9-1999

Manufacturing Strategy and New Venture Performance: A Comparison of Independent and Corporate Ventures in the Biotechnology Industry

Shaker A. ZAHRA
Georgia State University

Gerard GEORGE
Singapore Management University, ggeorge@smu.edu.sg

Published in Journal of High Technology Management Research
Volume 10, Issue 2, September 1999, Pages 313-343
https://doi.org/10.1016/S1047-8310(99)00012-7

MANUFACTURING STRATEGY AND NEW VENTURE PERFORMANCE: A COMPARISON OF INDEPENDENT AND CORPORATE VENTURES IN THE BIOTECHNOLOGY INDUSTRY

SHAKER A. ZAHRA, GERARD GEORGE
Georgia State University, Syracuse University

Little empirical research has compared the manufacturing strategies of corporate and independent new ventures. This study explores these differences with data from the young, science-based biotechnology industry, and examines the performance effects of manufacturing strategy variables including scope, competitive thrust, and capabilities. The results show that the corporate and independent biotechnology new ventures pursue significantly different manufacturing strategies, and that different dimensions of manufacturing strategies affect the performance of corporate vs. independent ventures quite differently. © 2000 Elsevier Science Inc.

INTRODUCTION

New ventures play a major role in the creation and growth of high technology industries. These young organizations usually succeed by transforming scientific discoveries into innovative product and process technologies that meet customer needs. New ventures, whether established by independent entrepreneurs or corporations, must develop a wide range of capabilities in order to capitalize on the opportunities that exist in their industries (Chaston & Mangles 1997; Roberts 1991). In particular, new ventures need to develop or acquire excellent manufacturing capabilities that transform their innovations into products and goods (Berry & Cooper

Direct correspondence to: Gerard George, Department of Strategy & Human Resources, School of Management, Syracuse University, Syracuse, NY 13244-2130; Tel: (315) 443-3391; Fax: (315) 443-5457; E-mail: Gegeorge@syr.edu
The financial support of the Beebe Institute at Georgia State University and the Franklin Institute at Syracuse University is gratefully acknowledged.

1999; Hamilton, Vila & Dibner 1990), build market share, ensure survival, lead to sales growth, and achieve profitability (Marino & DeNoble 1997; Pisano & Wheelwright 1995). Consequently, building strong manufacturing capabilities is considered among the most important challenges for managers of technology-based ventures (Hamilton & Singh 1992; Kazanjian & Drazin 1990). Developing these capabilities can be achieved by acquiring modern production technologies and gaining the skills that ensure the superiority of the ventures' products (Carey et al., 1997; Keeley & Roure 1990). According to Pisano and Wheelwright (1995), the lack of effective manufacturing capabilities has led to delays in new product development and introductions, and resulted in lower company performance among some high technology companies, especially in the biotechnology industry.

The resource-based theory of the firm (Penrose 1959; Grant 1995; Teece, Pisano, & Shuen 1997) suggests that success in today's markets goes to firms that have achieved and nurtured effective capabilities through sustained investments in acquiring relevant assets, resources, and skills (Grant 1995). To succeed in building viable manufacturing capabilities, new ventures also need to develop effective manufacturing strategies (Minor, Hensley, & Wood 1994). The content of these strategies specifies new ventures' manufacturing goals and strategic priorities, the scope of their operations, and competitive approaches (Bantel 1997; Ettlie & Penner-Hahn 1994; Garrone & Rossini 1998). Currently, research on the content of the manufacturing strategies in high technology new ventures is in its infancy and little is known about the differences in manufacturing strategies that exist between ventures created by entrepreneurs and those developed by corporations.

This study examines the differences in manufacturing strategies between new ventures established by corporations (hereafter "corporate ventures" or CVs) and those founded by independent entrepreneurs (hereafter "independent ventures" or IVs). The study also explores the relationships between the manufacturing strategy variables and key indicators of new venture performance (NVP), including innovative outputs (i.e., patents). We address these two issues in the context of the dynamic U.S. biotechnology industry where both CVs and IVs struggle for survival. Given that the industry represents a major scientific paradigm shift, traditional prescriptions about effective manufacturing strategies may not be useful for biotechnology ventures. Most prior research on manufacturing strategies has been conducted in established companies (e.g., Anderson, Cleveland, & Schroeder 1989; Vickery, Droge, & Markland 1993) but new ventures that lack the resources and therefore cannot copy strategic choices of established firms. Further, given that IVs and CVs battle each other for market share, identifying the differences that might exist in the content of their manufacturing strategies can clarify a source of variation in their financial performance. The study, therefore, responds to calls for empirical research that determines the sources of differences in NVP by exploring the effect of CVs' and IVs' manufacturing strategies on performance (McCann, 1991), and by using multiple measures of new venture financial (Minor et al., 1994) and innovative performance (patents).

The study also explores the impact of manufacturing strategies on NVP using a sample of biotechnology ventures, one of the key industries of the future (Shan & Song, 1997). This industry has enriched the lives of more than 100 million people with nearly 40 drugs that have already been approved by the Food & Drug Administration (FDA). With market capitalization of $83 billion and high-value job creation

of 118,000 in the U.S. alone, the biotechnology industry has potential to revolutionize research and product development in several other industries such as human therapeutics, agriculture, veterinary sciences and environmental sciences, among others (BIO 1998). To date, research on the biotechnology industry has focused on examining the effects of strategic characteristics (Liebeskind et al., 1996; Powell, Koput, & Smith-Doerr 1996), institutional linkages, alliance patterns (Deeds & Hill, 1996), and R&D activities (Pisano 1990; Shan et al., 1994). However, the role of manufacturing capabilities as an important strategic tool within this industry has been largely ignored. This study is one step toward understanding the manufacturing strategies used in this industry.

The next section of the paper presents the study's theoretical background and hypotheses, emphasizing the anticipated differences between CVs and IVs in their respective manufacturing strategies. The expected associations of manufacturing strategies and the performance of biotechnology CVs and IVs are then discussed. Next, an empirical study that tests the hypotheses is summarized. The paper concludes by discussing the results and their implications for managerial practice and future research on the manufacturing strategies of both CVs and IVs.

THEORY AND HYPOTHESES

Research on the determinants of NVP suggests that a venture's external environment, competitive strategy, internal organization and culture, and capabilities influence its performance (Carter et al., 1994). Consequently, researchers have studied the strategies new ventures use in developing strong capabilities that lead to superior performance (McGrath, Venkataraman, & MacMillan, 1994), measured by profitability and growth (Chaston & Mangles, 1997; Thayer, 1995).

The resource-based theory of the firm (Grant, 1995) posits that competitive advantage designed around a strong set of capabilities is essential for achieving superior NVP (McGrath et al., 1994; Teece et al., 1997; Pisano & Wheelwright, 1995). Strong manufacturing capabilities can give a new venture a significant competitive advantage. These capabilities are the skills and competencies a venture gains from its manufacturing assets, resources (both tangible and intangible), knowledge, and experience (Teece et al., 1997). When manufacturing capabilities are embedded in the venture's culture and systems, they become difficult for competitors to decipher or imitate (Grant 1995), thus protecting the firm's competitive advantage.

Manufacturing is one of the key areas where a venture can develop strong capabilities that become the foundation of successful market performance (Berry & Cooper, 1999; Teece et al., 1997; Vos & Allegra, 1998; Zahra & Das, 1993). One reason is that information on the venture's manufacturing operations are usually difficult for competitors to gather, which can reduce imitation by the firm's rivals. These operations also benefit from, and contribute to, the venture's other functional activities (e.g., product design) and lead to higher NVP (Chaston & Mangles, 1997). The learning gained within manufacturing operations can also revise and redefine the venture's product portfolio and its competitive approach. An effective strategy ensures that manufacturing operations' priorities and capabilities are consistent with the venture's mission (Leong & Ward, 1995).

Considerable effort has been devoted to studying manufacturing strategy and

its impact on a company's performance (Ettlie & Penner-Hahn, 1994). Yet, little attention has been given to the content of the new ventures' manufacturing strategies in high technology industries, the focus of this paper. Pisano and Wheelwright (1995: 93) warn that, "Few managers of high-technology companies view manufacturing as a primary source of competitive advantage." This thinking can undermine the profitability and survival of young companies.

Little is known about the differences in the content of manufacturing strategies followed by different types of new ventures within the same industry. To fill this gap in the literature, this paper examines the potential differences in the manufacturing strategies of CVs versus IVs. The paper proposes that differences in resources and capabilities can explain the variations in the manufacturing strategies used by CVs and IVs (McDougall, Deane, & D'Souza, 1992). As indicated in Table 1, CVs typically benefit from having access to their sponsors' financial resources, distribution channels, marketing expertise, existing technologies, and manufacturing facilities (Block & MacMillan, 1993). CVs usually rely on the sponsors' "deep pockets" in financing their strategies that emphasize the pursuit of a broadly defined market (MacMillan & Day, 1987). Corporate sponsors often view investments in CVs as worthwhile because they may create new markets, offer a window into emerging technologies, or increase their sponsors' ability to achieve growth and profitability (Table 1).

The IVs' resources are frequently more constrained than those of CVs, because IVs primarily obtain resources from their owners and venture capitalists. While the IVs' access to financial resources might be limited, these firms benefit from their owners' direct and active involvement in the decision-making process. Owners and venture capitalists' insights, experience and long-term orientation are important assets for IVs (Shrader & Simon, 1997). The owners' incentives are also usually closely aligned with those of the firm, because the ventures' success creates wealth for their owners and investors. Owners will work hard to develop the capabilities needed for the IVs' success. With significant prior research and training in the biotechnology industry, these owners are also connected to important sources of knowledge and capital in the industry, which can ease the transfer of best skills into the IVs' operations (Roberts, 1991). Further, the IVs' flexible and lean organizational structures also allow these firms to move quickly to capitalize on opportunities in their industry–whether in developing products or adopting new technologies. In turn, this speed helps in penetrating new markets (Neven, Summe, & Uttal, 1990).

Companies organize and manage their CVs quite differently (Block & MacMillan, 1993), a factor that makes it difficult to generalize about these firms. The information provided in Table 1 suggests that CVs and IVs face different challenges and benefit from different capabilities. Though these factors can influence the strategic choices CVs and IVs make, we know very little about their direct effect on these ventures' manufacturing strategies. However, one previous study suggested that CVs and IVs' differences in the goals and resources can lead to significant variations in these firms' respective manufacturing strategies (McDougall et al., 1992). The following section predicts the expected differences in CVs' and IVs' manufacturing strategies.

Manufacturing Strategy Variables in CVs versus IVs

CVs and IVs need to develop manufacturing strategies that allow them to build capabilities that ensure success. Manufacturing strategy embodies the process and

TABLE 1
Differences between Independent and Corporate Ventures

Dimensions	*Independent Ventures (IVs)*	*Corporate Ventures (CVs)*
Goals	Employment and autonomy for the owner Profitability and wealth creation for the owner Opportunity to use owner's expertise	Market creation & Window into new technology Growth Profitability
Financial resources	More limited than the CVs because IVs primarily draw upon the resources of the owners and venture capitalists who have a long-term orientation.	Greater than the IVS, as resources of the corporate sponsor and venture capitalists provide resources. Short-term orientation.
Non-financial resources	Owners experience Venture capitalists Networks	Greater in magnitude than in IVs, the venture draws heavily upon the sponsors' established operations, excess capacity, and expertise.
Decision making process	Simple and informal structure Frequent communication Quick feedback Longer-time horizons	Formal hierarchy Communications through official channels Tight corporate controls Short-term time horizons
Decision makers	Owner Top management team	Salaried managers
Managers' dominant skills	R&D Manufacturing & operations	Marketing & distribution
Skill-base	More focused; more entrepreneurs in top management	More diverse; more managers in leadership
Organizational structure	Simple	Multi-layered, with tight controls from the corporate sponsor.
Executive incentives and compensation	Tied directly to venture performance through stock option.	Based on plan achievement, seniority and position in hierarchy

content of the choices made by a new venture to use its manufacturing capabilities to achieve superior performance. The process component of manufacturing strategy usually defines how a company develops or acquires the necessary manufacturing capabilities, coordinates its operations, and deploys its manufacturing capabilities to achieve superior performance (Ettlie & Penner-Hahn, 1994). The content of manufacturing strategy defines the scope, goals, and competitive approaches used in manufacturing operations to gain superior performance in a firm's markets. This paper focuses on the content of manufacturing strategies.

The strategic management (Andrews, 1971; Fahey & Christensen, 1986) and the manufacturing strategy literatures (Leong & Ward, 1995; Minor et al., 1994) highlight three key dimensions of the content of a firm's strategy: (a) the scope of manufacturing operations (the breadth of product lines); (b) the goals and competitive thrusts of manufacturing operations (product uniqueness, product innovation, quality, and low cost); and (c) the approaches and sources of manufacturing capabilities (vertical integration, capital spending, and external sourcing). Scope defines where a firm intends to exploit its manufacturing assets, resources and capabilities. The goals and competitive approaches establish the priorities for a new venture's manufacturing operations in pursuit of superior performance in chosen markets. Finally, the competitive approaches and sources dimension defines how a venture will use its manufacturing capabilities to achieve its competitive goals and priorities. Thus, while industry structure, regulatory forces and financing practices may affect NVP, the scope, goals, and competitive approaches followed by new ventures in their manufacturing operations can yielded additional performance benefits (higher NVP), as would be suggested by both the resource-based and strategic choice perspectives (Grant, 1995).

Manufacturing Scope. A venture's emphasis on offering products to its markets is an important component of its manufacturing strategy (Buzzell & Gale, 1987). This emphasis is clarified in the choice of the product line breadth, which determines the scope of a firm's manufacturing operations. Product line breadth impacts the venture's ability to meet customer needs and achieve economies of scale, and consequently, cost and pricing structures (Bantel, 1997). The choice of product line breadth, therefore, depends on a firm's resources that can be used to develop manufacturing capabilities. In some industries, manufacturing a broad product line leads to a higher market share and increased profitability, without increasing production costs (Berry & Cooper, 1999; Kekre & Srinivasan, 1990). Thus, a venture can leverage its manufacturing capabilities over a broader market. Presently, little is known about how the CVs and IVs define the scope of their manufacturing operations.

CVs usually compete in a broadly defined market by serving multiple customer groups with different needs (Hofer & Sandberg, 1987). Therefore, CVs are expected to manufacture a broader product portfolio than IVs. The CVs' access to greater resources usually allows them "to enter the market in a bigger way than IVs" (McDougall et al., 1992, p. 65). In fact, these authors found that CVs have broader product lines than their IV counterparts, which supports Biggadike's (1976) conclusion that aggressive CVs that enter their markets on a large scale are more likely to succeed than their rivals. MacMillan and Day (1987) also found that aggressive CVs–defined as those ventures that serve a large market–are more successful than their competitors.

Given their access to the sponsors' various resources (Table 1), CVs are expected to follow a strategy of aggressive entry by targeting a large market and offering a broad product line (Block & MacMillan, 1993). This expectation is reinforced by Shan, Walker and Kogut's (1994) finding of a positive relationship between areas of research (i.e., diversity of subfields) and innovative outputs such as the number of new products and patents. Clearly, some CVs may find it useful to enter a broad market. However, it should be noted that Shan and colleagues did not consider product breadth nor did they distinguish between CVs and IVs. Given that a single biotechnology product can have multiple applications, some new ventures may not develop different, multiple product lines. Instead, new ventures might focus on developing more applications of the same products, thereby reducing the costs of R&D and manufacturing while deepening their expertise. Also, the dynamism of the biotechnology industry and the uncertainty of its future growth may reduce the payoff from having a broad product line. Some biotechnology firms have been unable to commercialize their products, raising a question about the desirability of having a broad product line. However, the above observations suggest the following hypothesis:

H1: CVs will manufacture broader product lines more than IVs.

The Goals and Competitive Thrust of Manufacturing Operations. Theoretically, new ventures can use their manufacturing capabilities to achieve an array of competitive priorities and objectives. Differences in these goals can lead to significant variations in the competitive priorities assigned to the ventures' manufacturing operations. These priorities typically include new product innovation, quality, or low cost manufacturing, as discussed below.

Product Innovation and Uniqueness. New ventures need to offer highly differentiated products to distinguish themselves from established companies (Bell & McNamara, 1991), especially in the early years of an emerging industry such as biotechnology (Pisano & Wheelwright, 1995). Biotechnology ventures, therefore, can use their manufacturing resources to develop those capabilities that allow them to create and introduce differentiated products and gain market share (Grant, 1995). Researchers stress the importance of new products for achieving high NVP (Keeley & Roure, 1993; Robinson, 1990). Hamilton et al., (1990) also suggest product innovation can contribute significantly and positively to the success of biotechnology companies. Product innovation influences a venture's product designs and content and determines the timing of their introductions (Wheelwright & Clark, 1992), which impacts market success (Carter et al., 1994). Researchers (e.g., Pisano & Wheelwright, 1997) have suggested that product innovation is a key source of high performance among biotechnology companies.

This study expects IVs to focus their resources on developing those manufacturing capabilities that promote specialized products. Instead of blanketing the markets with numerous products, IVs will selectively develop differentiated products with high profit margins. This strategy is compatible with the niche orientation IVs use. This orientation helps them avoid extending themselves beyond their core capabilities while avoiding head-to-head competition with established rivals. Manufacturing differentiated products is also compatible with IVs' founders' and owners'

significant R&D experience. Consequently, these founders emphasize developing innovative products and will make this a priority in their manufacturing operations (McDougall et al., 1992; Shrader & Simon, 1997). The IVs' limited resources will constrain the number of their new products.

CVs are expected to develop more new products than IVs, probably because CVs typically target more customer groups than IVs. Further, as noted earlier, CVs usually have access through their sponsors to the major engineering, marketing, organizational and financial skills required for product innovation. Access to these capabilities can enhance the CVs' ability to develop new products. Therefore:

H2: CVs will emphasize product innovation in their manufacturing strategy more than IVs.

Manufacturing for Product (Technology) Commercialization. Commercializing new products is among the biotechnology industry's most important challenges (Carey et al., 1997). Commercialization centers upon quickly transferring a product (technology) from the venture's R&D lab to the market. Even though the speed of product commercialization in the biotechnology industry depends significantly on the regulations that govern clinical trials, it also depends on having an appropriate organizational structure, maintaining close ties with customers and suppliers, and gaining access to appropriate distribution channels (Burrill & Lee, 1992).

Manufacturing capabilities, in particular, can be used to accelerate the commercialization of the venture's products (Berry & Cooper, 1999), thus generating the revenues and capital necessary for a firm's survival. Voss and Allegra (1998) note that the time to new product approvals has been shortened due to regulatory reforms. Faster approvals will pressure companies to have appropriate manufacturing capabilities in place to quickly introduce their products to the market. Biotechnology companies are also likely to face more intensive competition from rivals who are eager to imitate their products and should have the manufacturing capabilities needed to respond to these challenges. Commercialization depends also on the ventures' success in process innovations and having the manufacturing systems necessary to develop complex designs. Manufacturing capabilities, therefore, can determine the success of the new venture's product innovations (Pisano & Wheelwright, 1995).

Given that CVs have access to their sponsors' established distribution channels, and marketing and production resources (McGrath, MacMillan, & Venkataraman (1995), these firms can gain considerable advantages in commercializing their biotechnology products quickly and efficiently. Much depends, however, on the sponsors' willingness to share these resources and the relatedness of the CVs' products to the sponsors' products. Even when the products are somewhat related, they demand different production, marketing and distribution systems, a factor that has led some corporations to give their CVs greater autonomy in their operations. These observations suggest that both CVs and IVs have advantages of their own. The implications of these advantages for product commercialization activities have not been studied and are not well understood, a gap in the literature this study aims to fill. Other factors might challenge the expectation that CVs will surpass IVs in their emphasis on commercialization. For instance, some corporate sponsors

may have elaborate control systems in place (Burgelman & Sayles, 1986); these controls can slow new ventures' commercialization activities. Thus, some CVs may become slow in commercializing their products.

IVs are expected to emphasize the commercialization of new products as a strategic priority in their manufacturing strategies more than CVs. IVs have to quickly commercialize their products, otherwise they risk failure. The IVs' limited resources do not allow them to sustain significant losses for a long period of time (Shrader & Simon, 1997). Biotechnology IVs frequently depend on the success of their first product to support R&D for other products in their research pipeline. After having spent significant resources over several years developing a single product, IVs will be eager to enter commercialization immediately after FDA approval (BIO, 1998). Consequently, most ventures will have elaborate plans in place prior to FDA approval to speed up commercialization (Edwards, 1997). Strong manufacturing capabilities, therefore, enhance commercialization (Wheelwright & Clark, 1992), and the IVs' manufacturing strategies will reflect this urgency. Therefore:

H3: IVs will emphasize technology commercialization more than CVs.

Quality as a Manufacturing Thrust. Determining the thrust of the manufacturing strategy also requires attention to quality, a factor that can affect a new venture's ability to build market share and gain profitability (Buzzell & Gale, 1987; Carter et al., 1994; Minor et al., 1994). Some research, therefore, has sought to delineate the major dimensions of quality (Hunt, 1992) and relate them to competitive success. This study examines the overall level of emphasis placed on product quality as a key dimension of a biotechnology venture's manufacturing strategy (Carter et al., 1994). If significant differences are found between CVs and IVs in emphasizing product quality, then future research can investigate the variations between the two venture types in particular quality dimensions.

Quality is particularly important among biotechnology companies because of the strict standards imposed by regulatory agencies on the industry (Pisano & Wheelwright, 1995; Voss & Allegra, 1998). The complex designs associated with biotechnology products also make it imperative to achieve high reliability and consistency in manufacturing operations. Minor changes in manufacturing processes invite close scrutiny by regulatory bodies and firms have to conduct additional clinical tests. Failure to meet or maintain high quality standards can lead to the failure of biotechnology ventures. Therefore, the firm should use its resources to achieve the desired levels of quality (Hayes, Wheelwright, & Clark, 1988; Minor et al., 1994). Manufacturing capabilities can also determine a firm's ability to meet customer specifications, make its products easier and safer to use, and increase product durability and reliability. It also enables the venture to maintain high quality standards.

Even though both biotechnology IVs and CVs can benefit significantly from emphasizing high product quality, McDougall et al., (1992) found that information technology IVs emphasized this variable in their manufacturing strategies significantly more than CVs. This finding is consistent with the niche strategy typically followed by many IVs. Offering high quality products usually helps IVs differentiate

their products from those made by their rivals. In reality, IVs have little choice but to stress high product quality to attract customers because these firms usually lack the financial resources or experience needed for broad marketing efforts. Biotechnology IVs can also use their reputation for making high quality products as a major "bargaining chip" in securing the capital needed to fund their ongoing operations. Therefore:

H4: IVs will emphasize a higher quality in their manufacturing strategies than CVs.

Low Cost/Low Price as a Manufacturing Thrust. The growth of the biotechnology industry is explained, in part, by its capacity to offer relatively inexpensive substitutes for existing drugs and chemicals (Burrill & Lee, 1991). Consequently, pricing is important in examining the biotechnology ventures' manufacturing strategies. Burrill and Lee (1992) observe that: "Price competition . . . is a growing market reality. Discounts, promotions, and pure marketing muscle are becoming critical determinants of success" (p. 27). Biotechnology companies have to offer inexpensive substitutes for generic drugs because insurance companies and hospitals are under enormous pressure to lower the costs of health care. In turn, these groups have pressured biotechnology and drug companies to lower their manufacturing costs. Strong manufacturing capabilities can determine the success of this strategy. CVs and IVs are expected to differ significantly in their use of low-cost, low-price manufacturing strategies.

Biotechnology firms face serious price pressures. Though life-saving therapeutics may command premium prices, the ongoing consolidation of the health insurance industry creates significant pricing pressures. In spite of competitive pressures being lower due to patent protection and FDA approval processes, CVs are expected to emphasize low cost orientation more than IVs because of their reliance on a broader product portfolio (Hypothesis 1) and higher levels of product innovation (Hypothesis 2). As CVs have more revenue generating products than IVs with shared overhead costs in manufacturing plants and equipment, they are less likely to charge higher selling prices than IVs that have fewer products on the market. Thus, while pricing strategies depend on the nature of the biotechnology products and given that IVs may offer high quality and highly differentiated products, they are expected to charge higher prices than CVs. This expectation does not, however, suggest a linear relationship between price and quality. With the prevalence of innovative manufacturing systems, biotechnology ventures can offer their diverse customers (doctors, insurance companies, and hospitals) low price, high quality products. Still, comparatively speaking, IVs are expected to charge higher prices for their differentiated products more than CVs. This is especially true because of CVs' access to their sponsors' existing facilities and other resources that can lower their manufacturing costs. CVs' sponsors can also enforce tight cost controls on their firms, a factor that can also lower the CVs' overall costs (Burgelman & Sayles, 1986). Therefore:

H5: CVs will emphasize a lower cost orientation in their manufacturing strategy than IVs.

Competitive Approaches and Sources of Manufacturing. New ventures also need to develop or acquire those manufacturing capabilities needed to transform their chosen strategic thrusts into actual market achievements. These ventures can increase their capital spending to build capabilities internally, vertically integrate, or outsource some of their manufacturing, as discussed below.

Capital Spending. A major challenge facing biotechnology companies today is the lack of adequate manufacturing infrastructure. This deficiency, which may result from the ventures' newness or lack of resources, can handicap the effective execution of manufacturing strategies (Thayer, 1993; 1995). To overcome this deficiency, a biotechnology venture needs to invest in developing an appropriate infrastructure that allows it to achieve efficiency, enjoy smooth operations, quickly commercialize its products, and achieve success. Infrastructure typically embodies a firm's manufacturing facilities, technologies, and human capital. Individually and in combination, these areas can lead to important manufacturing capabilities (Grant, 1995; Wheelwright & Clark, 1992). Capital spending, for example, can spur process innovations that ensure the successful manufacturing of new biotechnology products. Process innovations are important because of the complexity of new biotechnology products and the high quality standards expected by regulatory agencies and customers (Pisano & Wheelwright, 1995).

The CVs' access to their sponsors' resources, broad market scope, and prolific product introductions are expected to encourage greater capital spending than IVs. The need for capital spending becomes greater if CVs differ significantly from their sponsors' traditional businesses, as is happening with the CVs established by pharmaceutical companies (Thayer, 1995). Given the inherent differences in the production technologies and methods between these ventures and their sponsors, heavy capital spending is necessary to build and support the CVs' manufacturing operations. Therefore:

H6: CVs will emphasize capital spending in their manufacturing strategies more than IVs.

Vertical Integration. Biotechnology new ventures also need to consider whether or not to vertically integrate their operations as they seek to develop their manufacturing capabilities (Shan & Song, 1997; Thayer, 1993). Vertical integration can determine a new venture's economies of scale and scope (Buzzell & Gale, 1987), its control over the quality of its products, and the timing of its product introductions.

Despite the potential importance of vertical integration for the development of manufacturing capabilities, it has significant drawbacks. Besides being costly and time consuming, vertical integration can create a dysfunctional bureaucracy that slows effective responses to the venture's market, a factor that may explain the reluctance of biotechnology ventures to pursue this strategy (Burrill & Lee, 1992). Moreover, flexible manufacturing systems have increased a company's capacity to make a variety of products and achieve economies of scope (Galbraith & DeNoble, 1992), without the use of vertical integration. Similarly, the increased modularity of manufacturing processes into transportable "core manufacturing competencies," where a firm can perform some activities internally and contract out other functions, also reduce the venture's need for vertical integration (Galbraith & DeNoble, 1992).

Recent work on alliance profiles of biotechnology firms has investigated the performance effects of horizontal or vertical linkages (Powell et al., 1996; Shan et al., 1994). However, little is known specifically about the extent of vertical integration in biotechnology ventures' manufacturing strategies. Still, theory would suggest that few IVs would pursue this option and would use substitutes for vertical integration. IVs' limited resources will curtail their desire to vertically integrate their operations. Such integration may also increase the founders' administrative responsibilities and slow down the firm's operations. In contrast, CVs are expected to pursue vertical integration more aggressively than IVs. CVs' access to their sponsors' resources and broad scope often encourages the pursuit of this strategy. CV sponsors may have an incentive to vertically integrate the new venture's activity to avoid loss of control over the operations and reduce information leakage about its progress toward new product development or commercialization. Therefore:

H7: CVs will emphasize manufacturing vertical integration more than IVs.

Manufacturing Sourcing. External sources can also help in building a venture's manufacturing capabilities that lead to high NVP (Hayes et al., 1988; Lerner, 1997a). External sources complement and enhance the venture's internal sources. New ventures, therefore, use both external and internal sources. External sources can give biotechnology new ventures raw materials, semi-finished goods, and other items from multiple sources, thereby overcoming these ventures' lack of vertical integration. External sources also quicken the ventures' acquisition of manufacturing capabilities (Lerner, 1997b; Shan & Song, 1997).

Even though both CVs and IVs make use of external sources, CVs are more likely to emphasize external sourcing than IVs because they usually target a larger market and offer a variety of products. Pressured to meet these needs, many CVs may find external sourcing an attractive strategy. The established reputations of corporate sponsors may also simplify the ventures' access to a network of suppliers, a factor that encourages new ventures to outsource their manufacturing and reduce the sponsors' financial burdens. Outsourcing can also reduce production costs. Conversely, IVs must work hard to build a network of suppliers over several years because they must overcome the liabilities of newness and establish trust with their potential suppliers. Therefore:

H8: CVs will emphasize external sources more than IVs.

Manufacturing Strategy and NVP

The proposition that the content of the manufacturing strategy is conducive to superior company performance has been supported in the literature (Vickery et al., 1993). Yet, a review of past research (Minor et al., 1994) shows that only a few studies have been conducted on this issue, and most evidence is derived from samples of established companies (Vickery et al., 1993), which raises a question about their generalizability to new ventures. This study aims to fill this gap in the literature.

The study advances three points about the potential relationship between a biotechnology venture's manufacturing strategy and its performance. First, this strategy is expected to significantly influence the NVP by helping to focus the venture's investment in building or acquiring those manufacturing capabilities that enable it to meet customer needs. Prior research (e.g., Stuart & Abetti, 1987) suggests that new ventures that offer innovative products enjoy high NVP. Further, NVP is improved by having high quality products (Block & MacMillan, 1993). Sourcing can also reduce manufacturing costs, enhance the acquisition of capabilities, and improve NVP.

Second, manufacturing strategy variables can influence new ventures' innovative outputs, especially patenting activities. Patents represent an important milestone in biotechnology new ventures' progress toward creating and commercializing new products. They also enhance the ventures' reputation for innovation and technological leadership, and represent an important asset that is highly valued by the market, investors and venture capitalists. Given these benefits, biotechnology firms have devoted considerable resources to obtaining patents. This study extends the literature by exploring the potential associations between a new venture's manufacturing strategy variables and its patents, aiming to establish if the content of manufacturing strategy variables contribute to the ventures' innovative outputs.

Third, not all manufacturing choices are conducive to superior NVP. This is especially true in the early years of the venture's life cycle, where a firm must invest heavily in developing or acquiring manufacturing capabilities. While these investments are necessary, they may not improve the performance of biotechnology new ventures. Given that Hypotheses 1 through 8 posit that CVs and IVs will pursue different manufacturing strategy variables, it follows logically that manufacturing strategy variables differentially impact the performance of CVs and IVs. That is, each venture type is expected to bundle up its chosen manufacturing strategy variables differently to achieve high performance. This suggests that those manufacturing variables predicted to form the content of CVs' manufacturing strategies are expected to significantly influence their performance. The same logic applies to the variables predicted to constitute the IVs' manufacturing strategies. Therefore:

H9: The association between manufacturing strategy variables with financial and innovative performance will vary significantly between CVs and IVs.

METHOD

Sample and Data

Data from new U.S.-based biotechnology ventures were used to test the study's hypotheses. Although several researchers have examined this important industry (e.g., Hamilton & Singh, 1992; Walker, Kogut, & Shan, 1997; Shan & Song, 1997), they have offered little documentation of the content of the ventures' manufacturing strategies or their implications for NVP. As noted previously, the biotechnology industry was chosen for study because of its importance as a high technology frontier (Carey et al., 1997) that has stimulated the creation of hundreds of new ventures. The

number of U.S. biotechnology companies has grown from 470 (Office of Technology Assessment, 1988) to 1287 in 1997 (BIO, 1998). The industry raised a total of $7.8 billion capital in 1997 for new ventures and strengthened existing research programs (BIO, 1998). With the potential for high profits coupled with high risk and intense competition, the industry has pressured new ventures to build their core competencies to survive and succeed.

The newness of the biotechnology industry itself, raises a question as to the manufacturing capabilities required for achieving superior performance. The industry represents a paradigm shift, which challenges the efficacy of traditional manufacturing systems and practices. Biotechnology companies have to struggle to find which manufacturing choices work and which ones fail. Companies often have to do this while under significant pressures to be more efficient. For example, biotechnology firms including Chiron have incurred the wrath of Wall Street analysts because of ineffective manufacturing practices (Piercey, 1996). Analysts believe that biotechnology companies should strive to reduce their costs of goods sold in order to maximize profit margins and generate cash to sustain on-going R&D expenses.

Data were collected by a mail survey that allowed simultaneous access to many new ventures. This was desirable because public sources did not contain detailed information about some of the key manufacturing strategy variables explored in this study (e.g., cost orientation). Also, most IVs did not publish annual reports, and data on CVs were subsumed within the sponsors' operations. As reported below, wherever possible, secondary data were also collected to verify the survey data.

The development of the survey went through several iterations. The original questionnaire was revised based upon feedback from 17 venture managers (not included in the main study) and a follow-up review by three biotechnology managers. The final survey targeted the ventures' chief executives officers (CEOs) or highest ranking managers, considered the most knowledgeable individuals about the new ventures' operations (Kazanjian & Drazin, 1990).

Company names and addresses were gathered from *New Developments in Biotechnology* (Office of Technology Assessment, 1988), *Bioscan* (1989), *North Carolina Companies in Biotechnology* (several years), and the *Philadelphia Inquirer's* (1991), and three leading newspapers (*Los Angeles Times, New York Times, and Washington Post*), all for the 1989-91 period. Combined, these sources produced 893 names.

To be included in this study, a venture had to meet three criteria. First, to be considered a "new venture," the firm had to be in existence for eight years or less, as done in prior research (Biggadike, 1976; McDougall et al., 1992). Second, the firm had to be headquartered in the U.S., thereby limiting the geographic scope of the research. Third, the venture had to be active in one or more of the major areas that constituted the domain of the biotechnology industry: human diagnostics, pharmaceutic/therapeutic, specialty chemicals, plant agricultural, animal agriculture, food processing, waste management, and equipment/appliances (Burrill & Lee, 1992; Office of Technology Assessment, 1988). The third criterion ensured the inclusion of companies that actually engaged in the development, production and marketing of biotechnology products while excluding venture capitalists and other companies that offered consulting and other services to the industry. Using the

above three criteria, 443 ventures were identified and surveyed. However, 54 questionnaires were undeliverable because the companies moved or ceased to exist. Two mailings conducted one month apart yielded 112 completed responses; a response rate of about 29%.

Responding ventures averaged 4.9 (sd = 2.4) years in age and employed 71 (sd = 57) people. These ventures were located in different parts of the U.S.: 17% in San Francisco, 15% in New York, 15% in Washington, D.C., 10% in Boston, 7% in Los Angeles, 12% in San Diego, and the remaining 23% operated in 29 other regions or states. Finally, 68 (64.15%) were IVs and 38 (36.85%) were CVs.

Three steps were followed to determine the absence of response bias. First, responding companies were compared to non-responding companies on: age ($t = .94$, $p < .41$), employees ($t = 1.07$, $p < .23$), and sales growth ($t = .83$, $p < .44$). Second, the χ^2 test compared responding and non-responding ventures by ownership (CVs vs. IVs). This test was insignificant ($p = .29$), indicating that there was no significant relationship between participation in the study and ownership type (CVs vs. IVs). Finally, using the t-tests, respondents to the first and second mailings were not significantly different in age ($t = .69$, $p < .46$), employees ($t = .73$, $p < .38$), and sales growth ($t = .79$, $p < .31$). Although these analyses indicated that the sample represented its target population, caution is necessary in making generalizations to established companies or ventures located outside the U.S.

Other factors indicated the absence of response bias. For example, most of the surveys were completed with only minimum levels of missing data (surveys with excessive missing data were excluded in calculating the response rate). Also, many respondents provided detailed comments about their company's operations. Further, 70% of the respondents requested summaries of the results, showing their interest in the study. To establish the reliability of the data, the questionnaire was sent to a second senior manager in each responding venture (n = 112). Forty-seven of these managers returned completed responses, which were then matched with replies from the main survey. Correlations indicated significant agreement on each of the manufacturing strategy variables ($p < .01$ or better). Previous research has shown strong convergent validity between perceptual and archival measures of strategic choices (Carter et al., 1994, p. 27).

Measures

The data used in this paper are a part of a larger study on the dynamics of competition in the U.S. biotechnology industry. Measures of the venture's origin, manufacturing strategy, NVP, and control variables were developed.

Venture Origin. Ventures created and run by individual entrepreneurs were classified as "IVs" (n = 68). Ventures owned by established firms were classified as "CVs" (n = 38). This classification was consistent with prior research (e.g., McDougall et al., 1992; Shrader & Simon, 1997). However, six firms were excluded from analysis because of changes in their ownership between the time of their establishment and data collection. Four IVs were later acquired by corporations. At the time of the data analysis, two of these ventures were being "spun off" by their corporate sponsors and their future was uncertain. Two CVs were redesignated "joint ventures" by their sponsors. Given the small number of joint ventures and

other non-classifiable firms in the sample, the six firms were excluded from further consideration. Thus, the analyses reported in this paper are based on 106 of the 112 responding firms.

Manufacturing Strategy. The Appendix presents the measures of the new ventures' manufacturing strategy variables, each of which was measured by a multi-item index.[1] As noted in the Appendix, significant associations were found between archival and survey-based measures for a subset of the responding companies, further supporting the validity of the survey-based measures. Still, caution is necessary because lack of secondary data made it impossible to validate all of the study's measures.

New Venture Performance (NVP). Biggadike (1976) observed a lack of agreement on the domain and measurement of NVP. Yet, the complexity of NVP makes the use of multiple indicators a must (Brush & VanderWerf, 1992; Chandler & Hanks, 1993). Using different measures can more comprehensively gauge NVP, thereby giving a more accurate assessment of a venture's performance. Consequently, this study used three NVP measures, covering a 3-year period each.

Growth in sales (measured as a percentage) has been widely used in past research (Biggadike, 1976; Feeser & Willard, 1990). Brush and VanderWerf (1992) also suggest that growth in sales is among the most commonly used criteria and is considered superior to many other NVP measures (Chandler & Hanks, 1993). Secondary and survey data were then correlated for a subset of the sampled ventures ($r = .71$, $n = 23$), further supporting the validity of the survey measure.

Market share growth, the second objective NVP measure, has also been used in past empirical research (e.g., McDougall et al., 1992) because it reflects a venture's ability to build market share, which is important for profitability (Buzzell & Gale, 1987). Given the vague boundaries of the emerging biotechnology industry (Grant, 1995), market share data may present an inaccurate measure of NVP. Further, the fact that companies themselves defined market share growth raises the possibility that these firms defined this variable differently, adding noise to the data.

Satisfaction with performance was also measured using a multi-item index (refer Appendix). Executives rated their satisfaction with each item, weighted by that item's importance. The performance index is derived from past research (e.g., Covin & Slevin, 1990; Stuart & Abetti, 1987) and supplements the information gained from the other two objective NVP criteria. Inter-rater agreement on the index was .67 ($n = 47$, $p < .001$) and Cronbach-α was .85. Three additional factors indicated the validity of the NVP index. First, when factor analysis was used, it produced one significant factor, which supported convergent validity of the index. Second, the content validity of the index (i.e., the extent to which the measure adequately reflects the theoretic domain of NVP) was supported by the literature. Third, the correlations of the index with objective performance measures were significant (all at $p < .001$): growth in sales ($r = .64$) and growth in market share ($r = .59$), supporting the criterion validity of the index.

New Venture Innovative Output. To gauge the venture's success in patenting, a three-item scale was used. As reported in the Appendix, this measure correlated significantly with the number of applications for patents ($n = 41$; $p < .01$) and the number of patents obtained by 71 of the responding firms ($p < .001$).

Control Variables. Three variables were used as statistical controls: the venture's age, size, and market scope. Research shows that ventures' age and size may influence their performance (Powell et al., 1996; Shan et al., 1994). The ventures' participation in certain markets varies also by their age and size (Burrill & Lee, 1991). Consequently, both the ventures' age and size were included as controls in the analysis of NVP. Age was measured by the number of years a new venture has been in existence. Size was measured by the number of the venture's full-time employees. The market scope of the venture was used as a third control variable because it might have influenced the choices of many of the venture's manufacturing strategies (Hofer & Sandberg, 1987), such as the number of new products. Market scope was measured by the number of segments pursued by a venture.

ANALYSIS

Hypotheses 1 through 8 were tested using the t-test and discriminant analysis. T-tests initially determined the variations between the CVs and IVs in their manufacturing strategy variables. T-tests were then followed by a two-group discriminant analysis to establish if and where the CVs and IVs differed in their overall manufacturing strategies. After examining the classification matrix, significant discriminant loadings helped to identify manufacturing strategy variables that significantly separated CVs from IVs.

Hypothesis 9 was tested using multiple regression analysis, where the three NVP measures were treated as the "dependent" variables and the manufacturing strategy measures were entered as "predictors." The six regression analyses performed to test H9, a new venture's age, size and market scope were first entered as statistical control variables, followed by the manufacturing strategy variables.

To examine the associations between the content of manufacturing strategy variables and patents, regression analysis was used. Initially, two separate regressions (one for the IVs and the other for the CVs) were attempted, following the procedure just described for financial performance. The dependent variable in both analyses was the company's self-reported "emphasis on patenting."

RESULTS

Testing H1 Through H8: The Content of Manufacturing Strategies

Table 2 displays the mean scores for CVs and IVs. The t-tests revealed that CVs were significantly younger and larger than IVs (both at $p < .05$). CVs, however, pursued more broadly defined markets than IVs ($p < .01$). The CVs emphasized the following variables significantly more than IVs: product breadth, low cost, capital spending, vertical integration, and external sourcing. IVs exceeded CVs in product innovation and commercialization. The two venture types did not vary significantly in quality.

Repeated t-tests ignored the interrelationships among the venture's manufacturing strategy variables (Hair et al., 1992) and, therefore, a discriminant analysis was performed. Before conducting this analysis, all manufacturing strategy variables

TABLE 2
T-tests of Manufacturing Strategies and Performance: Independent vs. Corporate Ventures

	Scale		Origin		
Variables	*# Items*	α	*Independent (IV)*	*Corporate (CV)*	*t-value*
Manufacturing Strategy					
(a) manufacturing scope:					
Product Line Breadth	3	.72	2.61	3.68	−2.01*
(b) manufacturing thrust:					
Quality	3	.71	3.41	2.98	1.02
Product innovation	3	.74	3.21	2.09	2.97**
Commercialization	2	.67	3.41	2.31	2.11*
Low Cost	3	.67	1.90	3.44	−3.02**
(c) manufacturing sourcing:					
Capital Spending (internal)	3	.73	2.21	3.46	−2.11*
Vertical Integration	3	.73	1.63	3.51	−2.16**
External Sourcing	4	.70	2.25	3.66	−1.99*
General Characteristics					
Age (years)			5.82	3.31	2.09*
Size (employees)			63.12	88.09	−2.17*
Market Scope			1.11	3.53	−3.31**

Internal consistency for the 2-item scale was measured using simple r.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

were standardized (mean = 0; sd = 1) because the measures had different scales. CVs and IVs were then coded 0 and 1, respectively; therefore, a positive sign showed that IVs significantly surpassed CVs on a given variable and vice versa. A venture's age, size and market scope were also included in the discriminant analysis.

Following Hair et al. (1992), discriminant loadings with an absolute value of .30 or above were significant. Loadings, which showed the contribution of a variable to a multivariate set, were more stable than simple coefficients and were therefore emphasized in interpreting the data in Table 2. The analysis yielded one significant function (canonical correlation = .81, Wilks' $\lambda = .21$) that correctly classified 83.3% of the ventures. This ratio exceeded the value of Press' Q of 43.01 ($p < .001$), indicating that the discriminant function successfully separated the CVs from the IVs. The classification matrix appears in Table 3.

The results from discriminant analysis (Table 4) were consistent with the t-test results presented earlier, with the exception of vertical integration. Nine of the eleven variables included in the analysis were significant (with absolute loadings of .30 or higher). Six of the nine significant variables were manufacturing strategy-related, of which the product line breadth contributed the most to the discriminant function (i.e., it had the largest loading). It was followed by (in a descending order): commercialization, product innovation, capital spending, low cost, and external sourcing. Emphasis on quality and vertical integration were not significant. Though not statistically significant in the discriminant analysis, t-test results (Table 2) show that CVs stressed vertical integration in manufacturing strategies more than IVs (t-

TABLE 3
Discriminant Analysis of Technology Strategy Variables: Independent vs. Corporate Ventures

Variables	*Expected Sign*[a]	*Coefficient (weights)*	*Loadings (structure correlation)*
Manufacturing Strategy			
(a) manufacturing scope:			
Product Line Breadth	−	−.76	−.74
(b) manufacturing thrust:			
Quality	+	.37	.21
Product innovation	−	−.62	−.59
Commercialization	+	.66	.66
Low Cost-Low Price	−	−.55	−.43
(c) sources of mnfg. capabilities:			
Capital Spending	−	−.59	−.57
Vertical integration	−	−.26	−.17
External Sourcing	−	−.32	−.43
General Characteristics			
Age[b]	+	.46	.33
Size[b]	−	−.31	−.35
Market Scope[b]	−	−.42	−.36

[a] Independent ventures = 1 (n = 68) and corporate ventures = 0 (n = 38).
[b] Control variables.

value = −2.16, $p < .01$). Finally, CVs were significantly larger and had a significantly broader market scope than IVs. However, the IVs were significantly older than CVs.

Testing H9: The Correlates of IVs' versus CVs' Performance

Biotechnology IVs and CVs reported 19.79% and 10.02% growth in sales, respectively ($t = 4.11$, $p < .001$). IVs and CVs also had scores of 3.45 and 2.69, respectively, on the NVP index ($t = 2.27$, $p < .05$). However, with scores of 3.01% and 3.16%, respectively, IVs and CVs did not differ significantly in market share growth.

To test H9, three separate regression analyses were performed for the IVs and CVs, for a total of six runs. In these analyses, market share growth, sales growth, and an overall performance index were treated as the "dependent" variables. In each analysis, the study's control variables (age, size and market scope) were first entered, followed by the manufacturing strategy variables, as reported in Table 5.

TABLE 4
Discriminant Analysis: Cross-Classification Matrix

	Venture Type	
Venture Type	*Independent*	*Corporate*
Independent	54	7
Corporate	14	31
% Correctly Classified = 83.3		

The analyses for the IVs were significant, explaining between 17 and 27% of variance in NVP. Quality and commercialization were positively and significantly associated with the IVs' three performance measures. Product innovation was positively associated with both sales growth and market share growth. Vertical integration and external sourcing, however, were negatively and significantly associated with the three measures of the IVs' performance. Further, the IVs' product line breadth, low cost, capital spending, age, size, and market scope were not significant in the three regressions.

The regressions for the CVs were also significant, explaining between 19% and 23% of variance in the performance measures. Product line breadth was positively associated with all three NVP measures. Low cost manufacturing orientation and external sourcing were positively associated with both market share growth and the performance index. Commercialization and high quality were positively associated with the overall performance index. However, both capital spending and vertical integration were negatively associated with the CVs' three performance measures, while product innovation was not significant in any of three regression equations. Finally, as the data in Table 5 show, the CVs' age and size were significantly and positively associated with the three NVP measures, whereas the CVs' market scope was significantly and positively associated only with sales growth.

The Results for Patents

The regression results for patenting appear in Table 6, where the patenting index was regressed on manufacturing strategy variables after introducing the statistical control variables. Separate analyses were performed for CVs and IVs. As Table 6 shows, the regressions explained 11% and 7% of the variance in the patenting index. The regression was significant for IVs but insignificant for CVs. Also, among IVs, product line breadth was positively and significantly associated with patenting, but sourcing was negatively associated with this variable. IVs' age (one of the control variables) was also positively associated with the patenting index. Though the equation for CVs was not significant, sourcing and company age had positive and significant associations with patenting.[2]

DISCUSSION

The results contribute to our understanding of the role of manufacturing strategy in determining the success of young, high technology firms. Despite the progress made in studying the overall competitive strategies of new ventures (Carter et al., 1994), little attention has been given to the role of manufacturing in determining the success and failure of these young companies (Galbraith & DeNoble, 1992). The results clarify some of the differences between the profiles of the CVs and IVs in the biotechnology industry. Even though researchers have looked into particular strategic choices (e.g., alliances) that determine biotechnology companies' performance (Powell et al., 1996; Liebeskind et al., 1996), they have not analyzed the differences in manufacturing strategies within an emerging high technology industry. Using data from biotechnology new ventures, this study extends the literature by showing that: CVs and IVs emphasize significantly different manufacturing strategy

TABLE 5
Manufacturing Strategy of Independent vs. Corporate Venture Performance: Regression Results

	Independent (n = 68)			*Corporate (n = 38)*		
Variables	*Sales Growth*	*Share Growth*	*Performance Index*	*Sales Growth*	*Share Growth*	*Performance Index*
Intercept	1.47	.87	.91	1.13	1.61*	.87
Age	.06	.05	.03	.21*	.19*	.22*
Size	.08	.03	.07	.19*	.19*	.23*
Market scope	.11	.07	.05	.19*	.10	.01
Manufacturing Scope						
Line Breadth	−.11	−.07	−.05	.38**	.29*	.23*
Manufacturing Thrust						
Quality	.66***	.47**	.22*	.11	.13	.21*
Product Innovation	.29*	.22*	.15	.08	.09	.12
Commercialization	.42***	.25*	.37**	−.07	−.14	.29*
Low Cost-Low Price	.07	.13	.03	.09	.36**	.25*
Manufacturing Sourcing						
Capital Spending	.11	−.01	−.02	−.29*	−.26*	−.37**
Vertical Integration	−.27*	−.21*	−.37**	−.23*	−.22*	−.22*
Sourcing	−.28**	−.39**	−.24*	.14	.34**	.23*
R^2 =	.17	.24	.27	.19	.21	.23
F =	4.03*	4.11**	5.94**	3.41*	3.08*	4.03**

* $p < .05$.
** $p < .01$.
*** $p < .001$.

TABLE 6
Manufacturing Strategy of Independent vs. Corporate Ventures' Patenting: Regression Results

	Emphasis on Patenting Index		*Actual Patent Count*
	IVs	*CVs*	
Intercept	1.26	−.57	1.04
Age	.19*	.24*	.28*
Size	.13	.11	.23*
Market scope	.07	.02	.10
Venture origin (IVs = 1)			.37**
Manufacturing Scope			
Line Breadth	.23*	.12	.09
Manufacturing Thrust			
Quality	.04	.03	.01
Product Innovation	.15	.07	.03
Commercialization	.09	.14	.15
Low Cost-Low Price	.07	−.03	−.07
Manufacturing Sourcing			
Capital Spending	−.12	.04	−.05
Vertical Integration	.13	−.11	−.01
Sourcing	−.29*	.31*	.21*
R^2 =	.11	.07	.11
F =	3.11*	1.08	2.91*

* $p < .05$.
** $p < .01$.
*** $p < .001$.

variables; manufacturing strategy variables significantly influence NVP; and significantly influence the performance of CVs and IVs. This section develops these three points.

The Content of Biotechnology CVs' versus IVs' Manufacturing Strategies

The results supported six of the study's eight hypotheses on the content of new ventures' manufacturing strategies. As predicted, CVs had significantly higher scores than IVs in: manufacturing product line breadth (H1), product innovation (H2), low cost manufacturing orientation (H5), capital spending (H6), and external sourcing (H8). Conversely, but still consistent with predictions, IVs emphasized commercialization (H3) significantly more than CVs.

Even though the above findings are consistent with expectations, the results on product line breadth and the low cost manufacturing orientation contradict the results reported by other researchers. For example, the results on product line breadth are in conflict with those reported by Shrader and Simon (1997), who found no significant differences between the CVs' and IVs' emphasis on market breadth. These different findings might reflect differences in the samples and the measures used.

As noted earlier, viewed in the context of the biotechnology industry, a broad product line may not be desirable. A broad product line would require significant additional R&D expenditures to maintain and support these products. Each new

drug requires an investment of about $200–$350 million over a time frame of seven to twelve years (BIO, 1998). The capital investment needed to support a broad product line is more likely to come from a stable CV (with established pharmaceutical partners) than from an IV. For example, Amgen Inc. (the largest independent biotechnology company in the U.S.) founded in 1981 launched its first product (Epogen) in 1989, its second (Neupogen) in 1996, and its third (Infergen) in 1997. Amgen conforms to the general trend that biotechnology ventures support new product additions by generating cash from a single blockbuster product (Edwards, 1998). Biotechnology companies appear to broaden their portfolio only after the success of their narrow product strategy.

A strategy of a single-product focus can be risky. The failure and eventual takeover of Cetus Inc., for example, has been blamed on a futile focus on interleukins when in 1990 the FDA refused approval of its single product prototype (Liebeskind et al., 1996). Overall, though propositions of 'narrow' versus 'broad' product portfolios may have intellectual appeal, many biotechnology new ventures are constrained by the resources available to develop a broad product portfolio. Obviously, market and product line breadth are not the same thing; a venture can compete in a broad market by offering a wide variety of applications with the same product line (Grant, 1995). Future studies, therefore, are necessary to clarify the extent of the differences, if any, between the CVs and IVs in the breadth of their markets and product lines.

The fact that CVs have a significantly higher score on the low cost manufacturing orientation (H6) also contradicts some previous results (e.g., Shrader & Simon, 1997). In the current study, CVs have a significantly higher score than IVs on low cost manufacturing, possibly because the CVs' sponsors (mostly pharmaceutical and drug companies) are also under pressure to reduce costs. This pressure might have filtered down to the CVs, highlighting the importance of reducing manufacturing costs as a strategic priority. CVs might have followed this strategy to convince their sponsors of their value-added. Pharmaceutical and drug companies have created or acquired CVs as a means of developing and marketing drugs inexpensively (Burrill & Lee, 1992). Thus, both the parent corporations and their CVs have an incentive to lower the cost of manufacturing activities.

Another explanation to consider is the IVs' and CVs' financing practices. Negative earnings are generally not well tolerated by *Wall Street* investors. In particular, reactions to lower than expected earnings reported by established pharmaceutical corporations that typically tend to be large-capitalization stocks are harsher than reactions to independent ventures that are small. Pharmaceutical firms have a large market capitalization and are traded for high price-earnings multiples. Therefore, a relatively small change in earnings would be reflected as a large drop in stock price. Because these corporations have several products on the market, investors follow earnings' news closely. Hence, these firms attempt to streamline production costs to improve profit margins (Piercey, 1996). On the other hand, stock valuation for independent ventures is based largely on future product potential than on existing earnings, which reduces the need for a low cost orientation. For example, Merck Inc., a large pharmaceutical firm with a market capitalization of nearly $150 billion can be more volatile in comparison to a $83 billion capitalization of all independent biotechnology ventures in the U.S. (BIO, 1998). Emphasis on cost savings and improved profit margins, therefore, is stronger in pharmaceutical firms and CVs.

One area where CVs and IVs do *not* differ significantly in their manufacturing strategies (Tables 1 & 2) is the emphasis on quality (H4). The results on this variable, which are counter to expectations, deserve comment. Specifically, the finding that IVs do not have a significantly higher quality score than CVs suggests that both venture types have understood the strategic importance of quality for competitive success and have used this variable in their manufacturing operations. Still, the results contradict McDougall and colleagues (1992) who found that information technology IVs significantly exceeded their CV counterparts in emphasizing quality. Although the differences in the two studies' findings may stem from the samples and measures used, the present results may be industry-specific because the stringent FDA approval process may define biotechnology product standards. High quality is expected from all new biotechnology ventures because the risk of product failure because of inadequate quality does not only cause product failure but also threatens firm survival. Thus, CVs and IVs must be high quality producers. Future research using data from other industries, therefore, can help to determine if significant differences exist in the relative emphasis CVs and IVs place on quality. A clearer picture of these differences might emerge, moreover, from using a multidimensional measure of quality and relating these dimensions to NVP.

Next, the t-test results suggest that CVs and IVs differ significantly in their emphasis on manufacturing vertical integration. These results might be inconclusive because the discriminant analyses for vertical integration were not significant, a finding that is consistent with Burrill and Lee (1992) who observed that vertical integration is not a high priority in the biotechnology industry. Both CVs and IVs might have already found alternative ways (e.g., outsourcing) to acquire their capabilities without vertically integrating their manufacturing (Carey et al., 1997; Lerner, 1997a,b). Given the cross-sectional nature of the current database, one cannot conclusively identify the reasons for or against the ventures' vertical integration. By tracking their strategic choices over time significant differences between the CVs and IVs in backward and forward manufacturing integration can be better understood.

Overall, the results show that biotechnology CVs and IVs pursue different manufacturing strategies, reflecting different ways to reach customers and achieve high performance. Not all of the manufacturing choices made by biotechnology CVs and IVs are associated with high NVP. Consequently, the study sought to identify those manufacturing variables that are significantly associated with NVP, as discussed next.

Manufacturing Strategies and NVP (Hypothesis 9)

The study also examined the associations between the manufacturing strategy variables and measures of the financial and innovative performance of new ventures. This section reviews the study's findings in this regard.

New Venture Performance. The results support H9 by revealing that the performance of biotechnology CVs and IVs usually benefit from different sets of manufacturing strategy variables. Quality and commercialization are positively associated with the IVs' three NVP measures. Product innovation is also positively associated with growth in sales and market share. Conversely, the performance of the IVs is

negatively associated with external sourcing and vertical integration. However, Table 5 reveals that the CVs' performance is enhanced by an emphasis on having a broad product line. CVs' share growth and overall performance index are also positively associated with external sourcing and a low cost orientation.

When the results for the CVs and IVs are compared, six trends are noted in the data. First, whereas a broad product line is conducive to high performance among CVs, the same variable is negatively (but insignificantly) associated with the three measures of CVs' performance. IVs, therefore, do not appear to gain a performance advantage from a broad product line, which supports H2. Resource constraints often compel IVs to pursue focused manufacturing operations.

Second, IVs also benefit from emphasizing quality more than CVs (Table 5), even though the two venture types do not vary significantly in their quality scores (Table 3). Thus, while CVs and IVs may stress quality about equally, they may do so differently. Differences in implementing quality, therefore, may explain the variations noted in the association of quality with NVP.

Third, commercialization and a strong focus on product innovation are more important for the IVs' than the CVs' successful performance. One reason is the IVs' limited resources and narrow market (and product) focus, which pressure these companies to excel through innovation and rapid commercialization.

Fourth, the positive and significant signs found between manufacturing external sourcing and the CVs' market share growth and the overall NVP index is contrasted with the negative signs found with the IVs' three performance measures. Sometimes, external sourcing negatively impacts the IVs' performance because of the rising costs of coordinating the inputs obtained from different suppliers. IVs have to integrate externally acquired capabilities with their internal skills, which can depress short-term performance (Zahra & Das, 1993).

Fifth, the results indicate that capital spending has negative signs with the three NVP measures of both venture types, but it is significant only among CVs. These negative signs are consistent with Marshall and Buzzell (1990) who reported a significant negative association between capital spending and performance. Thus, while capital spending is important for having an up-to-date manufacturing infrastructure, it may be a necessary–but insufficient–condition to gain superior short-term NVP because the payoff from capital spending may take years to materialize. Further, the contribution of capital spending to NVP may be indirect by influencing those manufacturing capabilities that enable the venture to exploit growth opportunities in the industry. Longitudinal analyses are necessary to establish these long-term benefits from capital spending among new ventures.

Sixth, vertical integration is also negatively associated with the performance of both CVs and IVs, probably because the heavy costs associated with this option can reduce NVP (Buzzell & Gale, 1987). Vertical integration can also slow down a new venture's operations and weaken its ability to achieve profitability. The CVs and IVs, therefore, should weigh this short-term negative effect against the long-term gains they may derive from this option; it may take years for a new venture to gain the benefits of vertical integration.

Virtually all manufacturing sourcing variables have negative coefficients in the regression equations (Table 5). These results may be sample-specific. Still, manufacturing sourcing variables may be less important than other factors (e.g., marketing) because of recent growth in contract research organizations (CROs) that perform

batch processing, prototype development, or initial testing of products. CROs, present in a research park or a proximate region, form clusters of high technology firms that allow CVs and IVs to outsource more of their non-core manufacturing activities than previously possible (Thuermer, 1997).

To summarize, the results show that the overlap between those manufacturing strategy variables that lead to high NVP among CVs and IVs is limited. IVs and CVs benefit from using different manufacturing strategies. This study does not identify how new ventures implement these strategies and future research should closely examine this issue.

New Venture Innovative Outputs (Patenting). The results also show that manufacturing strategy variables have a modest impact on a venture's self reported emphasis on patenting, and that IVs benefit more than CVs from the contributions manufacturing strategy variables make in this regard. Perhaps, as widely believed in the literature, the IVs' owners have to work hard at making every thing count toward achieving superior financial performance. IVs' owners prior R&D experience may also help in transforming their operations into a source of innovation and patenting. If this were true, then these owners would be more attentive to finding ways where they can cultivate the fruits of their manufacturing investments by gaining more patents. Further, as IVs gain experience, they focus more on patenting, as indicated by the positive correlations noted between IVs' age and patenting (Table 6). Still, the results might also reflect the long discovery cycle that characterizes biotechnology R&D activities where several years elapse between discovery and clinical trials.

Another variable of interest in terms of patenting is the firms' use of external sources. Sourcing is positively associated with emphasis on patenting probably because external sourcing can expose the firm to different sources of innovation, which can enhance patenting. The results, however, show that the associations between sourcing and patenting vary between CVs and IVs; sourcing has a negative effect among the IVs but has a positive effect on patenting among CVs. It is possible that CVs and IVs use different sourcing strategies, which would lead to variations in the effect of sourcing on patenting. Researchers need to corroborate this finding and identify the sources of the variations in the effect of external sourcing on patenting.

A final variable of interest relative to patenting is product line breadth, which was positively and significantly associated with patenting among IVs. The breadth of the IVs' product application can stimulate patenting. IVs' owners are also pressured to protect their discoveries by adopting a strategy of patenting to capitalize on the applications they may develop in their operations. Also, patent royalties may generate the funds needed for future R&D. CVs may not feel the same types of pressures because of their access to their sponsors' resources.

In summary, the results suggest that the content of manufacturing strategy variables have a modest effect on new ventures' emphasis on patenting or their actual number of patents. Where there is a significant effect, IVs appear to benefit more than CVs in patenting from the contributions of their manufacturing strategy variables. The next section of the paper will highlight the implications of the results on performance and content of new ventures' manufacturing strategies for managerial action and future research.

Limitations and Future Research Directions

Besides the issues outlined above, the results indicate a need for more empirical research to document changes in the priorities new ventures place on manufacturing strategy variables over time. As biotechnology companies grow, the strategic issues they face will undoubtedly change (Grant, 1995), requiring major changes in these ventures' manufacturing priorities. Theory building efforts can benefit from incorporating these evolutionary changes in new ventures' competitive priorities and determine any corresponding changes in their manufacturing strategies (Hamilton et al., 1990; Minor et al., 1994).

Replications with data from other industries are also necessary to validate our findings and establish their generalizability. One drawback of this study is its exclusive focus on the biotech industry. Management literature points to the importance of industry structure in determining a company's strategic choices. Therefore, it would not be surprising to find industry-related differences between IVs and CVs in their manufacturing strategies. For instance, in our study we found no difference between IV and CV emphasis on quality. Future research can extend our findings by including data drawn from multiple industries, thereby allowing scholars to generalize their results to a larger population. As noted earlier, our results may also reflect the present stage of the biotechnology industry's life cycle or the stage of commercialization of its products and technologies. Longitudinal research designs are necessary to document the changes in new ventures' manufacturing strategies over time. These analyses can also overcome our study's cross-sectional designs that preclude making causal inferences about the relationship between a venture's manufacturing strategy and NVP. Longitudinal analyses are desirable also to understand the effect of subsequent changes in the ventures' manufacturing strategies on any changes that may occur in NVP. Such longitudinal studies can also overcome survivor bias, which is one of the limitations of this study. Finally, the complexity of the biotechnology industry also suggests that a larger sample might better capture new ventures' strategies.

Future studies should also examine the patterns of ownership in the biotechnology industry and how they may affect manufacturing strategy choices. More and more new ventures are entering into strategic manufacturing alliances. Established companies are also active in securing partial equity positions in new ventures (Burrill & Lee, 1992). These and similar changes in the ventures' ownership patterns can affect their manufacturing strategy choices, especially external sourcing and vertical integration. Future research should determine the effect of the content of CVs' and IVs' manufacturing strategies on the sources of biotechnology firms' competitive advantages. These sources might include the ventures' ability to achieve speedy market commercialization, develop a reputation for market responsiveness, build a reputation for process and product innovation, and obtain patents that are highly valued as significant technological developments. By clarifying how the content of CVs' and IVs' manufacturing strategies may affect these variables, researchers can also improve our understanding of the contributions of manufacturing to the survival and success of high technology new ventures.

A related issue that deserves attention in future research is the potential differences that might exist in the CVs and IVs' goals, structures and resources, and how these variables influence these ventures' strategic choices, including manufacturing

strategies. As noted earlier, wide variations exist in how IVs and CVs are organized, financed and managed. This study and previous research have not captured these differences and how they influence a firm's manufacturing strategy. Researchers can enrich the literature by exploring these relationships.

This study contributes to theory testing and building in several ways. Using the resource-based theory, the study offers a test of some potential of variations among independent and corporate-owned biotechnology new ventures. Little is currently known about the major sources of differences between these different types of firms and how these differences may affect their strategic choices and, ultimately, performance. Also, the study provides some insights into the importance of manufacturing strategy variables for NVP in a young industry. These results support the strategic choice approach which posits that those companies that pursue effective strategies will gain higher performance than those firms that fail use such strategies. The results also add to our knowledge of the differences between CVs and IVs in manufacturing strategies. This information can be useful for building and revising theories about the sources of superior performance in the biotechnology industry. Hamilton and Singh (1992) highlight the need to develop theories of organizational evolution in technology-based industries such as biotechnology. As knowledge of the types and sources of differences that exist among CVs and IVs accumulates, better theories of determinants of NVP can also be developed.

High technology ventures contribute greatly to the growth of the U.S. economy. Understandably, researchers have devoted considerable attention to examining the strategies that determine the success or failure of these ventures. The current results extend the literature by showing that manufacturing strategy can enrich new ventures' performance, and that independent and corporate-sponsored ventures follow different manufacturing strategies in pursuit of superior performance.

NOTES

1. The correlations between the two sets of managerial responses to these measures averaged .62 ($p < .001$) consistent with the literature (McDougall et al., 1994).

2. We also regressed the number of actual patients obtained by 71 of the firms in the sample. Using dummy regression (IVs = 1 and CVs = 0), the analysis was significant and had an adjusted R^2 of .11 ($p < .01$). The following variables were significantly associated with a venture's number of patents: company age, company size, IV origin, and sourcing. Of the significant variables, sourcing was the only manufacturing strategy-related.

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APPENDIX

This Appendix presents the study's measures of manufacturing strategy variables and new venture performance.

Manufacturing strategy variables. Respondents provided data, reflecting their venture's actual, rather than planned (or desired), activities over the immediate past three years. Multi-item indexes were developed to measure these activities. In each case, the average response score was used in the analysis. Average scores were calculated by summing item scores and then dividing the total by the number of items. All items followed a 5-point response rate, and the phrase "This Company . . .," as follows:

1	2	3	4	5	NA
Very True	Untrue	Neutral	True	Very True	Not Applicable

This Company

Product line breadth	
. . . offers a broad line of products.	1 2 3 4 5 NA
. . . produces & markets many products.	1 2 3 4 5 NA
. . . offers a wide variety of products in its product line.	1 2 3 4 5 NA
Quality	
. . . stresses being a high quality producer.	1 2 3 4 5 NA
. . . competes primarily on the basis of quality.	1 2 3 4 5 NA
Product Innovation	
. . . introduces many new products to the market.	1 2 3 4 5 NA
. . . introduces more new products than competitors.	1 2 3 4 5 NA
. . . is well known for introducing breakthrough-type products.	1 2 3 4 5 NA
Commercialization	
. . . has reduced the time between the development and market introduction of new products significantly.	1 2 3 4 5 NA
. . . introduces products to the market faster than the competition.	1 2 3 4 5 NA
Low Cost/Low Price	
. . . pursues market leadership by being a low cost producer.	1 2 3 4 5 NA
. . . charges higher prices than those of competitors (reverse scored).	1 2 3 4 5 NA
. . . stresses charging the lowest prices in the market.	1 2 3 4 5 NA
Capital Spending	
. . . emphasizes capital spending more than major competitors.	1 2 3 4 5 NA
. . . spends more than the industry average on new plants.	1 2 3 4 5 NA
. . . has first rate manufacturing facilities.	1 2 3 4 5 NA
Vertical Integration	
. . . distributes products directly to customers.	1 2 3 4 5 NA
. . . produces most of its raw materials internally.	1 2 3 4 5 NA
. . . is vertically integrated	1 2 3 4 5 NA
Sourcing	
. . . has many suppliers.	1 2 3 4 5 NA
. . . develops its products internally (reverse).	1 2 3 4 5 NA
. . . contracts out a major portion of its R&D activities.	1 2 3 4 5 NA

(*continued*)

APPENDIX
(*Continued*)

New Venture Performance (NVP). Executives provided data for a 3-year period on growth in sales and growth in market share. These measures are explained in the text. Because data were gathered through the survey—a common practice in the literature—validation of the performance figures was necessary. Thus, data were collected for a subset of companies, using annual reports and trade publications. When annual reports were used, only data on the particular CVs were included. Secondary and survey data were then correlated, as follows: sales growth ($r = .71$, $n = 23$) and market share growth ($r = .66$, $n = 19$).

A third performance measure (6 items, $a = .85$) was developed to gauge managers' perceptions of their new venture's performance. Two evaluations, per item, were used. The first indicated the importance of each item (the "importance" score). The second indicated the extent top managers were satisfied with the unit's performance of each items (the "satisfaction" score). Importance scores were multiplied by their corresponding satisfaction scores. The sum was then divided by 6 (the number of items in the scale).

	How Important is this goal for your company					*How Satisfied are you with the company's achievement of the goal*				
	Unimportant				Very Important	Dissatisfied				Very Satisfied
Return on investment	1	2	3	4	5	1	2	3	4	5
Return on equity	1	2	3	4	5	1	2	3	4	5
Sales growth	1	2	3	4	5	1	2	3	4	5
Net profit margin	1	2	3	4	5	1	2	3	4	5
Market share	1	2	3	4	5	1	2	3	4	5
Return on assets	1	2	3	4	5	1	2	3	4	5

New Ventures' Innovative Output: Emphasis on Patenting (3 items, $a = .78$). Pilot interviews indicated that companies were unwilling to provide data on their patenting activities. Hence, a multi-item index measured a venture's emphasis on patenting. The index was then correlated with patent applications or actual counts for a subset of 41 ventures ($r = .53$, $n = 41$, $p < .01$). In addition, the index significantly correlated with the actual number of patents obtained by 71 firms in the sample ($r = .61$, $p < .001$). The patenting measure used in the study was as follows:

1	2	3	4	5	NA
Very True	Untrue	Neutral	True	Very True	Not Applicable

This Company

*. . . holds important patent rights	1	2	3	4	5	NA
*. . . has more patents than its key competitors	1	2	3	4	5	NA
*. . . has increased its patenting efforts over the past 3 years	1	2	3	4	5	NA

Pilot interviews indicated that companies were unwilling to provide data on their patenting activities. Hence, a multi-item index measured a venture's emphasis on patenting. The index was then correlated with patent applications or actual counts for a subset of 41 ventures ($r = .53$, $n = 41$, $p < .01$).