IJMR
September 2001

Innovation management in context: environment, organization and performance

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Several decades of research into innovation management have failed to provide clear and consistent findings or coherent advice to managers. In this paper, I argue that this is because innovation management 'best practice' is contingent on a range of factors, and that we need better characterizations of the technological and market contingencies which affect the opportunity for, and constraints on, innovation. I review research on innovation together with relevant studies from organizational behaviour and strategic management, and develop a model which may help to guide future innovation research on the relationships between environmental contingencies, organization configurations and performance. I identify uncertainty and complexity as the key environmental contingencies that influence organizational structure and management processes for innovation.

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How Does Innovation Affect Organizational Performance?

There is a gap between managers' perceptions of, and the reality of, criteria for successful innovation (Cooper and Kleinschmidt 1993). For example, one study found that only 7% were aware of the main findings of research, and only half of these had attempted to apply the results of the research (Barclay 1992). Moreover, the innovation processes used by firms have changed very little although the business environment has changed significantly (Wind and Mahajan 1997).

Conceptually, it is not difficult to identify the contribution innovation can make to competitiveness (Table 1). However, it is more difficult to establish a strong empirical relationship between innovation and performance. For example, at firm level, the relationships between innovation inputs and outputs is much weaker than at industry level. The weakness in the relationship may be caused by methodological shortcomings or by the random unpredictability of innovation.

There are two approaches to measuring innovation at the level of the firm. One utilizes indicators available in the public domain, such

Table 1. Innovation and competitive advantage

Type of innovation	Competitive advantage
Disruptive	Re-writing the rules of the competitive game, creating a new 'value proposition'
Radical	Offering a highly novel or unique product or service, premium pricing
Complex	Difficulty of learning about the technology keeps entry barriers high
Continuous incremental innovation	Continuous movement of the cost/performance frontier

Source: Adapted from J. Tidd, J. Bessant and K. Pavitt (2001) *Managing Innovation: Integrating Technological, Market and Organizational Change*, 2nd edition. Chichester: Wiley.

as R&D expenditure, number of patents and new product announcements. The other uses survey instruments to capture a broader range of indicators such as the proportion of technical, design or research personnel, and proportion of sales or profits accounted for by products launched in the past three or five years. Table 2 lists the main measures used, their main strengths and weaknesses, and an indication of possible levels of comparison. The main conclusion from this is that there is no single best measure of innovation. Some indicators work well for certain sectors, for example, R&D for large chemical and electrical firms, and others work well for certain fields of technology, for example, patents for mechanical technologies or product announcements for software and services.

Measuring innovation inputs and outputs is difficult, but establishing the relationship between these measures of innovation and firm performance is more problematic. Two broad classes of performance measure are used. The first is concerned with accounting and financial performance, for example, profitability, return on investment (ROI) and share price. The second with market performance, usually share or growth.

Many traditional accounting and financial indicators concentrate on short-term measures of performance, and therefore may undervalue innovation. Kay (1993) argues that there can be no long-term rationale for a firm that does not add value, as value added is essentially the difference between the market value of outputs and the cost of inputs (including capital). Walker (1979) uses a R&D/value added ratio, and points out that identical R&D expenditures in different industries do not necessarily indicate identical innovation activity. Budworth (1993) proposes a similar 'innovation ratio' based on the ratio of cash outlay to cash return, so that when, or if, a company with a portfolio of different products reaches steady state, the innovation ratio will be equivalent to the ratio of innovation spend to value added. On this basis, it is possible to calculate an innovation ratio for specific sectors and companies. For example, Budworth calculates the ratio for the UK mechanical engineering sectors to be around 14%. As the value added for that sector is some 50% of turnover, this suggests that at least 7% of revenue should be devoted to innovation in order to sustain intangible assets. Conceptually, this ratio is similar to the depreciation charge for tangible assets.

Geroski (1994) shows that the profit margin of innovators – using matched data from the SPRU database and company accounts – is higher than non-innovators, controlling for other influences. However, the effect is rather small, suggesting that benefits may have been captured by users. Innovating firms are also more protected from cyclical downturns. Scherer and Revenscraig (1982) looked at the relationship between profitability and lagged indicators of capital input, marketing expenses and R&D. The main conclusion was a rate of return to R&D of about 33%, with an average lag of about five years. Process R&D had four times the rate of return of product R&D but was more risky with a more variable return.

Table 2. Strengths and weaknesses of measures of innovation

Measure	Strengths	Weaknesses	Possible levels of comparison			
			Country	Industry	Tech. field	Firm
R&D	• regular and recognized data on main source of technology	• lacks detail (technical fields) • strongly underestimates small firms, design, production engineering, and software	✓	✓	✘	✓
Patents	• regular detailed and long-term data • compensates weaknesses of R&D statistics	• uneven propensity to patent • misses software (but now patentable in USA)	✓	✓	✓	✓
Significant innovations	• direct measure of output	• measure of significance • cost of collection • misses incremental changes	✘	✓	✘	✓
Innovation surveys	• direct measure of output • comprehensive coverage	• variable definition of innovation • cost	✓	✓	✘	✓
Product announcements	• close to commercialization	• misses in-house process innovations, and incremental product improvements • possible manipulation by marketing and public relations	?	✓	✘	✓
Technical employees	• measures tacit knowledge	• lack of homogeneity of qualifications	✘	✓	✓	✓
Expert judgements	• direct use of expertise	• finding independent experts • judgements beyond expertise	?	✓	✓	✓

✓ = Yes; ✘ = No; ? = Maybe.
Source: Patel (2000) in Tidd (2000).

The use of stock market value as a performance indicator has a major advantage over other financial measures such as profits or ROI, as it is likely to reflect the affect of innovation sooner. The simplest market value model assumes that the market value of the firm is proportional to its physical or tangible capital, and the intangible capital. Pakes (1985) observed a significant (though noisy) effect, and Hall (1993) raises an important worry about whether stock market valuations of innovation are consistent. The valuation of R&D capital collapsed from a value of unity to a quarter over the 1980s, a result that is robust to measurement and specification tests. The view frequently taken is that the Stock Exchange consistently undervalues shares of the firms which spend on R&D because expensed (as opposed to capitalized) R&D reduces earnings per share (EPS) in the year of expenditure, one of the major performance criteria used by analysts (Arnold and Moizer 1984). Some industrialists believe that this approach systematically undervalues long-term R&D and capital expenditure. The fact that there is a weak correlation between company valuations, in terms of the price to earnings (P/E), and expenditure on R&D suggests that the problem of under-valuation is industry specific, if it exists at all. The problem appears to have more to do with a lack of communication between industry and its investors. Countering the view that analysts are short sighted is the fact that analysts in the UK grade the importance of R&D information with 2.32 on a scale of seven (with 1 as the ‘best’) making it the fourth most important with product development third with 2.36 (Pike *et al.* 1993).

Beyond R&D expenditure, research suggests a significant independent effect of patents on the market value of firms. Griliches *et al*. (1991) examined the relationship between patents and the market value of the firm and found that, with the exception of the pharmaceutical industry, changes in market value due to changes in the patent rate were not significant, accounting for only around 1% of the total fluctuations in market value. Product announcements may be a more generic indicator of product innovation. A benefit of using product announcements as a measure of market innovation is that it lends itself to an event-study methodology to link product announcements with the market value of a firm. For example, one study of more than a thousand product announcements in the *Wall Street Journal* found that these had a positive affect on the share price of the originating firm (Chaney *et al.* 1991). The study found that firms introducing new products accrue around 0.75% excess market return over three days, beginning one day before the formal announcement. The average value of each new product announcement was found to be $26m (in 1972 dollars). Of course, the precise return and value of each product announcement depends on the industry sectors: the highest returns were found to be in food, printing, chemicals and pharmaceuticals, computers, photographic equipment and durable goods. The study also found that the average P/E ratio of the firms making new product announcements was almost twice that of the firms which made no new product announcements. This implies that the stock market is valuing the long-term stream of future earnings generated by the innovative firms at a much higher rate than the non-innovators.

Our own research on innovation and financial performance identified relationships between innovation measures such as expenditure on R&D and new product announcements, and performance measures such as value added and market to book value (Tidd 2000; Tidd *et al*. 1996). For example, expenditure on R&D as a proportion of sales (R&D intensity) has a significant positive affect on value added and the number of new product announcements made, which suggests that R&D activities contribute to increasing both the number of new products introduced and their value. Our research also confirms that R&D intensity has a significant positive effect on the market to book value, which supports the findings of previous work (Sciteb/CBI 1991). Using the ratio of new product announcements to absolute R&D as a proxy for research efficiency indicates that the efficiency of research also has a significant positive affect on the market to book value. This suggests that the market also values the *efficiency* of R&D, that is the organization and management of innovation.

The relationship between innovation and market share and growth is less well understood. The PIMS (Profit Impact of Market Strategy) database, established in 1972, includes data on some 3000 business units representing 450 companies. For each business unit, PIMS collects data on market conditions, competitive position and financial and operating performance. Generally, profitability declines as the market evolves over time as product and service differentiation fall, and competition tends to shift to price. Conversely, high rates of market growth are associated with:

(1) high gross margins
(2) high marketing costs
(3) rising productivity
(4) rising value added per employee
(5) rising investment
(6) low or negative case flow. (Buzell and Gale 1987)

The importance of market share varies with industry. Intuition would suggest that share would be most important in capital-intensive manufacturing and production industries, where economies of scale are required. However, PIMS suggests that market share has a much stronger impact on profitability in innovative sectors, that is those industries characterized by high R&D and/or marketing expenditure. For the R&D and marketing-intensive businesses, the ROI of the market leader is on average 26 percentage points higher than the average small-share business. In the manufacturing-intensive businesses, the corresponding difference is only 12 points. This suggests that scale effects are more important in R&D and marketing than in manufacturing. In the short term, high rates of product introduction and high expenditure on R&D are associated with lower profitability and ROI, but both factors are positively related to long-term value enhancement of a business (Clayton and Turner 1998, 2000).

Why Has Research Failed to Produce Innovation Management 'Best Practice'?

Several decades of research on the management of technology and innovation have created many insights into the innovation process, but to date have failed to provide a comprehensive framework to guide innovation research or management practice. Studies of innovation have been based on a broad range of disciplines, including management science, economics, geography, sociology and psychology, and have therefore adopted very different methods, definitions and samples. This diversity of research has limited the accumulation of knowledge regarding innovation management. In addition, most studies have failed to include some measure of performance or success, which makes it difficult to translate much of the research into management prescription (Tidd 2000; Tidd *et al.* 1996). In this paper, I attempt to identify some of the emerging themes of research on innovation management, focusing on the relationships between environment, organization and performance.

Much of the research on the management of innovation has attempted to identify some generic 'best-practice', but most studies have been based on the experience of specific sectors. For example, the dominant models of technology management are derived from the experience of US high-technology firms (Christensen 1997; Pisano 1997), whereas many of the 'rules' for product development are based on research on the practice of Japanese manufacturers of consumer durables, such as electronics or automobiles (Clark and Fujimoto 1991). However, there is unlikely to be 'one best way' to manage and organize innovation, as industries differ in terms of sources of innovation and the technological and market opportunity, and organization-specific characteristics are likely to undermine the notion of a universal formula for successful innovation (Tidd 1997). For example, a review of research on organizational innovation identified four factors which affect the management of innovation: type of innovation, stage of innovation, scope of innovation and type of organization (Damanpour 1991). Similarly, a review of research on innovation management calls for a re-examination of the relative importance of organization context and industry dynamics (Drazin and Schoonhoven 1996), an approach adopted by us at length elsewhere (Tidd *et al.* 2001).

Contingency theory offers the potential to understand better how context affects innovation management. The central concept is that no single organizational structure is effective in all circumstances, and that instead there is an optimal organizational structure that best fits a given contingency, such as size, strategy, task uncertainty or technology (Donaldson 1996). Therefore the better the fit between organization and contingency, the higher the organizational performance (Donaldson 1999; Drazin and Van de Ven 1985). This relationship between contingency, structure and performance has been supported by a substantial body of research conducted in the 1960s and 1970s, including qualitative comparative case studies (Burns and Stalker 1961; Chandler 1966) and quantitative analysis of large samples (Child 1972; Lawrence and Lorsch 1967). Clearly, one of the primary tasks of contingency research is to identify the dominant contingencies that influence organizational structure. According

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to a large number of seminal studies, three contingencies appear to be associated consistently with organizational structure: size, technology and task uncertainty.

There is a well-established body of research that has examined the relationship between formalization, specialization and firm size, the Aston Group (Pugh and Hickson 1976; Pugh *et al*. 1969) being the most influential work on this subject. Woodward (1965) identified technology as a contingency, and discovered a relationship between production technology, organizational structure and performance. However, Woodward's operationalization of technology was relatively crude, based simply on the flexibility and scale of production processes, whereas Perrow (1970) developed a finer grain typology of technology, based on task analysability and variability. Lawrence and Lorsch (1967) proposed that the rate of environmental change affected the need differentiation and integration within an organization, and found support for this in their comparative study of organizational structures in three different sectors. Galbraith (1973) argued that, as task uncertainty increases, more information must be processed, which in turn influences the control and communication structures. More recently, management researchers such as Mintzberg (1983, 1994), Galbraith (1994) and Galbraith and Lawler (1993) have developed these ideas into more prescriptive management frameworks, which attempt to match organizational structural templates to specific task environments.

Contingency theory is strongly positivist, and has been much criticized, as it leaves little scope for other influences, such as managerial choice or institutional pressures (Powell and DiMaggio 1991). However, Child (1972) offers some accommodation of the competing theories by allowing some ''strategic choice'' within boundaries determined by contingencies, an approach developed by Chandler (1990). I will adopt a similar position here, and will argue that contingencies do influence the organization and management of innovation, but that they constrain rather than fully determine 'best practice', what I have referred to as ''strategic degrees of freedom'' (Tidd 1993). Therefore, what remains is to identify the most significant contingencies, and the best configuration of organizational structures and management processes in each case. Figure 1 presents a summary of the relationships between environmental contingencies, type and degree of innovation, organizational configurations and performance.

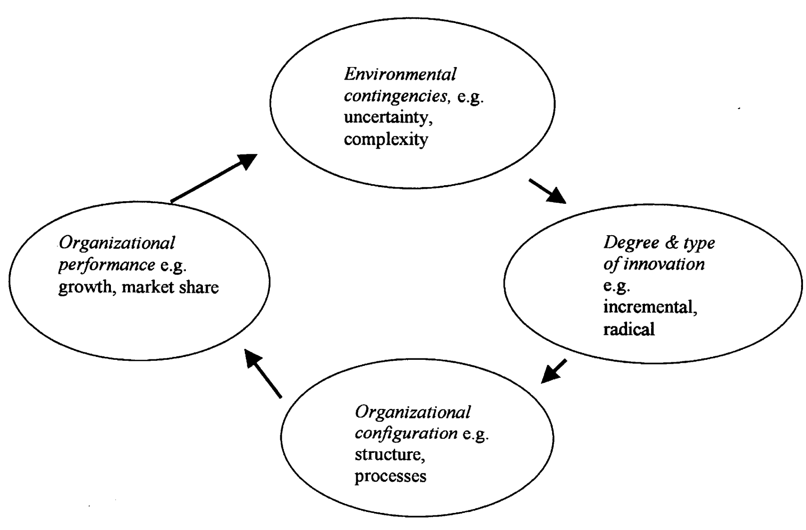

Figure 1. Innovation, environment and performance.

What Environmental Contingencies Affect Innovation Management?

Economists have long observed that industries differ in the amount of resources devoted to innovation, and in the rate of technological advance, whatever measure is used. Early explanations for such differences focused on differences in firm size or market structure, but more recent work has emphasized the role of technological opportunity (Geroski 1994). Although difficult to measure and model, three potential sources of technological opportunity have been identified (Klevorick *et al.* 1995): advances in scientific understanding; technological advances in other related industries; and positive feedback from prior technological advances. The relative importance of these different mechanisms varies by sector. For example, the pharmaceutical and semiconductor sectors both have strong links to basic science, the former to a narrow range of scientific fields, the latter to a much wider range of fields. In the food and electronics industries, material suppliers and equipment manufacturers are important sources of innovation. Customers are important sources of innovation in the machinery, electrical equipment and medical instrument sectors. Pavitt (1990) develops a similar taxonomy based on the primary sources of innovation: science based; scale intensive; information intensive; and supplier dominated.

Such differences in technological opportunity are associated with different market structures, firm strategies and organizational structures. Miller (1995) proposes four scenarios: technology races; technical parity competition; market contest; and learning in technology systems. In technology races, firms compete by acquiring intellectual property, for example, focusing on scientific research excellence in target fields in the pharmaceutical sector. In technical parity competitions, the scientific and technical knowledge is available to most firms, and firms must compete instead by developing and producing new products at low cost, for example, as in the automobile industry. In market contests, a continuous flow of improved and new products is necessary because product lives are short and imitation relatively easy. In this case, firms compete on the basis of creativity, cross-functional integration and time-to-market, for example, as in the consumer electronics sector. Finally, learning in technological systems consists of firms accumulating experience in solving the operational problems that appear in complex, networked technologies. Similarly, Langerak *et al.* (2000) identify a link between different R&D knowledge domains and the Miles and Snow (1978) strategic archetypes of prospector, analyser, defender and reactors.

A re-examination of the literature and recent research suggests that two contingencies exert a significant influence on the organizational and management of innovation: uncertainty and complexity (Tidd 1995, 1997). A review of 21 innovation research projects concludes ''environmental uncertainty influences both the magnitude and the nature of innovation . . . (which) suggests that future research should adopt environmentally sensitive theories of organizational innovation by explicitly controlling for the degree and the nature of environmental uncertainty'' (Damanpour 1996). In particular, perceptions of environmental uncertainty appear to affect the organization and management of innovation (Hauptman and Hirji 1999; Souder *et al.* 1998). The second contingency, complexity, is a function of the number of technologies and their interactions, and recent research suggests that innovation in complex products and systems is fundamentally different from that in other fields (Dvir *et al.* 1998; Hobday *et al.* 2000). Uncertainty and complexity need to be differentiated, as they appear to have different management requirements. Uncertainty is a function of the rate of change of technologies and product-markets, whereas complexity is a function of technological and organizational interdependencies. For example, a firm exposed to an environ-

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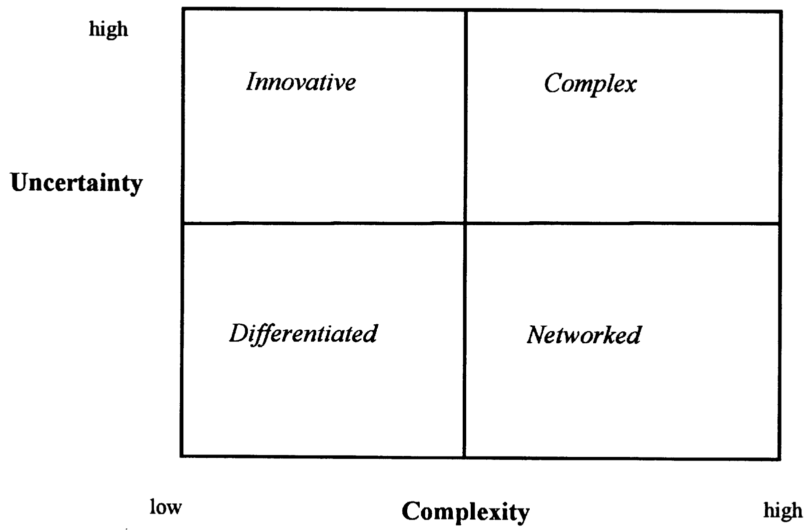

Figure 2. Effect of uncertainty and complexity on the management of innovation.

ment of rapid technological change might require high levels of internal R&D and linkages with the science base, whereas a firm attempting to manage complexity is likely to be imbedded in a network of collaborating organizations (Tidd 1995; Tidd and Trewhella 1997). Complexity does not necessarily imply uncertainty, or vice versa (Tidd 1997). However, we would expect extreme cases of complexity to be associated with uncertainty as the number of potential interactions increases. Figure 2 presents a simple two-by-two matrix, with uncertainty as one dimension and complexity as the other dimension. Each quadrant raises different issues and is likely to require specific organizational structures and processes to manage innovation:

- *Differentiated: low uncertainty, low complexity*. In this domain, product and service differentiation are the key issues, marketing competencies are critical, and a product or market multi-divisional structure typical, e.g. fast-moving consumer products.
- *Innovative: high uncertainty, low complexity*. In this domain, scientific or technological competencies are critical, and a functional structure typical, e.g. pharmaceuticals.
- *Networked: low uncertainty, high complexity*. In this domain, project management competencies are critical, and professional structures typical, e.g. construction (Gann 2000).
- *Complex: high uncertainty, high complexity*. The presence of both high uncertainty and high complexity demand a range of competencies, including flexibility and adaptation and learning. For example, the application of software to traditionally complex systems such as transportation, telecommunications and logistics has created new challenges to management and innovation (Hobday *et al.* 2000).

Together, these two contingencies may provide a more comprehensive typology of the environment of technology and innovation management, and help to guide management research and practice.

Degree and Type of Innovation Affect Management

The problem of not specifying the type and degree of the innovation examined is a substantial obstacle to the generalizability of innovation research (Wolfe 1994). Innovation can take two basic forms: *product* innovation, that is changes in the products or services that an organization offers; and *process* innovation, that is changes in the ways products and services are created and delivered. Sometimes the dividing line is blurred, for example, in the case of a new catalyst for chemical production, or a new service offering, but in most cases the distinction is useful. A second dimension of innovation is the degree of novelty involved. There are degrees of novelty, running from minor, incremental improvements right through to industry transformations. At any time, different environmental contingencies are likely to be associated with different types and degree of innovation. For example, traditional models of product and process innovation life cycles suggest a shift from product innovation to process innovation, and from radical to incremental innovation as an industry matures (Abernathy and Utterback 1978). This is important to note, because the ways in which we manage incremental, day-to-day change will differ from the methods used occasionally to handle a radical innovation in product or process. We can plot these two dimensions of innovation of a simple matrix that defines the space which has to be managed (Figure 3). On the novelty axis, innovation ranges from simple improvements to existing products and processes, through to radical 'new to the world' innovations. Booz Allen & Hamilton (1982) categorize projects into six types:

- improvements to existing products
- new-product lines
- additions to existing product lines
- new-to-the-world products
- cost reductions – process development
- repositioning – product augmentation development.

Clark and Wheelwright (1992) adopt a similar typology: research or advanced development; breakthrough development; platform or generational; and derivative or incremental. More recently, Christensen (1997) distinguishes between two fundamental

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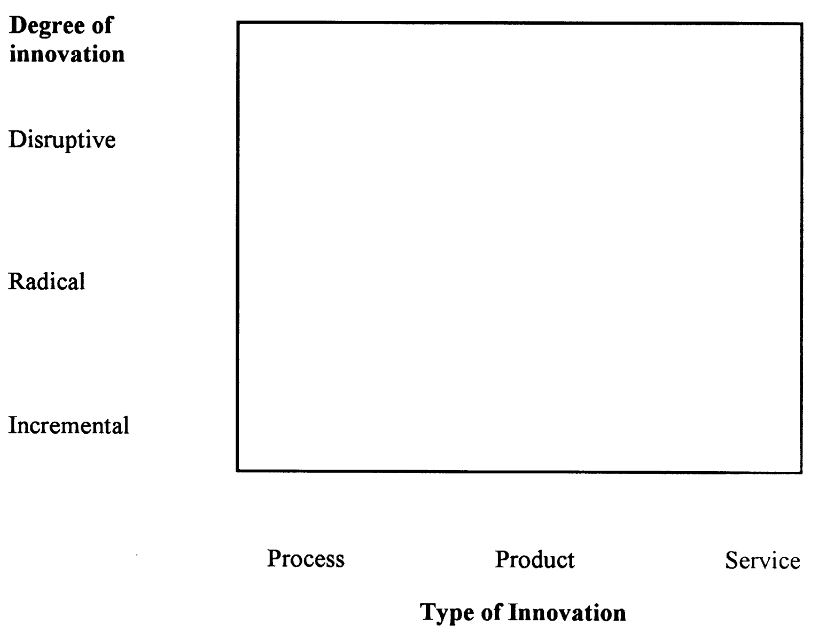

Figure 3. Innovation 'space': the type and degree of innovation.
Source: Adapted from J. Tidd, J. Bessant and K. Pavitt (2001) *Managing Innovation: Integrating Technological, Market and Organizational Change*, 2nd edition. Chichester: Wiley.

types of innovation, *sustaining* innovation, which continues to improve existing product functionality for existing customers and markets, and *disruptive* innovation, which provides a different set of functions which are likely to appeal to a very different segment of the market. Existing firms and their customers are likely to undervalue or ignore disruptive innovations, as these are likely to appear inferior to existing technologies in terms of measures of benefit and performance. Therefore, established firms tend to be blind to the potential of disruptive innovation, which is more likely to be exploited by new entrants. In such cases, segmentation of current markets and close relations with existing customers will tend to reinforce sustaining innovation, but will fail to identify or wrongly reject potential disruptive innovations. Our recent study of 50 development projects in 25 firms examined the relationship between the perceived novelty of a project and the structures, processes and methods used to manage the projects (Tidd and Bodley 2001). We identified significant differences in terms of both the use and the effectiveness of various structures, processes and tools. For example, heavyweight project managers and cross functional teams were more effective for the high-novelty projects, and customers and suppliers were twice as likely to be involved in the development and commercialization of the novel projects. This supports the notion that novelty is a significant factor affecting the organizational and management of innovation.

Organizational Responses to Complexity and Uncertainty

Under conditions of complexity and uncertainty, two organizational factors affect the ability of a firm to develop and commercialize new products and services: the internal organization of the firm, specifically functional links and the definition of business divisions based on product–market linkages; and links with other organizations, such as suppliers and customers, and networks of collaborating organizations (Tidd 1997). Kay (1993) refers to the sum of these structural characteristics forming the ''architecture'' of the firm.

Internal Organization

There is a significant body of research on the environment–strategy and strategy–structure linkages, but few studies addressed the specific issue of innovation (Dess *et al.* 1993; Miller 1996). The notion of a ''configuration'' emerged from such research, which is more than a typology derived from theory or a taxonomy based on empirical evidence. A configuration is an internally consistent combination of strategy, organization and technology that provide superior performance in a given environment. For example, the success of the multidivisional structure, or M-form, is associated with a strategy of diversification into related product areas. It emerged because the volume and complexity of information placed strains on the traditional functional structure. The historical success of the chemical and electrical industries has not been based on a single product, process or market, and they are examples of what Chandler refers to as ''extensible technologies'' (Chandler 1966, 1990). The chemical industry extended into textiles and pharmaceuticals, and the electrical industry into consumer electronics and machine tools. In contrast, the steel industry is an example of non-extensible technology, which has focused on cost reduction and product improvement, rather than diversification. This suggests that the scope of the technology has a significant influence on strategy and organization (Channon 1973).

However, the multidivisional form quickly became the *de facto* standard for large organizations, irrespective of the environment of technology. Multi-divisional firms can be efficient innovators, measured in terms of patents and new products per unit of R&D expenditure (Cardinal and Opler 1993), as the structure facilitates efficient innovation within specific product-markets. Indeed, one of the benefits claimed for the M-form organization is that it offers the potential to centralize research common to many different businesses, but to decentralize product development to the relevant divisions. However, in practice, the structure may limit the scope for learning new competencies: firms with fewer divisional boundaries are associated with a strategy based on capabilities-broadening, whereas firms with many divisional boundaries are associated with a strategy based on capabilities-deepening (Argyres 1996). In terms of financial performance, research suggests that performance at the level of business units is of much greater significance than that at the corporate level: "corporate returns will differ because their portfolios of business units differ . . . there is no evidence of 'synergy'" (Rumelt 1991, 182). Therefore, the structure makes it very difficult to identify and develop technologies and products which cross existing business divisions (Tidd 1994, 1995). Decentralizing R&D reduces the scope for exploiting the interrelatedness of technologies, and the most appropriate balance between corporate R&D by the divisions will depend on the strategy and technology (Tidd and Pavitt 2000). More recently, we have begun to examine alternative structures to deal with complexity and uncertainty, such as project-based firms and networked organizations (Gann and Salter 1998; Hobday *et al.* 2000).

External Linkages

In his seminal review of models of innovation, Rothwell (1992) proposed a "fifth-generation" model of innovation management, based on inter-company networking facilitated by IT systems. More recently, the term 'network' has become widely used in innovation research and practice, but is not usually clearly specified. There is little agreement on what constitutes a network, and the term and alternatives such as 'web' and 'cluster' have been criticized for being too vague and all-inclusive (DeBresson and Amesse 1991). Studies have focused on the role of inter-personal relationships in the innovation process, others on the links between different functional groups or business divisions, and some on the relationships between different organizations (Jones *et al.* 1998). The research community has tended to focus on the polar extremes – the role of the individual and strategic alliances, and has only recently recognized the need to bridge this gulf in studies of innovation networks (Fiol 1996).

A network is more than an aggregation of bilateral relationships or dyads, and therefore the configuration, nature and content of a network impose additional constraints and present additional opportunities. A network perspective is concerned with how these economic actors are influenced by the social context in which they are embedded and how actions can be influenced by the position of actors. A network can influence the actions of its members in two ways (Gulati 1998): first, through the flow and sharing of information within the network; secondly, through differences in the position of actors in the network, which both reflects and is a source of power and control imbalances. Therefore, the position occupied in a network is a matter of great strategic importance, and sources of power include technology, expertise, trust, economic strength and legitimacy.

Historically, networks have evolved from long-standing business relationships such as suppliers, distributors, customers and competitors. Over time, mutual knowledge and social bonds develop through repeated dealings, increasing trust and reducing transaction costs. Therefore, a firm becomes more likely to buy or sell technology from members of its network (Bidault and Fischer 1994). The process is path dependent in the sense that past relationships between actors increase the likelihood of future relationships, which can lead to inertia and constrain innovation. Indeed, much of the early research on networks concentrated on the constraints

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networks impose on members, for example, preventing the introduction of 'superior' technologies or products by controlling supply and distribution networks (Hakansson 1995). A network can never be optimal in any generic sense, and the inherent instability and imperfection of any network results in evolution. For example, Belussi and Arcangeli (1998) discuss the evolution of innovation networks in a range of traditional industries in Italy. The potential to design explicitly or participate selectively in networks for the purpose of innovation, that is a path-creating rather than path-dependent process, has only recently received attention (Galaskiewicz 1996). A study of 53 research networks found two distinct dynamics of formation and growth. One type of network emerges and develops as a result of environmental interdependence, and – through common interests – an emergent network. However, another type of network requires some triggering entity to form and develop – a so-called ''engineered'' network (Doz *et al.* 2000). In an engineered network, a nodal firm actively recruits other members to form a network, without the rationale of environmental interdependence or similar mutual interests.

Networks are appropriate where the benefits of co-specialization, sharing of joint infrastructure and standards and other network externalities outweigh the costs of network governance and maintenance. Where there are high transaction costs involved in purchasing technology, a network approach may be more appropriate than a market model and, where uncertainty exists, a network may be superior to full integration or acquisition. Different types of network are likely to be associated with different environmental contingencies and types of innovation. For example, complex products have to interface with the products and services of other vendors, and it is in the interest of all organizations to share knowledge in order to ensure compatibility. In such cases an 'open' network is most appropriate. In contrast, a 'closed' network seeks to control standards by economies of scale and proprietary standards in order to lock-in customers and other organizations in the network (Garud and Kumaraswamy 1993). Where the scientific base is abstract or technology complex or performance uncertain, new mediating institutions are likely to be created (Attewell 1996). These institutions stand between a complex technology and the user, and are able to benefit from economies of scale in 'rare event learning' where end users cannot. Thus consultants, systems integrators and service bureaus are commonplace in emerging or complex technologies. However, by reducing the initial burden on users, these mediating institutions may also reduce the potential for users to learn.

Conclusions

In this paper, I have attempted to draw together the broad and diverse research literature on innovation management and the relevant contributions of organizational behaviour and strategic management to develop a framework relating environmental contingencies, organizational configurations, innovation management and performance. My review suggests that the complexity and uncertainty of the environment affects the degree, type, organization and management of innovation, and that the greater the fit between these factors, or the more coherent the configuration, the greater the performance. However, it is clear that this hypothesis must be tested empirically, specifically using better measures of complexity and uncertainty. Together, a better understanding of these and other environmental contingencies may provide finer-grained theories to guide innovation management research and clearer and more consistent advice for management practice. The goal should be to identify the organizational configurations most suited to specific technological and market environments, rather than to seek a single ideal or best-practice model for any context. In this respect, research on the management of innovation has only just begun (Tidd *et al.* 2001).

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