research instrumentation). Firms which are process oriented rather than product oriented were not specifically incorporated in a dummy term in the test and constitute the reference category in our analysis.

We use dummy variables for technology and market environments in the models in two alternative ways. As a simple way of reflecting their main effects, version A includes dummy variables representing the separate effect of technology and markets. In version B, relevant environments are defined as product terms representing combinations of technologies and markets. In another study we run a similar analysis using *stage of technology progress* which adds generalizability to the results of using primary technologies and markets in high-technology environments (see Vilà, 1991).

References

Abemathy, William. J. and Kim. B. Clark (1985) "Innovation: Mapping the winds of creative destruction," *Research Policy*, 14: 3-22.

Anderson, Philip (1988) "The population dynamics of Schumpeterian competition," *Academy of Management Best Papers Proceedings*, Anaheim, CA, 150- 154.

Burrill, Steven G. (1989) *Biotech 90: Into the Next Decade*. New York: Mary Arm Liebert, Inc. Publishers.

Dibner, M.D. and LT. Osterhaus, (1987) "Biotechnology and Pharmaceuticals: Merging Together," *BioPharm*, September.

Dierickx, Ingemar and Karel Cool (1989) "Asset stock accumulation and sustainability of competitive advantage," *Management Science*, 35, 12, December: 1505-1511.

Dierickx, Ingemar and Karel Cool (1990) "Competitive strategy, asset accumulation and firm performance," Working Paper, INSEAD, Fontainebleu, France.

Dosi, Giovanni (1982) "Technological paradigms and technological trajectories," *Research Policy*, 11: 147-162.

Fildes, Robert A. (1990) "Strategic Challenges in Commercializing Biotechnology," *California Management Review*, 32, 3: 63-72.

Hambrick, Donald C. and Lynn M. Crozier (1985) "Stumblers and stars in the management of rapid growth," *Journal of Business Venturing*, 1: 31-45.

Hamilton, William. F. (1985) "Corporate strategies for managing emerging technologies," *Technology in Society*, 7:197-212.

Hamilton, William F. (1990) "The dynamics of technology and strategy," *European Journal of Operations Research*, Summer, 1990.

Hamilton William F., Joaquirn Vilà and Mark D. Dibner (1990) "Patterns of strategic choice in emerging firms: Positioning for innovation in biotechnology," *California Management Review*, Spring 1990.

Kogut, Bruce (1988) "Joint ventures: Theoretical and empirical perspectives," *Strategic Management Journal*, 9, 4: 319-323.

Macdonald, Roderick J. (1985) "Strategic alternatives in emerging industries," *Journal of Product Innovation Management*, 3:158-169.

Polanyi, M. (1967) *The Tacit Dimension*. New York: Doubleday.

Rumelt, Richard P. (1984) "Towards a strategic theory of the firm," In Robert B. Lamb (ed.) *Competitive Strategic Management,* Englewoods Cliffs: Prentice Hall, 556-570.

Schumpeter, Joseph A. (1950) *Capitalism, socialism and democracy*. 3rd edition, Lexington, MA: Lexington.

Shan, Weijian (1987) *Technological change and strategic cooperation: Evidence from the commercialization of biotechnology*, Ph.D. Dissertation, University of California, Berkeley.

Stuart, Robert and Pier A. Abetti (1987) "Start-up ventures: Towards the prediction of initial success," *Journal of Business Venturing*, 2: 215-230.

Teece, David (1987) "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy," In David J. Teece, Ed. *The Competitive Challenge: Strategies for Industrial Innovation and Renewal*, Cambridge, MA: Ballinger.

Tushman, Michael. L., and Philip Anderson (1986) "Technological discontinuities and organizational environments," *Administrative Science Quarterly*, 31: 439-465.

Vilà, Joaquim (1991) *Positioning strategies and prospects for success of emerging high-technology firms: The case of U.S. Biotechnology*. Ph.D. dissertation, The Wharton School, University of Pennsylvania.

Winter, Sidney G. (1987) "Knowledge and competence as strategic assets," In David J. Teece (ed.) *The competitive challenge: Strategies for industrial innovation and renewal*. Cambridge, MA: Ballinger.