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A BEHAVIORAL THEORY OF R&D EXPENDITURES AND INNOVATIONS: EVIDENCE FROM SHIPBUILDING

HENRICH R. GREVE
Norwegian School of Management BI

I base an integrated model of innovation development and launch on the behavioral theory of the firm. This model specifies that research and development expenses are increased when low performance causes "problemistic search" and when excess resources cause "slack search." Innovations generated by search are launched if low performance gives managers high risk tolerance. Using data from shipbuilding firms, I show that high performance reduces R&D intensity and innovation launches, and high slack increases R&D intensity, as predicted.

Innovations have the potential to transform organizations and industries, but they are also fraught with risk. The vast majority of innovations are worth little to the innovators, although some are extremely valuable (Bosworth & Jobome, 1999). Some innovations are valuable for the innovating firms but cause the decline of other firms in their industry (Christensen & Bower, 1996; Tushman & Anderson, 1986). Theory predicting how organizations adjust their innovation rates would allow identification of the conditions most likely to trigger innovations in a firm and the firms most likely to spark change in an industry. However, Cyert and March wrote that "one persistent problem in the development of a theory of the firm is the problem of innovations" (1963: 278), and this statement still seems to be true (Fiol, 1996).

An important source of difficulty is that innovations are launched when two processes are successfully completed: a development stage leading to an innovation, and a decision-making stage launching a product incorporating the innovation (Burgelman & Sayles, 1986). Accordingly, research on innovations has been split into two traditions, one on the process of developing innovations and the other on the decision to launch developed innovations into the market. Development theory examines how the acquisition and management of knowledge and innovative people affect innovativeness (Cohen & Levinthal, 1990; Fiol, 1996; Helfat, 1997; Hitt, Hoskisson, & Kim, 1997; Leonard-Barton, 1995; Nonaka & Takeuchi, 1995). Decision-making theory examines how organizations solve the opposition between innovations and organizational stability, legitimacy, and risk aversion (Bolton, 1993; Burgelman, 1991; Dougherty & Hardy, 1996; Fleming & Bromiley, 2000; Howell & Higgins, 1990; Tabak & Barr, 1998). Development theory has examined what kinds of organizations have high levels of innovativeness, while decision-making theory has focused on what conditions allow managers to take risks. The contribution of both processes to organizational innovations suggests that closer integration of these theories is needed.

The behavioral theory of the firm (Cyert & March, 1963) offers a good platform for integrating development and decision-making ideas of innovations. Developing innovations is a form of organizational search, so theories of innovation development correspond to the search stage of the behavioral theory of the firm. Decisions to launch innovations belong to the decision-making stage of the behavioral theory of the firm. Recognizing that search and decision making jointly contribute to firm innovations helps explain why organizational rates of innovation are highly variable over time as well as across organizations. It also offers an explanation for why organizations sometimes fail to launch innovations that have been developed in their R&D functions.

In this study, I used the behavioral theory of the firm to predict search intensity and innovation rates. The theoretical analysis addresses the problems of matching development and decision-making processes and generates hypotheses on how performance and slack affect R&D and on how performance affects innovation rates. The hypotheses were tested with data on 11 large Japanese

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shipbuilding firms whose innovations were followed over 26 years. Although they have faced difficult markets and cost disadvantages, Japanese shipbuilders have kept a high share of the world market (38 percent in the year 2000) through a range of adaptations, including product innovations. These firms are rather innovative overall, but rates of launching innovations vary both across firms and over the years within single firms. The firms launched between zero and eight innovations per year, and even the firms with the highest rates of launching innovations had several years with none. This variation is not explained by conventional innovation theory, but it can be explained by the behavioral theory of the firm.

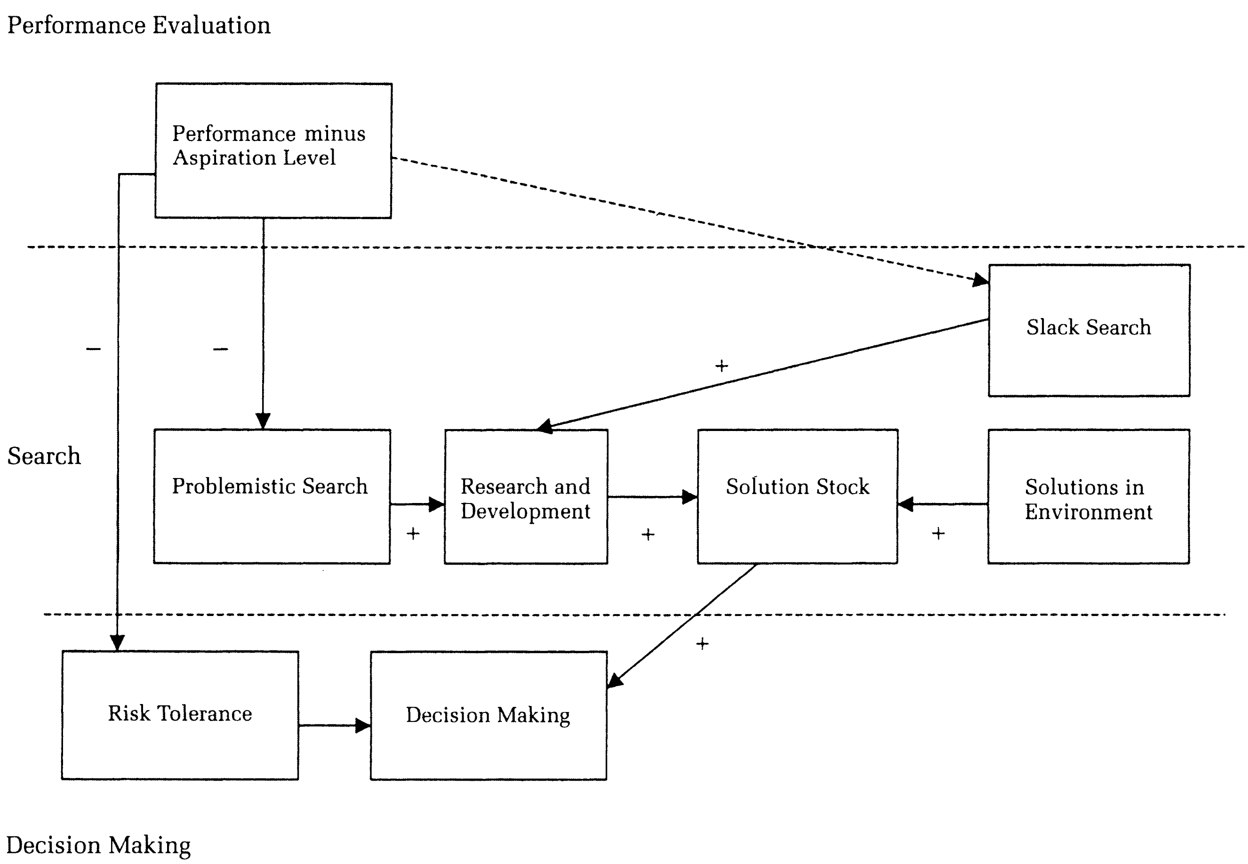
ORGANIZATIONAL DETERMINANTS OF R&D AND INNOVATION

Overall Model

The behavioral theory of the firm emphasizes the organizational processes of performance evaluation, search, and decision making, and leads to propositions concerning how these affect organizational changes. An application of this argument to the innovation process is shown in Figure 1, which is based on Cyert and March (1963: 127) and March (1994: 33). Managers evaluate organizational performance relative to their "aspiration level" and initiate problemistic search when performance is low. An *aspiration level,* "the smallest outcome that would be deemed satisfactory by the decision maker" (Schneider, 1992: 1053), is used by "boundedly rational" decision makers to determine the boundary between success and failure in continuous measures of performance (March & Simon, 1958). *Problemistic search* means "search that is stimulated by a problem . . . and is directed toward finding a solution to that problem" (Cyert & March, 1963: 121).

Other processes also generate solutions. Organizations with excess resources engage in *slack search,* which is search for "innovations that would not be approved in the face of scarcity but have strong subunit support" (Cyert & March, 1963: 279). Solutions may also exist in organizations' environments and are introduced to the organizations through contacts with consultants or with earlier adopters or sellers of these solutions. Problemistic search, slack search, and solutions in the environ-

FIGURE 1
Theoretical Model



ment jointly determine the stock of solutions available to decision makers.

Low performance increases managerial tolerance for risk because managers view performance below their aspiration level as a loss situation and are willing to take risks to improve it (Kahneman & Tversky, 1979). Thus, decisions are based on the availability of a problem, a solution, and a level of risk tolerance that makes the solution acceptable to the decision makers (March, 1994). If multiple solutions are present, managers may adopt more than one or select among them. The risk tolerance influences the capacity for adopting multiple solutions and the selection of solutions from the available candidates.

The components of this theory of innovations are problemistic search, slack search, and risk taking. Each of these leads to propositions on the drivers of firm innovations, which are developed next. Studying innovation launches requires integration of these different processes, however, which has two important theoretical implications. First, problemistic and slack search take place in multiple organizational locations and result in both innovations and in noninnovative solutions, such as imitation of others. Thus, search through R&D, which is the organizational process most directly involved with innovations, is one component of organizational search, and innovations are one type of potential solution. Second, having innovations in a pool of solutions is a necessary condition for launching innovations, but it is not a sufficient condition because other solutions may be chosen. The probability that a firm will launch an innovation equals the probability that an innovation is in the solution pool multiplied by the probability that an innovation in the pool will be launched. Innovation rates are thus affected both by the supply of innovations from processes such as R&D and by the managerial demand for risky solutions such as innovations.

Problemistic Search: Performance Relative to Aspirations

Problemistic search is triggered when managers find that organizational performance is below their aspiration level (Cyert & March, 1963). Intended to mend performance shortfalls, it is conducted in the parts of an organization that are close to the perceived problem or in the parts that have previously solved similar problems. Problemistic search results in increased R&D when decision makers judge that upgrading their organization's technology and product portfolio can solve the performance problems. This judgment happens under quite general conditions. Organizations that have resorted to R&D for solving problems in the past repeat this behavior through decision-making momentum (Kelly & Amburgey, 1991; Miller & Friesen, 1982). Organizations with a structure that gives the R&D function a voice in the decision-making process favor R&D in the budget allocation process (Boeker, 1989; Pfeffer & Salancik, 1978). Organizations facing a decline of market demand enter R&D races to carve out greater market shares (Ramrattan, 1998). The main roadblock to increasing R&D is that performance problems that are attributed to temporary external adversity are less likely to cause problemistic search than problems attributed to enduring internal deficiencies (Mone, McKinley, & Barker, 1998). Despite this caveat, evidence suggests that low performance leads to increased R&D (Antonelli, 1989; Hundley, Jacobson, & Park, 1996; Kamien & Schwartz, 1982) and new ways of doing R&D (Bolton, 1993).

Increased R&D expenditure can be channeled to the initiation of new R&D projects and to increased support of existing projects and, in organizations engaged in problemistic search, it is particularly likely to be channeled to projects near completion. Concentrating added resources on R&D projects near completion offers managers a compromise between the need to solve an urgent performance problem and the long lead times common in research and development. Thus, taking the view that performance below aspiration level will trigger problemistic search, I predict:

Hypothesis 1. When performance relative to aspiration level decreases, R&D intensity increases.

Slack Search: Organizational Resources

It is often suggested that increased organizational resources allow experimentation and organizational change (Cyert & March, 1963; March, 1981). Organizations with spare time and spare resources have greater opportunities for experimentation and less strict performance monitoring and so have the resources and managerial patience needed to innovate. High-level managers can formalize slack search by allocating amounts of time for product developers to work on their own projects and applying loose performance standards for new projects (Jelinek & Schoonhoven, 1990), but slack search can also occur informally, when product developers appropriate time for projects that are unknown to higher levels of management (Burgelman, 1991).

Slack exists as use of administrative resources beyond what is necessary for the short-term operation and maintenance of an organization. This type of slack is called absorbed slack. Facilities for research and development, staff specialized for development purposes, and time for development activities among other staff are examples of absorbed slack useful for developing innovations. Absorbed slack less useful for developing innovations includes costly facilities and perks such as high wage levels. Organizations that have experienced lengthy surpluses build up absorbed slack, which can be observed as higher costs than in those of other organizations with comparable outputs. Absorbed slack is distributed broadly in an organization, so research and development will be one of many recipients.

Slack also exists as financial reserves, which an organization can maintain by holding cash or financial instruments (unabsorbed slack) or by lending less than the organization potentially could lend (potential slack). Such reserves are not directly helpful in the development of innovations, but they may affect decisions to continue or discontinue R&D projects. This effect occurs because great financial resources lead to less strict performance monitoring of uncertain projects. Strict performance monitoring can cause new activities to be aborted before an organization has accumulated enough experience to know whether they will eventually improve its performance (Lounamaa & March, 1987). The impatient evaluation caused by low slack is particularly damaging for R&D projects, which are vulnerable to cutbacks because of the ambiguous performance signals that they generate (Garud & Van de Ven, 1992). Thus, greater levels of unabsorbed and potential slack make it easier to continue R&D projects.

The effect of slack search on R&D projects appears to oppose that of problemistic search. Problemistic search generates solutions when performance is low, but slack search is generated by high resources, which again are created by high performance (a dotted line indicates this relation in Figure 1). The opposition of problemistic and slack search can be resolved by distinguishing (1) resource stock from performance flow and (2) absolute performance from performance adjusted by aspiration level. Slack refers to the stock of resources available to an organization, such as employees' time, underused capital, and underused facilities. Performance does not necessarily mean resource acquisition, since organizations may have other goals, such as sales or quality. When it does refer to resource acquisition, however, managers are typically oriented toward "flow goals," such as the profits earned in the most recent accounting period, because investors use such goals to evaluate managers. The difference between resource stock and performance flow suggests that slack and performance do not necessarily covary much—a rich organization can have a period of low performance, and a poor organization can have a period of high performance. Moreover, managers judge performance relative to aspiration level, so their subjective evaluation of success depends on how the aspiration level is adjusted. An objectively rich and strongly-performing organization is subjectively unsuccessful if it has had even higher performance in the recent past or if its competitors have higher current performance (March, 1988). Performance is more subjective, short-term, and volatile than slack, so the two variables have distinct and separable effects on R&D. Thus, all else being equal, my prediction is:

Hypothesis 2. When organizational slack increases, R&D intensity increases.

Decision Making: Risk Preferences

Problemistic and slack search result in increased R&D budgets and innovation development but do not directly cause organizational innovations to be launched as products in a market. Managers of organizations with high performance may decide to avoid the risks inherent in organizational change and thus may reject innovations. Managers of organizations with low performance may change them in ways other than launching innovations, such as downsizing, productivity improvement, or diversification (Ahmadjian & Robinson, 2001; Anand & Singh, 1997). Of the three search processes shown in Figure 1, only two are primarily intraorganizational, and only one is stimulated by specific problems. The link between an organizational problem and an innovation is thus obscured by noise generated by alternate sources of solutions. Solutions compete for the attention of managers (Ocasio, 1997), so it is not guaranteed that an innovation will be the solution matched with a performance problem.

There are still two reasons to expect that solutions in an organization's environment will have lower effects on its generation of its own innovations than on its imitation of innovations made by others. First, imitation is strongly affected by contacts with prior adopters (Drazin & Schoonhoven, 1996; Rogers, 1995; Strang & Soule, 1998), but innovation is mainly conducted within a given organization (Burgelman & Sayles, 1986; Leonard-Barton, 1995). Second, risk theory suggests that innovations are more acceptable solutions when an organization has performance below its aspiration level. Individuals often show risk aversion, choosing alternatives with lower variance at some cost in expected value, but they are more prone to take risks when failing to attain their aspiration level (Kahneman & Tversky, 1979; Lopes, 1987; Schneider, 1992; Thaler & Johnson, 1990). Greater risk taking given performance below aspiration level has been found in studies of organizational change and risk taking (Bolton, 1993; Bromiley, 1991; Greve, 1998; Grinyer & McKiernan, 1990; Miller & Leiblein, 1996; Wiseman, McNamara, & Devers, 2001). Consequently, performance below aspiration level not only makes decision makers search for solutions, but also makes them more likely to accept risky solutions, such as innovations.

An innovation launch is strongly affected by risk considerations because it is a strategic decision that involves judging whether the risk of the innovation is acceptable to an organization. Risk-seeking managers prefer innovation to low-risk changes and may even adopt both an innovation and low-risk changes (thus adding to the aggregate risk of their organization), but risk-averse managers are likely to choose low-risk organizational change or no change at all. Because performance below aspiration level simultaneously increases risk taking and problemistic search, innovation launches are more likely when performance is below aspiration level. Not all studies show increased risk taking when organizational performance is low (McNamara & Bromiley, 1997). Although search and risk theorists have argued that organizations respond to low performance by making changes, others have suggested that organizations are inert owing to constraints from internal politics and external commitments (Hannan & Freeman, 1977), commitment to failing courses of action (McNamara, Moon, & Bromiley, 2002; Staw, Sandelands, & Dutton, 1981), and perceptual biases (Milliken & Lant, 1991; Mone et al., 1998). Organizational resistance to change suggests that the reaction to performance feedback differs for organizations with high and low performance. Performance above aspiration level can be seen as a good reason to avoid risky change, but performance below aspiration level triggers both efforts to change an organization and efforts to prevent such change (Greve, 1998). Since inertial forces counteract risk taking below an aspiration level but not risk reduction above it, the effect of performance on organizational change is weaker when performance is below the aspiration level. This formulation implies:

Hypothesis 3a. When performance relative to aspiration level increases, the rate of launching innovations decreases.

Hypothesis 3b. The rate of launching innovations decreases more rapidly for performance increases above aspiration level than for performance increases below aspiration level.

Past research and development could moderate the relationship of performance and innovations. Developing innovations is difficult and time consuming, so a solution that can be generated between one accounting cycle and the next is probably not a new innovation, but a minor modification or a rediscovery of an innovation made earlier. Problemistic search can still give quick results when it leads to reconsideration of innovations that have previously been rejected as too risky (Garud & Nayyar, 1994). When low managerial risk tolerance causes innovations to be rejected, the result is a lower rate of launching innovations and the creation of a buffer of stored innovations that can be launched on short notice (Garud & Nayyar, 1994). Leaks of knowledge and development efforts by competitors depreciate this innovation buffer (Levin, Klevorick, Nelson, & Winter, 1987), so the recent part of the buffer is the most likely to still be innovative. Thus, firms with a history of risk aversion will have unused innovations available, and they can respond rapidly by searching for innovations that have earlier been rejected. On the other hand, firms with a history of high risk taking or low search will have depleted their buffers of unused innovations and will not be able to respond quickly to problemistic search.

One might argue that risk theory should also apply to R&D expenditures because of the highly uncertain returns from R&D, especially if R&D expenditures are large. A counterargument is that R&D reduces a firm's risk because it gives the firm options to launch innovations but allows managers to base decisions as to whether or not to launch innovations on the expected returns and risk (Grenadier & Weiss, 1997). This argument, which is clearly consistent with the view of R&D as a search activity that contributes to a buffer of innovations, has been empirically supported by work showing that managers with incentives to reduce risks pursue R&D (Wiseman et al., 2001).

METHODS

The Japanese Shipbuilding Industry

This study uses data on the Japanese shipbuilding industry from 1971 to 1996. Japanese shipbuilding firms have a long history of importing foreign innovations and developing their own, initially to catch up with the more technologically advanced foreign industry and later to carve out unique niches in large and high-tech vessels (Chida & Davies, 1990). The firms entered the 1971–96 period as the dominant population of shipbuilders worldwide and were especially strong in high-margin markets that relied on innovative designs and modern shipyards (Chida & Davies, 1990). The study period had challenging economic conditions for the shipbuilders, with the 1973 oil shock causing a period of low demand, which was followed by increased competition from low-cost producers based in Korea and China. Firms responded with a variety of strategic changes, including cost reductions and diversification (Stråth, 1994). They also launched an average of one innovation per firm-year, thus maintaining a strategy of innovating despite having a wide range of other options and adopting some alternative strategies. I used a panel data set to analyze the effect of performance, slack, and other covariates on R&D intensity and innovation launches.

Measures

Dependent variables. *R&D intensity* was measured as research and development expenditures divided by sales. The data for these variables were downloaded from the Nikkei NEEDS database, which takes its data from corporate accounts. Research and development was measured because it is an important form of organizational search, but search also occurs elsewhere in organizations, such as in the production function (quality circles and less formal ways of identifying and solving production problems are examples). Analysis of a single measure of search will not reveal the total extent of organizational search, but it can indicate how organizations adjust that particular search activity. If different forms of search are adjusted according to the same behavioral rules, as the theory would suggest, analysis of R&D intensity can also indicate how the total search of an organization is adjusted.

Innovation launches was measured as the number of innovations made by a firm as reported by the monthly journals *New Technology Japan* and *Techno Japan* from 1971 to 1996. These journals nearly exclusively report innovations that are ready for market launch, but a few reports on the initiation or progress of R&D projects were found. I omitted such reports to preserve the focus on innovation launches. *New Technology Japan* is published by the Japan External Trade Research Organization, with a goal of comprehensive coverage of innovations ready for market entry. *Techno Japan* is published by the private company Fuji Marketing Research and covers innovations that represent strong engineering progress. Some innovations were found in both sources, but most innovations were found only in *New Technology Japan.* The descriptions of the innovations suggested that production process innovations might be underrepresented in the data. They constitute 33 of the 357 innovations, with the rest being innovations to accessories and equipment (84), communication and control (47), engines (60), propulsion (26), and whole vessels (107). The emphasis on product innovations is not surprising, given the export promotion function of *New Technology Japan* and firm secrecy regarding production processes, and this emphasis should be taken into account when one interprets the findings of this study.[1]

The use of journals reporting on the shipbuilding industry as data sources has advantages and disadvantages. The primary advantage is that the journals list each innovation meeting the industry's definition of a technological innovation and being launched as a product. The primary disadvantage is that the journals may overlook innovations by less prominent firms and process innovations. An alternative data source would be patents, which have the advantage of meeting a patent reviewer's definition of technological innovation. A disadvantage of patents is that they correspond better with the success of a development process than with a decision to launch, since firms have a reason to seek patent protection even for innovations judged to be too risky to launch as products: a firm can earn license fees by patenting such innovations. Patenting can also slow the depreciation of an innovation kept in the buffer by extending the time it takes other firms to invent around it (Levin et al., 1987). Patents do not solve the problem of "underdetecting" process innovations, as managers view patent protection as less effective than secrecy for process innovations and find process innovations difficult to patent (Levin et al., 1987).

Yet another alternative data source, firm documents such as annual reports, lack external review of the innovativeness of new technologies, so they are vulnerable to self-presentation concerns. The journals thus seemed to be the best choice.

The data contained some innovations that were

[1] One might argue that process innovations should be omitted from an analysis of innovations launches, as process innovations most likely will not be sold. An analysis omitting the process innovations gave results consistent with the analysis presented in Table 3.

jointly developed by two or more organizations, so 357 innovations gave a total of 401 innovation-organization matches. Joint innovations were assigned to each innovating firm, but this resulted in little double-counting since most collaborations were between a firm in the data and a firm not in the data (usually a supplier). The data included 246 innovations launched by firms in the data, 35 by smaller shipbuilders, 84 by firms that were not shipbuilders (mostly suppliers), 10 by research centers, and 2 by individuals. Innovations made by firms outside the study population did not enter the dependent variable, but they were counted in the control variable for innovations in the industry during the previous year. The Appendix lists examples of innovations made in each of three years: 1974, 1984, and 1994. Because five firms did not report R&D expenditures before 1976, in the analysis of innovation launches I needed to either omit R&D expenditures as a predictor or lose some observations. Preliminary analysis showed that the loss of observations did not affect the results, so results with R&D expenditures entered into the model are shown.

Performance variables. Accounting measures of performance were downloaded from the NEEDS database. Popular measures of performance are return on assets (ROA), return on sales (ROS), and return on equity (ROE). As ROE is affected by a firm's mix of equity and debt, it is difficult to compare across firms. Thus, either ROA or ROS is preferable, and in these data they correlated 0.86 with each other. The analyses with these two variables gave consistent results; the analysis with ROA is presented here since it is the more frequently used measure of the two. Following Cyert and March (1963: 123), I computed aspiration level *(A)* as a mixture of social and historical aspiration levels. The social aspiration level *(SA)* is the average of other firms' performance *(P),* calculated as the mean ROA of all large shipbuilders except a focal firm. The historical aspiration *(HA)* level is a mixture of past-period historical aspiration level and the previous performance of the focal firm. Letting a_1 and a_2 be weights, the formulas are:

$$A_{ti} = a_1 SA_{ti} + (1 - a_1) HA_{ti}.$$

$$SA_{ti} = (\sum_{j \neq i} P_{tj})/(N - 1).$$

$$HA_{ti} = a_2 HA_{t-1,\,i} + (1 - a_2) P_{t-1}.$$

Here, t is time, and i and j indicate firm. I estimated the weights by searching all parameter values by increments of 0.1 and taking the combination giving the highest model "log-likelihood." This procedure yielded a value of 0.8 for a_1 and a value of 0.2 for a_2, which means that industry-average performance had a weight of 0.8, firm performance in the previous period had a weight of 0.16, and the historical aspiration level in the previous period had a weight of 0.04.

To test for a different effect on innovations of performance above and below a firm's aspiration level, I specified performance as a spline function (Greene, 1993: 235–238). The spline specification was made by entering separate variables for performance above and below aspiration level, a procedure that yielded separate tests of Hypothesis 3a (decline in innovations as performance increases) above and below aspiration level. A Wald test of the difference of coefficients was used to test Hypothesis 3b (greater decline above aspiration level). I also used the spline specification for R&D intensity to make the models comparable, but the theory underlying this research did not give me reason to expect that R&D would be differentially affected by performance above and below aspiration level.

Slack variables. Three measures of slack used in earlier work were adopted here. *Absorbed slack* was measured as the ratio of selling, general, and administrative expenses (SGAE) to sales. *Unabsorbed slack* was measured as the ratio of quick assets (cash and marketable securities) to liabilities. *Potential slack* was measured as the ratio of debt to equity (Bromiley, 1991). Since greater debt gives lower borrowing ability, the prediction for this measure is a negative coefficient. All the slack measures require that the organizations be involved in similar forms of business, since they measure excess resources without adjusting for the normal resource requirement for a given business. Thus, analysis of slack effects requires a single-industry study population or controls for firm effects to give comparability; both were applied in this study.

In the analyses of R&D intensity, the slack variables were lagged by one year to test Hypothesis 2 (greater slack increases R&D intensity). In the analysis of innovations, I calculated these variables as five-year moving averages to take into account the time lag in developing innovations. The analysis of innovations also included a five-year moving average of R&D as a control for the effect of past search. The choice of one-year lagged variables or five-year averaged variables for slack and R&D did not affect the results, but five-year averages are more consistent with the duration of research and development projects. Good controls for slack search are important for testing hypotheses on effects of problemistic search and risk taking, as slack search provides an alternative source of solutions to organizational problems.

TABLE 1
Means, Standard Deviations, and Correlations[a]

Variable	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11
1. R&D intensity	0.01	0.01											
2. Annual innovation launches	0.97	1.32	−.02										
3. Previous-year innovations in the industry	10.92	7.96	−.24	.54									
4. Employees[b]	9.23	1.28	.48	.47	.38								
5. Annual production	8.84	2.58	−.16	.27	.45	.22							
6. Annual growth in shipping income	1.01	0.13	−.07	.30	.14	.07	−.08						
7. Annual freight rate	14.62	4.48	.02	.03	−.06	−.07	−.50	.13					
8. Performance, aspiration > 0	0.01	0.03	−.10	−.27	−.08	−.12	−.15	−.04	.13				
9. Performance, aspiration < 0	−0.01	0.02	.01	.01	.03	.03	.07	−.08	.02	.29			
10. Absorbed slack	0.08	0.03	.71	−.01	−.24	.39	−.15	−.07	.09	−.11	−.14		
11. Unabsorbed slack	0.57	0.07	−.21	.29	.49	−.01	.28	.19	.01	−.24	−.02	−.20	
12. Potential slack	1.85	1.88	−.21	.11	.28	−.14	.08	.19	.00	.03	−.03	−.18	.13

[a] There are 185 observations. Correlation coefficients greater than .14 are significant at the 5 percent level.
[b] Logarithm.

Industry control variables. To measure the effect of innovations in the industry on each firm's rate of innovating, I included the previous-year number of *innovations in the industry.* Innovations observed by managers facilitate discovery of market and technological opportunities, which increases the innovation rate of a firm (Greve & Taylor, 2000). The number of industry innovations in a previous year is thus a measure of the environmental sources of solution depicted in Figure 1. As a measure of firm size, the logged number of *employees* was entered. Asset value, which was also considered as a size variable, correlated highly with number of workers.

To control for the effect of economic trends in shipbuilding on R&D and innovation, I used the following annually varying measures: *Annual production* was the finished tonnage (scale: million gross tons) completed by the Japanese shipbuilders. *Annual growth in shipping income* was the total income of the shipping industry divided by its previous-year value, and *annual freight rate* was the average rate charged for freight between Hampton Roads, Virginia, near the Chesapeake Bay, and Japan (scale: dollars per ton). The latter two variables are leading indicators of the demand for new ships.

Model

The analyses took advantage of the panel structure of the data, which gave information on both cross-sectional differences between firms and temporal changes within each firm. Research and development intensity could be modeled by panel data regression analysis with controls for firm differences and inertia in the budget allocation process (Greene, 1993: 464–480). Preliminary analyses showed that variable effects were significant but fixed effects were not, so in the main analyses variable effects were applied. A fixed-effects model is also shown for comparison. Inertia in the budget allocation process caused autocorrelation of the R&D budget, so the models also included a control for first-order autocorrelation.

Annual innovation launches is a count variable that takes integer values from zero upwards. Both the basic Poisson model and models in which random or fixed effects were used to control for firm differences (Cameron & Trivedi, 1998) were estimated. Variations on the basic Poisson model, such as negative binomial and heterogeneity models (Winkelmann, 1997) were tried and found not to improve the fit or alter the results. The data thus do not appear to have overdispersion of events.

TABLE 2
Results of Linear Regression Analysis of R&D Intensity[a]

Variable	Model 1[b]	Model 2[b]	Model 3[b]	Model 4[c]
Intercept	−0.0051	−0.0053	−0.0091	
	(0.0062)	(0.0061)	(0.0058)	
Employees[d]	0.0025**	0.0026**	0.0025**	0.0003
	(0.0007)	(0.0006)	(0.0006)	(0.0006)
Annual production	−0.0004**	−0.0004**	−0.0004**	−0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Annual growth in shipping income	−0.0021	−0.0027†	−0.0030†	−0.0012
	(0.0015)	(0.0015)	(0.0015)	(0.0014)
Annual freight rate	0.0000	0.0000	0.0000	−0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Absorbed slack			0.057**	0.011
			(0.018)	(0.019)
Unabsorbed slack			0.0009	0.0059
			(0.0038)	(0.0038)
Potential slack			0.0000	0.0000
			(0.0001)	(0.0001)
Performance, aspiration < 0		−0.013	−0.013	−0.013
		(0.009)	(0.009)	(0.008)
Performance, aspiration > 0		−0.017*	−0.018*	−0.015†
		(0.008)	(0.008)	(0.008)
F[e]		0.09	0.10	0.03
Autocorrelation coefficient	.80	.80	.78	.78
Fraction of variance due to random effects	.36	.37	.18	
R^2	.33	.33	.49	
Difference from model 1		.00	.16	
Wald chi-square	22.31**	29.81**	50.36**	
df	5	7	10	

[a] Two-sided significance tests. Standard errors are in parentheses.
[b] Based on 11 firms and 229 firm-years. Models include random effects for firms and autocorrelation of disturbances.
[c] Based on 11 firms and 218 firm-years. Model includes fixed effects for firms and autocorrelation of disturbances.
[d] Logarithm.
[e] Test of the significance of the coefficient difference between aspiration levels above and below zero.
† $p < .10$
* $p < .05$
** $p < .01$

To check for underreporting, I estimated a zero-inflated model (Lambert, 1992) and a model with heterogeneity and endogenous underreporting related to firm size (Terza, 1998). The results of these models were consistent with those derived from the main analysis, indicating that underreporting of process innovations and small-firm innovations did not influence the model estimates.

RESULTS

Descriptive statistics are shown in Table 1. The correlations are low to intermediate, and performance and the three slack variables have low correlations with each other and with the control variables. Absorbed slack is positively correlated with firm size in these data, suggesting that a control for firm size is important for measuring the effect of absorbed slack. Experiments with models using subsets of the control variables revealed no estimation problems due to the correlations.

Search

Table 2 shows linear regression estimates of the R&D intensity of the studied firms. Model 1 has only the control variables; model 2 also has the variables testing Hypothesis 1; and model 3 includes all the variables. The results are consistent across models, so only the full model, model 3, is interpreted.

Performance. I tested Hypothesis 1 by entering variables for performance adjusted by the aspiration level, with separate coefficients above and below zero. The coefficients were expected to be negative and similar to each other. The estimates showed that performance negatively affected R&D intensity, consistent with problemistic search, but this effect was significant only for performance

TABLE 3
Results of Poisson Regression Analysis for Innovation Launches[a]

Variable	Model 1[b]	Model 2[b]	Model 3[c]	Model 4[d]
Intercept	−10.12	−8.86	−11.69	
	(1.52)	(1.70)	(2.95)	
Previous-year innovations in the industry	0.04**	0.04**	0.03†	0.01
	(0.01)	(0.01)	(0.02)	(0.02)
Employees[e]	0.67**	0.65**	0.99**	1.21*
	(0.11)	(0.12)	(0.30)	(0.59)
Annual production	−0.04	−0.05	−0.05	−0.05
	(0.04)	(0.04)	(0.04)	(0.04)
Annual growth in shipping income	1.28*	1.09*	0.90	0.67
	(0.56)	(0.56)	(0.6)	(0.62)
Annual freight rate	0.01	0.02	0.03	0.04*
	(0.02)	(0.02)	(0.02)	(0.02)
R&D intensity	−9.97	−5.97	8.04	35.23
	(18.65)	(18.36)	(22.81)	(30.08)
Absorbed slack	1.54	0.71	−2.97	−9.01
	(5.15)	(5.35)	(7.97)	(10.31)
Unabsorbed slack	3.30†	2.25	1.96	0.53
	(1.86)	(2.03)	(2.43)	(2.71)
Potential slack	−0.09	−0.05	−0.04	0.21
	(0.07)	(0.08)	(0.14)	(0.28)
Performance, aspiration < 0		2.99	3.32	2.64
		(5.24)	(5.70)	(6.06)
Performance, aspiration > 0		−34.12**	−27.02*	−20.10†
		(10.88)	(11.15)	(10.95)
Wald chi-square[f]		7.88**	4.90*	2.73†
Alpha			0.27	
			(0.25)	
Log-likelihood	−197.76	−186.30	−183.37	−153.49
Model significance test	133.35**	156.27**	82.19**	57.26**
df	9	11	11	11
Difference from model 1		22.92**	n.a.	n.a.
Maximum-likelihood R^2	.51	.57		

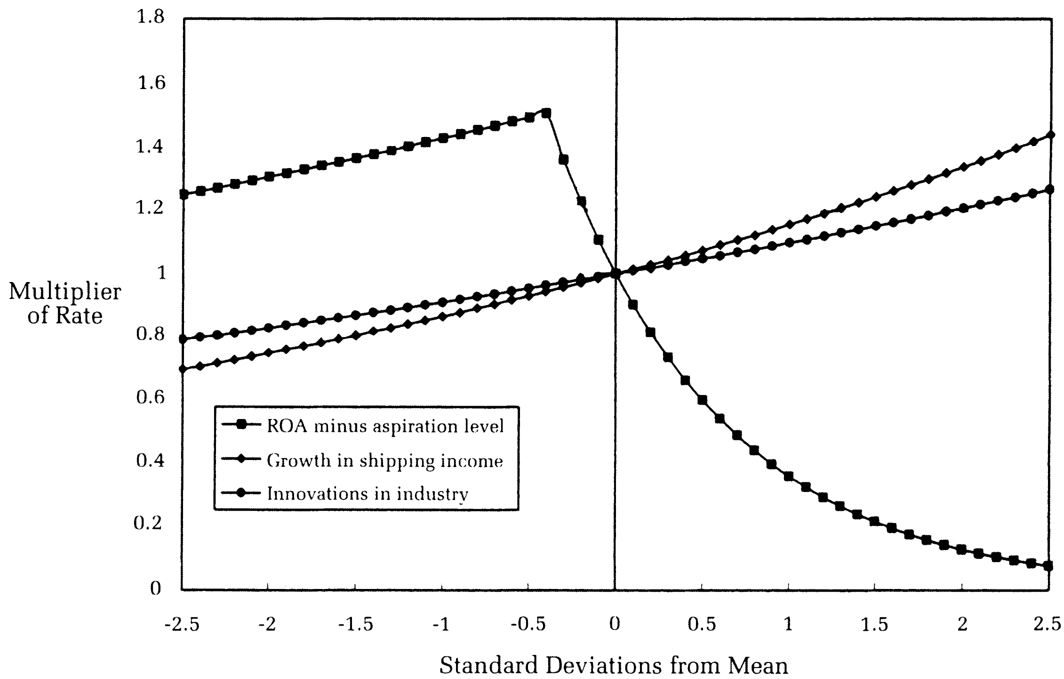
[a] Two-sided significance tests. Standard errors are in parentheses. Model tests are likelihood ratio tests for models 1–3 and a Wald test for model 4.
[b] Model has no firm effects. Based on 11 firms and 185 firm-years.
[c] Model has random effects for firm. Based on 11 firms and 185 firm-years.
[d] Model has fixed effects for firm. Based on 7 firms and 147 firm-years.
[e] Logarithm.
[f] Test of the significance of the coefficient difference between aspiration levels above and below zero.
† $p < .10$
* $p < .05$
** $p < .01$

above aspiration level. The coefficient estimates for performance above and below aspiration level were similar, however, and the difference (*F*-test) between the coefficients above and below zero was nonsignificant, suggesting that the model could be reestimated with a single performance variable. When this was done, the coefficient estimate was −0.016, which was significant at the 1 percent level. Hypothesis 1 is thus supported.

Slack. The coefficient estimates for the slack variables show that absorbed slack had a positive and significant effect, consistent with Hypothesis 2. No effect was found for the other forms of slack. Thus, firms with a large administrative component have a high level of search as indicated by R&D intensity. The large increase in variance explained (R^2) in model 3 shows that absorbed slack is very important for explaining R&D expenses. Hypothesis 2 is thus also supported, but only for absorbed slack.

Firm effects. Models 1 through 3 have random effects for firms, and the proportion of variance explained by the firm effects suggests that they are small. Indeed, a model without effects (not shown) gave results that are very similar to the displayed models. In model 4 fixed effects replace the random

FIGURE 2
Innovation Rate Multiplier Effects



effects. This substitution, which is equivalent to entering an indicator variable for each firm, gives a much stronger control for differences in the level of the R&D for different firms, and the results on some of the variables changed. In particular, slack was no longer significant, suggesting that the results of the previous model were mainly due to interfirm differences in slack rather than to within-firm change in slack over time. Slack changes slowly, and thus it is more effective for explaining how firms differ cross-sectionally in search intensity than how firms change their search intensity over time. The more volatile performance variable remained significant, though only at the 10 percent level. When a single performance variable was entered instead of separate variables for performance above and below the aspiration level, the estimate was −0.014, significant at the 5 percent level.

Innovation Launches

Table 3 shows Poisson models for the number of innovations a firm launched in a given year. As in Table 2, the initial model only has control variables. Models 2–4 have the full set of independent variables and different statistical controls.

Performance. In model 2, performance relative to aspiration level shows the expected negative relation to the number of innovations for performance above a social aspiration level. Below the social aspiration level, performance has a positive but insignificant effect. Thus, this model supports Hypothesis 3a, which predicts a declining rate of innovation as performance increases, for performance above aspiration level. The coefficients of performance above and below aspiration level are significantly different, with performance above the aspiration level showing a strongly negative effect on the rate of launching innovations, so Hypothesis 3b is also supported. The findings indicate that high performance suppresses innovation launches more than low performance increases them, consistent with inertia theory. The model fit statistics show a clear increase in "log-likelihood" and the variance explained when performance is entered, suggesting that performance is a good predictor of innovation rate.

Firm effects. Random effects for firms were entered in model 3, giving results that are the same as those for model 2. There is still support for a negative effect of performance above aspiration level, as predicted by risk theory (Hypothesis 3a), and this effect is weaker for performance below aspiration level than for performance above it, consistent with inertia theory (Hypothesis 3b). Finally, in model 4 firm fixed effects are entered, which reduces the significance level of performance to the 10 percent level.

Figure 2 displays the multiplier effects of performance relative to aspiration level, growth in shipping income, and innovations in the industry. In constructing the figure, I set the multiplier to unity at the origin and then varied each variable 2.5 standard deviations from the origin and computed new predicted values using the coefficient estimates of model 2. This procedure yielded a comparison of the effect strengths in a relevant interval of variation. Performance relative to aspiration level results in a sharply declining innovation rate above the aspiration level, with a change from the origin to +1.5 standard deviations giving a multiplier of 0.2. The curve increases slightly below the aspiration level, but this is not statistically significant. The aspiration level is about 0.4 standard deviations below the mean performance, so the curve bends to the left of the origin. Growth in shipping income gives a modest increase in the rate of innovation, with an increase of 1.5 standard deviations resulting in a multiplier of 1.25. The number of innovations in the ship building industry in the preceding year also has a small effect, with an increase of 1.5 standard deviations giving a multiplier of 1.15. Performance above aspiration level has the steepest slope in the specification, making it a good predictor of innovation rate. Indeed, if growth in shipping income and performance were both increased by 1.5 standard deviations, the predicted innovation rate would fall because the decrease caused by the performance effect is greater than the increase caused by the income effect.

Summary

The analyses of R&D intensity showed the predicted effects of both performance and slack, and the slack effect explained more variance. The analyses of innovation launches showed the predicted effect of performance. Thus, all predictions were supported: slack and performance adjusted by a firm's aspiration level affect firm search, and performance adjusted by the aspiration level affects the rate of innovation launch. Both analyses yield models that fit the data well (for R&D intensity, R^2 = .49; for innovations, R^2+ = .57). In both analyses, the fit is clearly higher in the final model containing the hypothesis-testing variables, than in the model with only control variables, although the controls-only models also fit well. The good fit to the data shows that the behavioral theory of the firm not only helps resolve conceptual issues in firm innovation, but is also empirically successful.

DISCUSSION AND CONCLUSIONS

The findings are clearly in favor of the view that problemistic and slack search are drivers of organizational search through R&D. The findings also show that organizations launch innovations in response to low performance. This study extends prior findings on how performance affects innovative efforts (Antonelli, 1989; Hundley et al., 1996; Kamien & Schwartz, 1982) by showing an effect on an innovative outcome: the launch of products incorporating new technologies. The findings are comparable to those obtained through other study designs and outcomes, and thus provide triangulation by replicating important findings across different dependent variables. Performance below a company's aspiration level has been shown to cause strategic reorientation (Audia, Locke, & Smith, 2000; Greve, 1998; Lant, 1992; Lant, Milliken, & Batra, 1992) and firm risk taking (Bromiley, 1991; Shapira, 1994; Wiseman et al., 2001). Add this prior evidence to the current finding that performance affects the rate of launching innovations, and it seems that performance relative to aspiration level functions as a "master switch" that affects a wide range of organizational behaviors (Greve, 2003). Add these findings on shipbuilding to extant findings of performance effects on strategies in airlines and trucking (Audia et al., 2000), furniture and software (Lant et al., 1992), radio stations (Greve, 1998), semiconductors (Boeker, 1997), computer workstations (Audia & Sorenson, 2001), and four high-tech industries (Bolton, 1993), and it seems that the theory applies across a wide range of industrial contexts.

Findings on slack search have been less clear than those on problemistic search, as studies have shown effects that are sometimes significant but rarely strong (Damanpour, 1991; Singh, 1986). Slack search was shown to have an inverted U-shaped effect on the rate of adopting technical and administrative innovations in one study (Nohria & Gulati, 1996), but the effect of slack search on launching technological innovations does not appear to have been investigated earlier. My analyses showed that absorbed slack affected search, but they revealed no effect of slack on innovation rates. The effect of slack in the development stage thus appears to be neutralized in the decision-making stage of the innovation process.

The conclusions come with some caveats related to the sample of firms used. The innovation rate of a focal industry may be linked to the rate of technological development in related industries; in particular, firms applying a quickly improving basic technology may demonstrate a high rate of search and innovation launches that just represents actions taken to keep up with expanding technological possibilities. In the software industry, for example, advances in processor speed, memory, and disk capacity have recently allowed launches of software innovations that would have exceeded computers' capacities a few years ago. It is not clear that such differences in the *level* of innovation rates imply that the *adjustment* of innovation rates differs from that in industries with more stable basic technologies. Still, one may retain some doubt about the generalizibility to technological environments with fast-moving basic technologies until further work has been done.

The effect of analyzing Japanese firms is also worth consideration. Although there are not theoretical reasons for them to differ from U.S. firms in their responses to performance and slack, there may be differences as to which goals receive attention. Managerial folklore would suggest that Japanese firms pay less attention to ROA and more to sales than their U.S. counterparts, and some researchers have made the same suggestion (Johansson & Yip, 1994). This suggestion seems to be contradicted by the present results on ROA and the findings of others who have studied how low profitability spurs change in Japanese organizations (Hundley et al., 1996; Kaplan & Minton, 1994; Lincoln, Gerlach, & Ahmadjian, 1996). Still, cultural and institutional differences may cause differences in responsiveness to different goal variables, and investigation of such issues should be encouraged once these basic findings are replicated in other contexts.

An important implication of these findings is the need to emphasize decision-making variables in innovation research. The historical emphasis on explaining firm differences in innovativeness by knowledge management or innovation process differences has given insights into why firms differ in innovativeness, but this emphasis leads to overlooking the great variability of firm innovativeness over time. An innovation doesn't leap straight from the laboratory to the market; rather, the decision to launch it is an important intervening step guided by problem solving and risk taking. Comparison of a firm's performance and aspiration levels strongly influences the decision-making step in the firm, and this influence results in innovation rates that respond to performance much like the rates of strategic changes do.

The findings suggest that innovation buffers are important. The effect of the decision-making step was so strong in these data that the firms appeared to be rolling out innovations exactly when they were needed, with innovation launches following the year after performance had been disappointing. Such quick reaction to adversity clearly cannot be the result of a full innovation development cycle, as one year is too short a time to develop the kind of complex innovations that shipbuilders make. Rather, it supports the argument that innovations are sometimes rejected and are added to a buffer that can be drawn on when low performance increases top managers' risk tolerances (Garud & Nayyar, 1994). The firms may also have been engaged in ongoing development processes and had innovations close to completion that also constituted a buffer for use in hard times.

This research thus supports earlier theoretical work on stages and buffers in the innovation process. Innovation development can be viewed as a sponge: capabilities fill the sponge with potential innovations, and good R&D practices squeeze the sponge to bring out innovations (Fiol, 1996). This model helps explain many inconsistent findings in the development process literature, as studies on capabilities only or R&D practices only are misspecified. The findings from this study suggest that there are two sponges: Innovations squeezed out of the development sponge enter the decision-making sponge, and are squeezed out by managerial risk tolerance. The conceptualization of a process with buffers (sponges) is likely to be very useful in guiding quantitative research on organizational innovativeness, and it may also stimulate qualitative research on how organizations treat innovations after their launches have been rejected. Such qualitative research would be a natural next step for research on rejection of innovation launches (Dougherty & Hardy, 1996; Dougherty & Heller, 1994) and would connect well with the observation that canceled R&D projects are sometimes continued in secret (Burgelman, 1994).

These findings also suggest an extension of work on innovation diffusion, which is a major portion of organizational research on innovations (Drazin & Schoonhoven, 1996). Diffusion research has a nearly exclusive focus on external influences on organizational decisions to adopt innovations (Strang & Soule, 1998). External influences are clearly important in adoption decisions, but it seems worthwhile to also investigate whether adoptions of external innovations are affected by performance feedback, just as a firm's decisions to launch its own innovations were in these data. It appears that very little work has investigated performance effects on imitation (but see Kraatz [1998]).

The findings can help researchers predict what kinds of firms are particularly likely to launch innovations that change the evolution of an industry. A firm with a history of high slack and low risk taking is likely to have amassed a large innovation buffer that it can use to respond to low performance by launching innovative products. This dynamic may account for the observations that large and seemingly inert firms can respond quickly and effectively to challenges (Chen & Hambrick, 1995;

Ferrier, Smith, & Grimm, 1999) and that, in consequence, small firms prefer stealthy competitive attacks (Chen & Hambrick, 1995). It seems that managers of large firms ignore competitors' innovations when they lead to gradual performance decreases (Christensen, 2000), most likely because they accommodate to slowly declining performance by reducing their aspiration levels (March, 1988).

Future theoretical work should examine the adaptiveness of the behavioral pattern of launching innovations in response to low performance. Both normative and behavioral risk-taking theory involves trade-offs between expectation and risk, and it is conventional to judge behavioral risk-taking strategies on the basis of how closely they match a normative strategy. Adapting risk to performance feedback is criticized because it causes temporal inconsistency in risk taking by allowing an innovation judged as too risky in times of high performance to become acceptable in times of low performance. Temporally inconsistent decision rules may be a source of inefficiency in an economy, but they also produce robust firms that can survive over time by forgoing some profits for the sake of reducing variability in profits (Levinthal & March, 1981; March & Shapira, 1992). Critical examination of the riskiness of a given innovation before launching it may be a reasonable managerial practice, as is a greater willingness to launch risky innovations in response to low performance.

Innovation research will be enriched if more studies will take into account the difference between developing and launching innovations and apply search and decision-making theory to these behaviors. This perspective predicts innovations well and has the potential to greatly increase the precision of innovation theory. It offers an explanation of the paradox of successful firms failing to innovate (Audia et al., 2000), and it raises interesting questions to explore in future research. How is innovation rate affected by the proliferation of profit centers and performance measures seen in large modern corporations? More frequent and more specialized performance measures should produce greater variability in performance, which increases the probability that a given organizational unit will be taking risks. How is an organization's innovation rate affected by its authority structure? Adding layers of management increases the potential for innovation rejections, giving theoretical foundation for the frequent suggestion that tall organizational structures are biased against innovations. Further, how is an innovation rate affected by the industrial structure? The role of interfirm comparison in determining aspiration levels suggests that great differences in the performance of organizations can set off innovation races by causing many organizations to fall below their aspiration levels. These questions offer a rich agenda for future research on firm innovativeness.

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Henrich R. Greve *(henrich.greve@bi.no)* is a professor of strategy at the Norwegian School of Management BI. He received his Ph.D. in business at the Graduate School of Business, Stanford University. His current research examines effects of performance feedback and top management teams on strategic change in organizations.

APPENDIX

Selected Innovations in 1974, 1984, and 1994

Date	Innovating Firm	Description	Remarks
January 1974	Hanshin Diesel and Japan Ship Machinery Development Association	A powerful new diesel engine	Firm is not in data. Innovation was codeveloped.
January 1974	Ishikawajima-Harima Heavy Industries	A 622,000 deadweight tons tanker	
February 1974	Mitsubishi Heavy Industries	The world's first two-stage supercharger for diesel engines	
March 1974	NHK Spring and Rockwell International	A liquefied natural gas (LNG) tank installation system	Firm is not in data. Innovation was codeveloped.
March 1974	Terazaki Electric and Noratom Norcontrol	A diesel engine control system	Firm is not in data. Innovation was codeveloped.
April 1974	Kawasaki Heavy Industries	A vertical, one-side butt-welding system with a backing material	
May 1974	Okura Trading	A new ocean-going pusher barge system	Firm is not in data.
May 1974	Ishikawajima-Harima Heavy Industries	The world's largest crane ship	
June 1974	Hitachi Shipbuilding	An overlay propeller shaft	
July 1974	Hitachi Shipbuilding	A new float-type mooring gear	
August 1974	Sasebo Heavy Industries	A new model of LNG tank	
August 1974	Mitsubishi Heavy Industries	A multipurpose marine simulator	
October 1974	Kobe Steel	The world's largest grab dredger	Firm is not in data.
February 1984	Mitsui Shipbuilding	An automatic steering system	
February 1984	Hitachi Shipbuilding	A new design for product carriers	
February 1984	Kawasaki Heavy Industries	The largest test vessel for deep ocean simulation ever constructed in Japan	
March 1984	Kokusai Denshin	The smallest ship antenna in the world	Firm is not in data.
July 1984	Sumitomo Heavy Industries	The world's largest crane barge	
November 1984	Mitsubishi Heavy Industries	A new electrical drive-turning balancer	
December 1984	Mitsubishi Engineering	A high-performance generator	Firm is not in data.
January 1994	Ishikawajima-Harima Heavy Industries	A new type of Houde damper using magnetic damping	
February 1994	Mitsui-Miike Machinery	A system for labor saving in bulk carrier unloading	Firm is not in data.
April 1994	A.D.D.	A prototype next-generation marine diesel engine	Firm is not in data.
August 1994	Ishikawajima Harima Heavy Industries	A compact hybrid antirolling device that can reduce rolling to one-third	
October 1994	Hitachi Shipbuilding	A miniature marine welding robot for sharply curved surfaces	