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THE PERILOUS LEAP BETWEEN EXPLORATION AND EXPLOITATION

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Research summary: *R&D-based exploration and exploitation are necessary in order for firms to have sustainable competitive advantage. Yet, transitioning between these orthogonal types of R&D is considered profound organizational change. Building on recent research showing that compact, significant changes in R&D expenditure is an antecedent to the transition between explorative and exploitative R&D, I show that this leap between exploration and exploitation is quite hazardous. The magnitude of changes in R&D expenditure, whether increases or decreases, is positively associated with organizational failure. Firms maintaining higher levels of absorptive capacity are more capable of surviving the leap from R&D-based exploitation to exploration, and firms that do not use reductions in R&D expenditure to manipulate short-term earnings performance are more likely to survive the leap from exploration to exploitation.*

Managerial summary: *In order to survive and thrive, innovative companies must be able to exploit their existing competencies, and to explore for new ones once those current competencies decline in value. However, transiting from one form of innovation to the other is difficult because the skills required to explore are fundamentally opposed to those required to exploit. In this article, I describe how difficult this leap between exploration and exploitation can be. I show that the move between R&D-based exploration and exploitation is related to organizational failure. In addition, firms that are superior learners are more likely to survive the leap from exploitation to exploration, and firms that are not cutting R&D expenditure to manipulate earnings are more likely to survive the leap from exploration to exploitation.*

INTRODUCTION

There is a broad consensus that R&D-based exploration and exploitation are necessary elements in the firm's innovation process (March, 1991, 1996, 2006). Firms conducting too much exploitative R&D are unable to find new forms of innovation once existing firm competencies become obsolete, falling into "competency traps" (Levitt and March, 1988). Firms conducting excessive amounts of exploratory R&D have limited ability to tap into the commercial value of their discoveries (Levinthal and March, 1993).

Some scholars have asserted that the skills required to undertake exploration or exploitation are incompatible, and cannot be practiced by one firm at the same time (He and Wong, 2004; March, 1991, 1996, 2006). R&D initiatives compete for scarce resources within the firm; allocating those resources across two opposing types of innovation compromises progress in both domains. Resources allocated to exploitation diminish chances of success in exploration, and vice versa. One way to mitigate the tension between exploration and innovation is by practicing these opposing modes of R&D sequentially, using temporal separation

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(Brown and Eisenhardt, 1997). The research focus of this article is on the consequences of practicing sequential ambidexterity.

Recently, Mudambi and Swift (2014) found that firms making compact, significant increases in R&D spending are moving from exploitative to exploratory R&D. They show that the magnitude of these shifts in firm-level R&D spending, whether positive or negative, is associated with increased innovative performance. This suggests that, in general, firms benefit significantly from practicing sequential ambidexterity.

In this article, I indicate that this is not the whole story. While Mudambi and Swift (2014) find that, in general, firms making the leap between exploration and exploitation are superior performers, this study shows that a significant portion of other firms fail to make the leap, and die in the process. By observing the inputs to the R&D process (i.e., shifts in R&D spending) rather than R&D-based outputs (e.g., patents or new products) to determine when and to what extent the firm is transitioning between R&D-based exploration and exploitation, we are able to observe firm performance *as firms are making the attempt* to transition between these opposing forms of R&D-based innovation, and observe organizational mortality rates as the process unfolds. Analysis provided below shows that the magnitude of compact, significant changes in R&D spending, in either direction, is associated with a higher incidence of firm mortality. These results are found after controlling for organizational failure that is attributable to the firm's financial health, and whether the firm is currently practicing exploration, exploitation, or simultaneous ambidexterity.

I identify contingencies that mitigate the risk of transitioning between R&D-based exploration and exploitation. Results provided below indicate that firms with higher levels of absorptive capacity are less likely to fail after a compact, significant increase in R&D spending, suggesting that firms with a stronger ability to identify valuable external knowledge and to assimilate it into their innovation processes are more likely to survive an aggressive transition into exploratory R&D. Firms that generate earnings performance that more frequently and extensively underperforms relative to their peer groups are less likely to fail following a compact, significant decrease in R&D spending. Firms that aggressively reduce R&D spending in order to improve earnings, rather than because the firm has good reason to transit from exploratory to exploitative R&D, are hollowing out the core competency in the firm, which significantly increases the likelihood of firm failure.

R&D MANAGEMENT AND ORGANIZATIONAL AMBIDEXTERITY

Perhaps the longest-standing view on how firms practice R&D-based exploration and exploitation is via sequential ambidexterity (Brown and Eisenhardt, 1997). Firms alternate between these orthogonal forms of innovation over time as market conditions change and demand different forms of innovation from the same firm (Tushman and Romanelli, 1985). R&D expenditure volatility can indicate the presence of sequential ambidexterity, wherein firms move between exploitation and exploration (Mudambi and Swift, 2011, 2014).[1]

However, Mudambi and Swift (2011, 2014) leave us with important unanswered questions. While this prior work has evaluated the performance benefits of practicing sequential ambidexterity, it did not consider the risks. In this article, I focus not on firm performance, but on firm survival. I show that sequential ambidexterity has ramifications far beyond firm performance, and indeed, has serious impacts to the very survival of the firm.

The idea that organizational ambidexterity can contribute to firm mortality has existed for some time. R&D-based exploitation requires refinement, efficiency, and execution. R&D-based exploration requires play, variation, and risk taking (March, 1991). These different skills sets are orthogonal and fundamentally incompatible (He and Wong, 2004). In his seminal papers, March described the adaptive process of alternating between exploration and exploitation as self-destructive (1991); in evaluating the appropriateness of the firm's rational technologies to choose exploratory or exploitative innovation, he observes that it produces "many more disasters than … glories of successful

[1] Most pharmaceutical R&D expenditure is associated with exploration (Gagnon and Lexchin, 2008), and early-stage product development work requires higher levels of R&D expenditure than late-stage activities. Exploratory R&D is more costly than exploitative (DiMasi, Hansen, and Grabowski, 2003; Dyer, 1996). In general, compact, significant increases in R&D expenditure are followed by increases in the technological scope of knowledge creation activities and an increased likelihood of the firm creating a highly-cited patent (Mudambi and Swift, 2014), indicating the firm is ramping up exploratory R&D.

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discovery" (2006: 208). March speculates that the increasing difficulty of transiting between exploration and exploitation can give rise to the "disposable organization" (1995).

We simplify our decision heuristics (Kahneman and Tversky, 2000; March, 2006), leading to errors in balancing exploration and exploitation. In retrospect, we assign probabilities of 100 percent to successes and 0 percent to failure, when in fact, the actual probability distributions were quite different. Thus, we overemphasize the importance and meaning and both successes and failures; the distinctions between them are far more subtle. The ability to move between exploration and exploitation is exacerbated because firms establish long-term incentive systems and financial targets that encourage one form of innovation over the other (March, 1991).

Increases in R&D expenditure and absorptive capacity

Firms pursue exploitative R&D during periods of relative stability, and move to exploration during short periods of intense change (Levinthal and March, 1993; March, 1991, 1996, 2006; Mudambi and Swift, 2011, 2014). This transition from exploitation to exploration is profound change, and requires that all elements of the firm modify its practices (March, 1991), thereby increasing the likelihood of firm mortality (Barnett and Freeman, 2001).

A broad body of scholars agrees that R&D-based exploration is risky. Exploration involves experimentation, pursuing new innovation that is relatively distant from the firm's existing knowledge base (He and Wong, 2004). Exploratory R&D is a stochastic process. The nature of this process makes it impossible to predict when valuable forms of new innovation will be discovered (Anderson and Tushman, 2001). Exploration requires significant flexibility from the firm, as it must adapt to new forms of innovation, and such firm-level change is hazardous (Hannan and Freeman, 1977). For example, Barnett and Freeman (2001) posit that increasing new product introductions create considerable disruption within the firm. They show that higher levels of new product introductions are associated with increased rates of organizational mortality.

Observing the magnitude of the single-year change in R&D expenditure is important. Firms that transition between R&D-based exploration and exploitation relatively slowly, over a multi-year period, place less stress on the organization than a firm that makes this transition swiftly, or all in one year. Thus, the larger the single-year change in R&D expenditure, the more risk incurred by the firm from significant organizational change. This leads to my first hypothesis:

Hypothesis 1a: The magnitude of compact, significant increases in R&D spending is positively related to the likelihood of organizational failure.

Prior research on absorptive capacity (Cohen and Levinthal, 1989, 1990) provides insights on firm-level capabilities that are necessary to make the leap successfully from exploitation to exploration. The firm cannot benefit from exploratory R&D by merely exposing itself to new sources of knowledge (Cohen and Levinthal, 1989, 1990; Escribano, Fosfuri, and Tribó, 2009). In addition to this exposure, the firm must have the ability to recognize commercially valuable new knowledge, and to assimilate it into its innovation processes.

Firms develop absorptive capacity in a path-dependent way, by engaging in R&D over time. These capabilities are particularly valuable when the firm engages in sequential ambidexterity. Higher levels of absorptive capacity leads to a heightened awareness of new opportunities that call for increased exploratory R&D. Rothaermel and Alexandre (2009) show that absorptive capacity positively moderates the relationship between ambidexterity and firm performance. They find that "an appropriate level of absorptive capacity allows a firm to overcome inherent tensions in ambidexterity that arise … from the simultaneous pursuit of exploration and exploitation … thus allowing the firm to harness ambidexterity benefits more fully" (2009: 760).

Absorptive capacity allows firm "researchers to prioritize potential research avenues and avoid costly and time-consuming research trials that end in failure or low-valued outcomes" (Fabrizio, 2009: 256). This capability is integrally linked with March's prescriptions for enhancing the likelihood of success via exploratory R&D. March (2006) suggests that firms can successfully explore by limiting the bet size. That is, firms that can find ways to explore by making smaller bets, rather than larger more consequential bets, are more likely to succeed.

By limiting bet sizes while exploring, "bad ideas can be sorted from good ones at a cost that is less than the return generated by the few good

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ones when they are scaled up" (March, 2006: 210). The firm's absorptive capacity, gained over time by conducting R&D activities in-house, enables the firm to distinguish between good and bad R&D projects, and in turn, limit the size of the bets placed in R&D-based exploration.

Firms with lower levels of absorptive capacity are more likely to engage in purely speculative exploratory R&D, with fewer criteria used to discriminate between good and bad R&D opportunities. Those firms incur the increased cost of exploratory R&D without enjoying the benefits of discovering new forms of valuable knowledge. This can cause firm failure. This leads to a second, complementary research hypotheses:

Hypothesis 1b: The firm's level of absorptive capacity negatively moderates the relationship between the magnitude of compact, significant increases in R&D spending and the likelihood of organizational failure.

Decreases in R&D expenditure and myopic loss aversion

Through the routine course of events, most firms return to exploitation once R&D-based exploration has yielded new forms of competitive advantage, which leads to reductions in R&D spending (Mudambi and Swift, 2014). Such changes in R&D expenditure are beneficial to the firm as it permits the firm to turn away from exploratory R&D and to begin refining its new forms of competitive advantage for commercial benefit. However, the leap from exploration to exploitation can also be risky; firms that abandon R&D-based exploration without having discovered a valuable new form of competitive advantage will be unable to engage in commercially valuable exploitation. To that point, March states: "History is filled with cases where the technologies of rationality have initiated or supported experimentation with new actions or strategies that offer novel approaches of great predicted value. Characteristically, the predicted values have failed to materialize .... These errors are costly, even deadly, in their consequences" (2006: 208).

Prospect theory helps us to understand another type of peril involved in moving from R&D-based exploration to exploitation. March (2006) explains that firms use "technologies of rationality" to manage the trade-offs between R&D-based exploration and exploitation. These rational techniques involve abstractions, data and decision rules in order to make choices between exploitation and exploration. These decision rules are often developed based on firm performance relative to reference point (Kahneman and Tversky, 2000). That is, firms that are performing above some reference point are risk-averse, and more likely to emphasize R&D-based exploitation regardless of the opportunities available to them via exploration.

Thus, the move from R&D based exploration to exploitation can be hazardous for three reasons. First, the skills required to undertake exploitation are orthogonal to those required to undertake exploration (March, 1991). Second, firms may return to exploitation only to find that the new forms of innovation discovered during the prior period of exploration are of little to no value (March, 2006). Third, firms performing above some internal performance objective are risk-averse, and more likely to move from exploration and toward exploitation, even when promising opportunities exist in R&D-based exploration. Missing out on opportunities to discover commercially valuable new forms of innovation can be profoundly costly as competitors seize new superior forms of innovation faster. This can impact firm mortality. This prevailing logic leads to a third research hypothesis.

Hypothesis 2a: The magnitude of compact, significant decreases in R&D spending is positively related to the likelihood of organizational failure.

We know that, on average, the magnitude of compact, significant decreases in R&D spending is positively related to firm performance (Mudambi and Swift, 2014). Yet, this new perspective suggests that this same measure can also be related to firm failure. Further inquiry enables us to discriminate between "good" and "bad" reasons to cut R&D spending by leveraging prospect theory (Tversky and Kahneman, 1991, 1992) again. Prospect theory predicts that decision-makers will go to considerable lengths to avoid losses (Abdellaoui, Bleichrodt, and Paraschiv, 2007).

Myopic loss aversion, an extension of prospect theory, is particularly informative within the context of this study. Myopic loss aversion predicts that decision-makers are more risk averse regarding decisions that are evaluated more frequently, and less risk-averse regarding decisions that are evaluated less frequently (Benartzi and Thaler, 1995). The returns to R&D are distant and less certain (Anderson and Tushman, 2001). Yet, short-term earnings results of publicly traded firms are evaluated quarterly, and managers are under great pressure to meet current earnings targets. Thus, myopic loss aversion suggests that firm decision-makers are more likely to be risk-averse regarding short-term earnings performance, and less risk-averse regarding long-term R&D prospects. Empirical research supports the predictions of myopic loss aversion. Using family firms as the research setting, Gomez-Mejia, Makri, and Larraza-Kintana (2010) show that when firm performance is in jeopardy, family decision makers prefer the more certain gains generated from lower R&D investments to the riskier chance at long-term gains from higher R&D investments.

One way to detect whether firms reduce R&D spending in order to improve short-term earnings performance is to evaluate the frequency and extent to which the firm generates earnings that are below the earnings performance of their peers *after* the firm undertakes a compact, significant cut in R&D expenditure. If the firm's earnings meet or exceed the earnings performance of its peer group firms after an R&D expenditure decrease, it is more likely that the firm undertook that R&D spending cut in order to meet earnings targets, and less likely that the firm has a viable reason to curtail exploratory R&D.

Prior work supports this assertion. Mudambi and Swift (2014) showed that the positive relation between compact, significant changes in R&D expenditure and firm performance is stronger among firms that generate earnings that are more frequently and substantially below their peer groups. Firms that frequently and substantially generate earnings that are below the benchmark average earnings of their peer groups are risk-seeking (Jegers, 1991), and are less likely to be using changes in R&D expenditure to manipulate short-term earnings. The benefits of meeting short-term earnings targets are more certain and closer at hand than the long-term, unreliable benefits from R&D investment. Thus, I expect firms that meet earnings expectations after an R&D spending cut are more likely to be engaging in myopic behavior. This leads to a fourth hypothesis.

Hypothesis 2b: The frequency and extent to which the firm's earnings have underperformed its peer group after a compact, significant decrease in R&D spending negatively moderates the relationship among the magnitude of compact, significant decreases in R&D spending, and the likelihood of firm failure.

DATA AND METHOD

In order to test these hypotheses, financial and R&D-related data was gathered on a sample of publicly traded U.S. manufacturing firms.

The data

Following Mudambi and Swift (2014), the main dataset is generated from the Compustat Annual North America database (Standard and Poors, 2012), which provides accounting and market information on all publicly traded firms in the United States. The sample is taken from all publicly traded manufacturing firms in the United States from 1997 to 2011 (a 15-year study period).[2] After removing observations with missing values, the data-set holds 3,173 firms and 22,251 firm-year observations.

In general, there is an indeterminate time lag between firm-level innovative effort and its impact on firm performance (Hall, Griliches, and Hausman, 1986). In constructing the datasets, I link each firm's largest annual change in R&D spending to the probability that the firm is de-listed from Compustat due to bankruptcy or liquidation in the three years following the firm's largest change in R&D expenditure. One hundred and fifty-six firms, or about 4.9 percent of firms in this sample, fail during the 15-year study period.

Dependent variable

Firm failure is routinely used as the dependent variable in studies focused on the consequences of organizational change (Barnett and Freeman, 2001), and the transition between R&D-based exploration and exploitation is major organizational change, involving all facets of the organization (Romanelli and Tushman, 1994). I estimate organizational failure as the natural log

[2] Using a sample comprised of all publicly traded U.S. manufacturing firms avoids concerns regarding sample selection.

of the odds (logit) that the firm will fail within three years after its largest annual change in R&D spending. Firms are de-listed in Compustat for a number of reasons, many of which are not related to organizational failure.[3] Firm failure is de-listing due to bankruptcy or liquidation. If the firm fails in the three years following its largest increase (or decrease) in R&D expenditure, the dependent variable is set to 1. Otherwise, the dependent variable is set to 0.

Independent variables

Compact, significant changes in R&D expenditure

Compact, significant changes in R&D expenditure are measured as the firm's largest one-year change in R&D spending over the 15-year study period as maximum of the absolute value for all normalized residuals for each firm from a Generalized Autoregressive Conditional Heteroskedastic (GARCH) time trend of R&D spending (Mudambi and Swift, 2014). This approach picks up unexpected changes in R&D spending net of R&D expenditure growth. It also identifies the most extreme change in R&D spending relative to all of the changes that the firm exhibits during the study period. Prior research has shown that the use of this independent variable is robust to the assumption of endogeneity (Mudambi and Swift, 2014).

Similarly to Mudambi and Swift (2014), I use a four-step process to estimate these changes. First, I use a GARCH model to estimate the firm-level R&D expenditure trend over time. These residuals represent the frequency and extent to which the firm's R&D spending diverges from a forecast that one would have predicted reasonably based on the firm's historical R&D expenditure trend (Anderson and Tushman, 2001). A firm with very small residuals is interpreted as a firm with a very smooth R&D expenditure profile.

Second, it is necessary to incorporate the variance of the stochastic process that generated these residuals in order to compare one with another. Therefore, these residuals are normalized. I generate studentized residuals, which are defined as:

$$\mathrm{e_{it}\,(stud)} = \frac{\mathrm{e_{it}}}{\left[Si\sqrt{\left(1-\mathrm{h_{it}}\right)}\right]} \tag{1}$$

where $\mathrm{s_i} = \sqrt{\mathrm{variance}\ \left(\mathrm{e_{it}}\right)}$, $1997 < \mathrm{t} < 2011$ and $\mathrm{h_{it}} = \mathrm{leverage}\ (\mathrm{e_{it}})$.

Third, I take the maximum of the absolute values for all residuals for the firm for each firm, that is, $\mathrm{e_i(max)} = \mathrm{Max}_{\ \mathrm{t}}\ [\mathrm{abs(e_{it}(stud))}]$, $1997 < \mathrm{t} < 2011$.

Fourth, I create two new variables. If the residual with the largest absolute value is positive, then the variable capturing increases in R&D spending is set equal to the absolute value of the increase, and the variable capturing decreases in R&D spending is set to 0. If the residual with the largest absolute value is negative, then the variable capturing increases in R&D spending is set to 0, and the variable capturing decreases in R&D spending is set equal to the absolute value of the decrease, as follows:

$$\text{R\&D spending increases} = \begin{cases} \mathrm{e_i\,(max)}\ \text{if}\ \mathrm{e_{it}\,(stud)}\ \text{is positive} \\ \text{zero if}\ \mathrm{e_{it}\,(stud)}\ \text{is zero or negative} \end{cases}$$

$$\text{R\&D spending decreases} = \begin{cases} \text{zero if}\ \mathrm{e_{it}\,(stud)}\ \text{is zero or positive} \\ \mathrm{e_i\,(max)}\ \text{if}\ \mathrm{e_{it}\,(stud)}\ \text{is negative} \end{cases} \tag{2}$$

In this way, I am able to measure the extent to which the firm makes a dramatic, compact change in R&D expenditure. Firms with relatively stable changes in R&D expenditure over the study period will have a relatively small maximum studentized residual. Firms that make very few substantial changes in R&D expenditure will have a larger maximum studentized residual. Note that firms that exhibit a relatively stable pattern of changes in R&D expenditure will have a smaller maximum studentized residual, because a studentized residual is calculated by dividing a forecast residual by the standard deviation of all residuals from the firm-level time series forecast. Firms with several large residuals about the GARCH trend generate large standard deviations across the residuals, which will result in a set of relatively small studentized residuals. Only firms with a set of relatively

[3] The Compustat reason for deletion from variable ("DLRSN") can take eight values. They are: (1) acquisition or merger, (2) bankruptcy, (3) liquidation, (4) reverse acquisition (1983 forward), (5) no longer fits original format (1978 forward), (6) leveraged buyout (1982 forward), (7) now a private company, (8) other.

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small residuals and very few large residuals will generate large studentized residuals.

Absorptive capacity

Prior research supports the view that sustained investment in R&D increases the firm's absorptive capacity (Rothaermel and Alexandre, 2009). This variable is commonly operationalized using R&D intensity (Cohen and Levinthal, 1989, 1990; Rothaermel and Alexandre, 2009), which is R&D expenditure divided by firm sales.

Firm earnings underperformance relative to industry peers

I follow Mudambi and Swift (2014) by using a lower partial moment (LPM) of the firm's earnings underperformance relative to target. The firm's earnings benchmark is the average return on assets of the industry within which the firm competes from the previous year (Miller and Reuer, 1996). The variable is calculated as follows:

$$RLPM = \sqrt{(1/m)\sum_{1}^{m}(x)^{n}}, \tag{3}$$

where m = number of time periods used in the measure, n is an arbitrary integer greater than or equal to 2, and x = target − actual. If target < actual, then x is set to 0.

Following Mudambi and Swift (2014), m is equal to 2 and n equal to 2.

Control variables

There is a broad literature providing empirical support for factors that affect firm performance. In this analysis, I use the same vector of control variables used by Mudambi and Swift (2014), and add three more control variables that capture the impact on firm failure that is attributable to the firm's financial health, the extent to which it is pursuing R&D-based exploration, and the extent to which it is pursuing R&D-based exploitation.

R&D intensity is also included as a control variable, since research shows that R&D-based innovation drives firm survival (Lee, 2003). I include firm sales to control for firm size. Earnings per share (net income divided by shares outstanding) is included to capture the effect of firm profitability on firm performance (Erickson and Whited, 2000). Firm performance has been shown to decrease over corporate diversification (Berger and Ofek, 1995). I use an entropy index to measure corporate diversification (Hitt, Hoskisson, and Kim, 1997). Lang, Ofek, and Stulz (1996) find that firm leverage effects firm performance. The firm's debt ratio (long-term debt divided by total assets) is included to control for the influence of leverage.

Clearly, the firm's financial performance is a major predictor of the probability of firm failure. While other measures of firm-level financial performance are included as described above, I also control for financial distress by including the firm's Altman's Z-score. The Altman's Z score is a predictor of a firm's likelihood to declare bankruptcy within the next three years (Altman, 1968), which is particularly relevant when studying firm failure. The Z score is calculated as:

$$\begin{aligned} Z = {} & 0.012X1 + 0.014X2 + 0.033X3 \\ & + 0.006X4 + 0.999X5, \end{aligned} \tag{4}$$

where X1 = working capital/total assets, X2 = retained earnings/total assets, X3 = earnings before interest and taxes/total assets, X4 = market value of equity/book value of total liabilities, X5 = sales/total assets.

I also control for the extent to which firms are practicing exploration, exploitation, or ambidexterity across the study period. In this way, I can determine the relationship between the magnitude of firm-level R&D spending increases or decreases and firm mortality, after controlling for the extent to which firms are already engaging in either, or both, form of innovation. I modify Mudambi and Swift's (2014) measure of the technological scope of the firm's knowledge creation activity to measure the extent to which the firm practices R&D-based exploration and exploitation, which was a measure of dispersion of firm knowledge creation across U.S. Patent and Technology Office (USPTO) technological classes. A firm engaging in knowledge creation across a wider dispersion of classes is engaging in more exploration, and vice versa.

R&D-based exploitation is calculated as the number of patents created in the same USPTO technological classes over the past three years. R&D-based exploration is calculated as the number of patents created in new USPTO technological classes over the past three years.

Estimation method

Event history analysis can be used to evaluate organizational mortality. However, this approach contains two drawbacks that prevent its use in this study. First, survival analysis precludes the use of firm-level fixed effects, which control for all variables that have not or cannot be recorded (Allison, 2005). Second, firms cease to appear in my dataset in ways that violate the assumptions of survival analysis (Lawless, 2002).

Multiple logistic regression analysis is used on the panel of firm-year observations to test each hypothesis. I use a fixed effects logistic regression to estimate equations using the log of the odds (logit) of firm failure within three years of the largest change in the firm's R&D expenditure as the dependent variable. This enables me to record firm mortality that occurs relatively soon after the change in R&D spending; a firm failure that occurred ten years after the firm's biggest change in R&D spending may not be related to the transition between exploration and exploitation. Using panel data with fixed-effects has the advantage of capturing unrecorded or unobserved differences between firms (Allison, 2005). The vector of control variables detects time-varying changes in the firm's environment, while the firm-level fixed effects pick up differences between firms.

ANALYSIS AND FINDINGS

The supporting information to this article shows the summary statistics of my dataset in Table S1. Measures of firm size, R&D intensity, firm debt, compact, significant increases in R&D spending, and compact, significant decreases in R&D spending are heavily skewed, and are log-transformed. Firm R&D intensity is negatively correlated to firm size, suggesting that firms achieve scale economies in R&D. Corporate diversification is positively correlated with firm size, suggesting that firms diversify as they get larger.

Primary tests

Hypothesis 1a predicts that there is a positive relationship between the magnitude of compact, significant increases in R&D expenditure and the probability of organizational failure. The results of the analysis are provided in Table 1 below. The base specification including control variables only is shown in column 1. The specification including the measures of the largest compact, significant increases R&D spending, and the largest, compact, significant decreases in R&D spending is shown in Table 1, column 2.[4] The log likelihood ratio indicates that the explanatory power of the specification shown in column 2 is greater than the specification shown in column 1. The parameter estimate on measure of compact, significant increases in R&D spending is positive and statistically significant. Hypothesis 1a is supported.

Hypothesis 1b predicts that absorptive capacity negatively moderates the relationship between the magnitude of compact, significant increases in R&D spending and firm mortality. This hypothesis is tested by adding the product of absorptive capacity (measured by R&D intensity) and the measure of compact, significant increases in R&D spending to the specification shown in column 2. The results of estimating this specification is shown in column 3. Once again, note that the log likelihood ratio indicates that the explanatory power of the specification shown in column 3 is greater than the specification shown in column 2. The parameter estimate on the interaction of absorptive capacity and the measure of compact, significant increases in R&D spending is negative and statistically significant. Hypothesis 1b is supported.

Hypothesis 2a predicts that there is a positive relationship between the magnitude of compact, significant decreases in R&D expenditure and organizational failure. The results of this analysis are also presented in Table 1, column 2. The parameter estimate on the absolute value of the measure of compact, significant decreases in R&D spending is positive and statistically significant. Hypothesis 2a is supported.

Hypothesis 2b predicts that the frequency and extent to which firm earnings underperform its peer group negatively moderates the relationship between the magnitude of compact, significant

[4] Prior research has shown that, in general, R&D-based exploration is more expensive than R&D-based exploitation (DiMasi *et al.*, 2003; Dyer, 1996; Mudambi and Swift, 2014). However, in some instances, it is possible that exploitation is more expensive than exploration. Note that the specifications used in this paper do not distinguish between the importance of the *direction* of R&D spending changes. Both increases, and decreases, are associated with increased firm failure.

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Table 1. Compact, significant changes in R&D expenditure and firm failure logistic regression

	DV = logit of firm failure			
	(1)	(2)	(3)	(4)
Intercept	−11.94	−7.23	−14.72***	19.80***
	0.03	*0.50*	*0.00*	*0.79*
Compact, significant increases in R&D expenditure		18.46***	23.19***	21.72***
		6.95	*9.52*	*11.15*
Compact, significant decreases in R&D expenditure		11.97***	12.04***	15.54***
		7.39	*8.93*	*9.31*
Firm R&D intensity	−2.36**	−15.23**	−10.31	−25.19**
	4.58	*4.24*	*2.10*	*4.73*
Firm underperformance relative to peers				43.16
				1.75
Increases in R&D expenditure × R&D intensity			−10.68**	
			6.13	
Decreases in R&D expenditure × firm underperformance				−92.05**
				5.50
R&D-based exploration	−0.53	0.13	0.15	3.92
	0.43	*0.02*	*0.08*	*1.16*
R&D-based exploitation	0.24*	−0.05	−0.02*	−0.06
	3.11	*0.01*	*0.01*	*0.01*
Altman's Z	−0.02*	−0.04	−0.04***	−0.07
	3.75	*0.33*	*6.12*	*0.48*
Firm size	0.31	−6.29**	−6.92***	−12.97**
	0.81	*5.71*	*8.83*	*5.67*
Firm profitability	0.00	0.00	0.00	0.00
	0.00	*0.00*	*0.00*	*0.00*
Firm debt	1.68*	−5.07	−5.84*	−12.38**
	2.76	*1.99*	*2.91*	*5.66*
Corporate diversification	0.78	3.66	4.16	8.42
	0.50	*0.85*	*1.18*	*2.65*
Log likelihood	−131.4	−24.8	−22.2	−16.0
Log likelihood ratio		213.23***	5.21**	17.50***

*Significant at 10%; **significant at 5%; ***significant at 1%.
n = 22,251.
The above table shows the estimates of regression equations estimating the impact that compact, significant increases and decreases in R&D expenditure have on firm failure. Chi squares are italicized above parameter estimates. Equations are estimated with firm-level fixed effects.

increases in R&D spending and firm mortality. This hypothesis is tested by adding the measure of firm earnings underperformance relative to peers as well as the product of earnings underperformance and the measure of compact, significant decreases in R&D spending to the specification shown in column 2. The results of estimating this specification is shown in column 4. The log likelihood ratio indicates that the explanatory power of the specification shown in column 4 is greater than the specification shown in column 2. The parameter estimate on the interaction of earnings underperformance and the measure of compact, significant decreases in R&D spending is negative and statistically significant. Hypothesis 2b is supported.

DISCUSSION

This article began by stating that the best firms perform both R&D-based exploitation and exploration, but that making the leap from exploitation to exploration can be perilous. While firms that successfully make the leap between R&D-based exploitation and exploration exhibit superior performance, I suggest that there is a dark side to proactive R&D management. In this article, I show that the magnitude of compact significant changes in R&D spending, whether positive or negative increase the probability of organizational failure, and that two different factors play an important role in enabling firms to survive this profound form of organizational change.

A critical success factor in exploratory R&D is the ability to identify commercially valuable new knowledge and to assimilate it into the firm's innovation processes. In analysis provided above, I show that firms with higher levels of absorptive capacity are more likely to survive the leap from R&D-based exploitation to exploration. These firms have an enhanced capability to conduct effective R&D-based exploration.

Compact, significant decreases in R&D spending can be attributable to firm-level transition from R&D-based exploration to exploitation, which occurs after a firm discovers a commercially valuable new form of innovation. I show that firms that more frequently and substantially generate short-term earnings *below* industry peers after the R&D spending cut are *more* likely to survive the move from R&D based exploration to exploitation. At first, this result seems counterintuitive; firms with weaker earnings performance have a better chance at survival. However, when we consider the context, we gain a valuable new insight. Firms that reduce R&D spending in order to maintain short-term earnings performance significantly increase the likelihood of firm failure.

It is important to note that the findings of this article are seen after controlling for the firm's likelihood to enter bankruptcy within the next three years due to financial distress (Altman, 1968). This is important; it indicates that, in addition to failing due to poor financial performance, firms can also jeopardize their very survival by making the leap between exploitation and exploration without the necessary capabilities or for the wrong reasons.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Table S1. Main database summary statistics.