The impact of failure experience in product development on knowledge usage and financial performance of the firm

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THE IMPACT OF FAILURE EXPERIENCE IN PRODUCT DEVELOPMENT ON KNOWLEDGE USAGE AND FINANCIAL PERFORMANCE OF THE FIRM

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ABSTRACT

We focus on the relationships between failure experience in product development and two aspects of R&D intensive firms, knowledge usage and financial performance. We hypothesize a positive relationship between failure experience and knowledge usage, as well as a curve linear (inverted U-shaped) relationship between failure experience and financial performance. We further propose that exploration in product development positively moderates the impact of failure experience on knowledge usage and negatively moderates the impact of failure experience on firm financial performance. A longitudinal study on 165 firms in the global pharmaceutical industry from 1990 to 2008 generally supports the hypotheses.

INTRODUCTION

A central notion in organisational learning theory is that organisations learn from experience (Argote and Miron-Spektor, 2011, Cyert and March, 1992, Huber, 1991, Levitt and March, 1988). Learning from experience has been widely argued to be a source of organisational knowledge, capabilities, and performance improvement (Argote et al., 1990, March, 2010). Organisations learn mainly by encountering problems (Cyert and March, 1992, Sitkin, 1992). Failure experience may lead to positive outcomes such as learning (Desai, 2010, McGrath, 1999, Nonaka and Takeuchi, 1995, Rerup and Feldman, 2011).

The notion that organisations learn from experience has led to a stream of literature on how organisational performance improves with experience (Argote, 1999, Miner et al., 1999, Pisano et al., 2001). Scholars examine various aspects of organisational learning outcomes, such as generation of new ideas and insights (Homsma et al., 2009), reduced accident cost (Baum and Dahlin, 2007), whether an attempt fails (Madsen and Desai, 2010), and whether an accident occurs (Desai, 2010). These studies generally reveal a positive relationship between failure experience and organisational learning outcomes.

Following this stream of literature, we introduce knowledge usage as a dimension of organisational learning outcomes. Knowledge usage refers to a firm's capability in converting research discoveries into product development. It is rooted in absorptive capacity theory (Cohen and Levinthal, 1990, Zahra and George, 2002). Absorptive capacity theory terms the ratio of realized absorptive capacity to potential absorptive capacity as an efficiency factor (Zahra and George, 2002). This factor suggests that firms differ in their ability to create value from their knowledge base because of variations in their capabilities to convert research discoveries into product development, or to transform R&D inputs into absorptive capacity (Zhang et al., 2007).

We investigate a hypothesized positive relationship between failure experience and knowledge usage in the empirical context of R&D intensive firms.

Organisations learn from experience and organisational performance improves with experience (Cyert and March, 1992, Huber, 1991, Levitt and March, 1988, Pisano et al., 2001, Rerup and Feldman, 2011, Thompson, 2001). Since failure is an important type of experience, scholars widely assume that organisational performance increases automatically along with learning from failure (Baum and Dahlin, 2007). Failure is a special type of experience because it not only undermines organisational financial performance but also signals problems in an organisation's history. There may not be a linear relationship between learning from failure and organisational financial performance as proposed in the literature. Little is known if organisations are capable of translating their learning from failure into financial gains. Some argued that this translation may not be explicit because factors that improve learning effects (i.e., a means of rent generation) may not improve firm financial performance (i.e., a means of rent appropriation) (Durand et al., 2008).

We further identify related boundary conditions on the impact of failure experience on firms' knowledge usage and financial performance. These boundary conditions are contexts that affect learning and moderate the relationship between failure experience and learning outcomes (Argote and Miron-Spektor, 2011). Organisational search is associated with exploring new knowledge and exploiting existing knowledge (March, 1991). Exploration employs varied and dispersed knowledge in new ways and exploitation leverages existing knowledge in well-understood ways (Levinthal and March, 1993, March, 1991). Since returns to exploration are less certain, further in time, and further in space than to exploitation (Levinthal and March, 1993), exploration and exploitation may also affect the relationship between failure experience and organisational financial performance. This study completes the development of the model by examining the conditional impact of exploration and exploitation on knowledge usage and financial performance.

Contributions

Our findings make a number of contributions to theory and research. First, this research contributes to organisational learning theory by examining the effects of a dimension of experience on learning outcomes. A special issue of *Organization Science* focuses on learning from rare events that have major consequences (Lampel et al., 2009). Researchers also show interests in learning from events that occur more frequently than rare events, such as learning from alliances (Lavie and Miller, 2008, Pangarkar, 2009, Zollo and Reuer, 2010) and learning from contracting experience (Vanneste and Puranam, 2010). Little empirical research has examined learning from events that occur highly frequently over time, such as failed product development. Understanding learning from various dimensions of experience contributes to organisational learning theory because experience with different properties can have different effects on organisational learning outcomes (Argote and Miron-Spektor, 2011).

Second, we advance the organisational learning literature by clarifying, articulating, and elaborating the effects of failure on firms' knowledge usage and financial performance longitudinally. Although previous studies acknowledge the importance of failure experience and the positive outcomes of learning from failure (Baum and Dahlin, 2007, Homsma et al., 2009, Madsen and Desai, 2010), it has remained equivocal an understanding of the learning effects that underlie the impact of failure experience on organisational knowledge usage and financial performance. We demonstrate longitudinally different routines of the impact of failure experience on organisational outcomes. What improves organisational learning may not automatically improve organisational financial performance. Organisational financial performance may not change in a linear manner consequently. This leads to the next contribution.

Third, the study contributes to the learning from failure literature by revealing a mixed blessing that failure gives to organisational financial performance. Learning from failure is essential to organisational adaptation. A heated debate in the literature is to what extent failure-induced learning triggers positive performance outcomes (Desai, 2010, Rerup and Feldman, 2011). This study reveals the double-edged impacts of failure on organisational financial performance. The influence of failure experience on financial performance is positive before a certain threshold. After this threshold, the influence of failure experience appears to become negative.

Fourth, in an effort to further enrich understanding of the impact of failure experience on organisational knowledge usage and financial performance, we examine the contingent role of exploration and exploitation in shaping the relationships between failure experience and knowledge usage and between failure experience and organisational financial performance. This study provides new insights about the boundary conditions in the internal context of organisations.

THEORY AND HYPOTHESES

Firm Knowledge Usage and Financial Performance

Firms vary in their abilities to assimilate knowledge and to transform the assimilated knowledge. Their learning outcomes and value creation are thus different because of variations in these capabilities. The capabilities to acquire and assimilate knowledge are associated with a firm's potential absorptive capacity. The capabilities to transform and exploit knowledge are connected to the firm's realized absorptive capacity. The ratio of realized absorptive capacity to potential absorptive capacity is termed as an efficiency factor (Zahra and George, 2002). Potential absorptive capacity is associated with the research (R) side of R&D. Realized absorptive capacity is related to the development (D) side of R&D. The efficiency factor thus reflects a firm's capability in converting R into D. We build knowledge usage based on this efficiency factor and use it to reflect a dimension of organisational learning outcomes that is associated with a firm's R&D.

We consider knowledge usage as an important feature of product development in R&D intensive firms. These firms invest much capital in R and require high efficiency and effectiveness to utilize them in D. Efficiency and effectiveness in R&D focus on using a firm's resources to maximize the production of innovations (McCarthy and Gordon, 2011), given a certain amount of R&D input. High levels of knowledge usage reflect a firm's exploratory, transformative, and exploitative abilities in acquiring and adopting knowledge (Lichtenthaler and Lichtenthaler, 2009). In order to increase the levels of knowledge usage and the value of R&D, firms adopt a number of strategies to improve the potential success of the transformation from invention to innovation, increase the number of experiments, run them in parallel, improve the instrumentation to produce a more accurate understanding of the relationship between cause and effect, and concentrate on fundamental technologies to reduce heterogeneity. Efficiently and effectively generating and utilizing knowledge may also facilitate a firm's problem-solving and, hence, its value creation and value capture (Nickerson et al., 2007). High levels of knowledge usage also enhances a firm's competitive advantage by forming barriers to other firms that have a relatively little amount of technology or perform poorly in integrating and transforming knowledge.

The Impact of Failure on Knowledge Usage and Exploration Contingency

The 1990's saw the emergence of the learning-from-failure perspective (Miner et al., 1999, Sitkin, 1992). This perspective is deeply rooted in the tradition of learning curves, which argues that firms learn from experience (Cyert and March, 1992, Levitt and March, 1988) and hence performance improves with experience (Pisano et al., 2001, Thompson, 2001). Failure is an important type of experience. Learning from failure experience is increasingly important as firms struggle to cope with rapidly changing environments as well as more complex and interdependent sets of knowledge (Carroll et al., 2002). Failure is far too expensive to waste because firms learn mainly by encountering problems rather than by experiencing success (Corbett et al., 2007, Cyert and March, 1992). Failure experience also improves organisational adaptation, reliability, and success (Carmeli and Schaubroeck, 2008).

The learning-from-failure perspective suggests that small losses are effective in the activation of learning, and it identifies such losses as fruitful learning opportunities (Miner et al., 1999, Sitkin, 1992). The more negative consequences a firm experiences, the more it is induced to learn (Homsma et al., 2009). Firm-level failure experience is associated with experiments and provides the organisation with opportunities to learn from failed product development (Cannon and Edmondson, 2005). Failed product development may have lessons in the feasibility of a new technology or the attractiveness of a new market. Scholars find that the knowledge gained from failed product development is often important in achieving subsequent successes because new products are a function of prior failed products (Maidique and Zirger, 1985). Better understanding of the knowledge base in a firm is positively associated with capabilities of the firm to convert research discoveries into product development.

Hypothesis 1a. There is a positive relationship between failure experience and knowledge usage.

The firm's knowledge base evolves through exploration and exploitation (March, 1991). The essence of exploration is experimentation with new alternatives. The essence of exploitation is the refinement and extension of existing competences (Rosenkopf and Nerkar, 2001, Taylor and Greve, 2006, Vassolo et al., 2004, Vermeulen and Barkema, 2001). Firms attempt to adapt to their environments through processes of exploring new routines and exploiting existing ones. Projects depend on each other and are based on what knowledge is passed on from one project to the next (Maidique and Zirger, 1985, Rothwell and Gardiner, 1989). Product development involving exploration requires different kinds of knowledge and support than exploitative product development. These differences influence the relationship between failure experience and knowledge usage.

Exploitation enhances organisational functioning by reducing variability in learning outcomes. Exploitative product development projects rely mostly on knowledge that already exists in the firm in which they are initiated. A firm that engages in exploitation may become focused and is therefore able to benefit from using knowledge gained through failure experience on subsequent product development projects. The frequency of utilizing a routine will increase its efficiency and effectiveness, as well as the likelihood of desirable outcomes (Levinthal and March, 1993). When a firm follows its trajectory in its area of expertise, the accumulated failure experience will be positively related to knowledge usage because the knowledge the firm gains from failure can be efficiently utilized in subsequent similar product development projects.

In exploratory product development, goals involve the accumulation of knowledge and capabilities that are relatively unfamiliar or unknown in the firm. The firm experiences a process of non-local search, identifying new technologies and extending its knowledge base. Search and change leads to failure, which leads to more search and change (Levinthal and March, 1993). Although exploration contains new ideas that are most likely to fail, failure experience provides invaluable lessons for the firm to learn. The diversified knowledge base also facilitates learning from failure. As a result, firms have more chances to learn if their failure experience is associated with more diversified knowledge than with more focused knowledge.

Hypothesis 1b. Exploration positively moderates the positive relationship between failure experience and knowledge usage. Specifically, when exploration is higher, the increase of knowledge usage associated with increasing failure experience is faster than when exploration is lower.

The Impact of Failure on Financial Performance and Exploration Contingency

Scholars suggest that firms' financial performance can be negatively affected if they fail to deliver new products at the end of a product development cycle (Sharma and Lacey, 2004). Similar arguments are proposed when scholars examine the impact of ceased R&D projects on firms' market value (Girotra et al., 2007, Sharma and Lacey, 2004). Failure can harm employees and financially undermine the organisation (Lee et al., 2004).

Failure is positively related to organisational learning, however. Based on real option reasoning, scholars argue that a high level of failure can be positively associated with frim financial performance, provided that the cost of failing is bounded (McGrath, 1999). Similar appealing ideas can be found in recent studies on the impact of failure experience on subsequent firm performance (Baden-Fuller, 2005, Baum and Dahlin, 2007, Kim and Miner, 2007). The key issue is not avoiding failure but managing the cost of failure while maximizing gains. Following the tradition of learning curves, learning from failure may also diminish R&D cost. These arguments support a positive relationship between failure experience and firm financial performance. Although learning from failure provides a firm with the opportunity to learn how to avoid similar failure in subsequent product development (Baum and Dahlin, 2007, Carmeli and Schaubroeck, 2008), it does not imply that a positive relationship between failure experience and firm financial performance remains unchallenged. A large amount of failure does more harm than good to the firm, although organisations learn more from failure with increased severe consequences (Homsma et al., 2009). An increasing number of failure events may compensate the benefits of learning from failure because failure generates little returns.

The underlying logic of learning from failure is that firm financial performance should benefit from an amount of failure experience below a threshold over which more failure will offset the benefits of learning. The negative impact of failure experience on firm financial performance becomes thus stronger as failure experience accumulates.

Hypothesis 2a. There is an inverted U-shaped relationship between failure experience and firm financial performance.

Returns to exploration are less certain, further in time, and further in space than those to exploitation (Levinthal and March, 1993, March, 1991). Product development that is exploratory is thus likely to benefit less from increasing levels of learning from failure. Since both failure and non-local search bring uncertainty to the firm, product development that is exploratory experiences the negative effects of uncertainty and risk more strongly than product development that is exploitative. The underlying logic of the effects of exploration and exploitation on the relationship between failure experience and firm financial performance is that the uncertainty associated with exploration strengthened the negative impact of failure experience on firm financial performance and thus offset the benefits of learning from failure. We thus expect that in exploratory product development firm financial performance is lower than in exploitative product development. The pace of the changes in the slope of the relationship between failure experience and firm financial performance becomes slower with increasing failure experience.

Hypothesis 2b. Exploration negatively moderates the inverted U-shaped relationship between failure experience and financial performance. Specifically, when exploration is higher, change in financial performance associated with increasing failure is slower than when exploration is lower.

Figure 1 presents the hypothesized relationships between the focal variables, the impact of failure experience on knowledge usage and financial performance, as well as exploration contingencies.

(Insert Figure 1 here)

METHODS

Data and Sample

We tested the hypotheses using panel data on the global pharmaceutical industry during the period from 1990 to 2008. This industry is an ideal empirical setting for this study because of its R&D intensity, high frequency failure events, and consistent regulations. The 165 sample firms were selected by overlapping the four data sources, Pharmaprojects, Research Insight, Derwent Innovations Index, and PR Newswire.

Measures

Knowledge usage. Knowledge usage refers to a firm's capability to transform research discoveries into product development. Following the logic of the efficiency factor (Zahra and George, 2002), which is the ratio of realized absorptive capacity to potential absorptive capacity, a firm's annual knowledge usage was measured using the following equation,

Knowledge usage = (the number of patents involved in drug development / the number of patents in the firm's stock) / R&D expenditure of the firm.

A firm's patent stock can be considered as an indicator of potential absorptive capacity, which refers to the capabilities to acquire and assimilate knowledge. The number of patents involved in the drug development projects can be viewed as an indicator of realized absorptive capacity (Zahra and George, 2002). The ratio of the number of patents involved in drug development to the number of patents in the firm's stock reflects the efficiency of the firm's patent usage. We divided this efficiency factor by the firm's R&D expenditure to denote how effective the firm is in using its knowledge, given a certain amount of R&D input. The information about patents involved in drug development was obtained from Pharmaprojects. Data on the sample firms' patent stock was obtained from Derwent Innovations Index. Data on R&D expenditure was collected from Research Insight.

Transforming patents into products, or inventions into innovations, is of particular importance to the pharmaceutical firms because they face the duel challenges of significant resource and speed demands in both patent races and commercialization, as well as high failure rates and high R&D costs (DiMasi and Grabowski, 2007). In the pharmaceutical industry firms seek to improve and accelerate the drug development process and to utilize patents efficiently because drug development and commercialization is constrained by the period of patent protection. Patents are of central importance in a series of drug development activities because they offer a firm the exclusive right to develop, make, sell, and gain profit from a new product. Given the limited period of patent protection (between fifteen and twenty years in the pharmaceutical industry) as well as the long cycle (ten years on average) of drug development processes, the efficiency and effectiveness in patent utilization is strategically important to pharmaceutical firms. The more efficiently and effectively a firm can use its patents, the less cost it may have, and the higher profit it may gain potentially from its products. High levels of knowledge usage also reflect a firm's capabilities of exploring, understanding, and creating value from patents. Two key features in this industry are the economies of scope and the economies of scale (Cockburn and Henderson, 2001, Nightingale, 2000). In order to understand the patents, pharmaceutical firms may use as many patents as possible in its innovation process. These patents may carry various patent classes. In order to reduce the cost of finding new drugs, pharmaceutical firms tend to use their patents in mass-production processes of parallel experimentation on complemented by computer simulations.

Financial performance. We measured firm financial performance as a firm's market return (MR) and return on equity (ROE). MR was measured as a ratio of a firm's market value in year *t* to its market value in year *t*-1. Market value represents investors' expectations about firms' market performance and is used in scholarly research (Lavie et al., 2011). In the sample firms of this study, market value has high correlations with factors, such as the natural logarithmic transformation of the number of employees ($r = 0.6464$, $p < 0.001$). We thus used the ratio of the firm's market value in year *t* to its market value in year *t*-1 to proxy its MR in year *t*. This ratio has low correlations with other factors. Data on market value were collected from Research Insight. ROE assesses how efficiently a firm uses its resource (Rothaermel and Alexandre, 2009). We applied a logarithmic transformation to enhance the normality of the variable's underlying distribution. Data on ROE were collected from Research Insight.

Failure. Failure was measured as a ratio of the number of ceased drug development projects to the number of all the drug development projects in a firm in year *t*. Values for this variable range from 0 to 1, with 0 denoting a scenario in which all the drug development projects were not ceased by a firm in a year, and 1 denoting a scenario in which all the drug development projects were ceased by a firm in a year. The data on the status of drug development projects were obtained from Pharmaprojects.

Exploration. Exploration was measured as the ratio of therapy codes that were new to a firm in year t to the total number of therapy codes used by the firm in that year. The data on therapy codes were obtained from Pharmaprojects. A therapy code is considered new if the firm did not use it in the three-year period (year t-3 to year t-1) prior to year t. The logic of this measure is consistent with that used in prior research (Katila and Ahuja, 2002). They use a ratio of previously unused knowledge to a firm's knowledge base in a given year to measure the exploration of new knowledge. Values of exploration range between 0 and 1.

Control variables. *Alliance* was measured as the natural logarithmic transformation of the number of alliances announced by a firm in a year. Data on alliances were obtained from LexisNexis. *Cash burn* was measured as the natural logarithmic transformation of the ratio of R&D expenditure to cash in a year. Data on R&D expenditure and cash were obtained from Research Insight. *R&D experience* was measured as the total number of drug development projects divided by the number of employees in a firm in a year. Numbers of drug development projects were obtained from Pharmaprojects. Numbers of employees were collected from Research Insight. *Firm age* was measured as the number of years since the firm was legally founded. We transformed the variable by taking its natural logarithm.

Analysis

We used fixed-effects models to analyse the longitudinal data in this study. Testing the hypotheses in this study involves both failure and its square term entering multiple regression, as well as linear by linear and curvilinear by linear interactions among failure, its square term, and exploration in multiple regression. We used hierarchical regression analysis to test the hypotheses because this procedure allows examination of statistical associations for evidence of nonlinearity (Cohen et al., 2003). Hierarchical regression analysis is widely used to assess curvilinear-by-linear interactions in organisation and management research (Baer et al., 2010, Lechner et al., 2010, Tiwana, 2008a, Tiwana, 2008b).

Failure and its square term were highly correlated with each other. Considerable multicollinearity can also be introduced into multiple regression with an interaction (Marquardt, 1980). In order to remove this nonessential multicollinearity that exists due to the scaling of a variable, as well as the impact of high levels of multicollinearity on estimating regression coefficients, we centred a variable to deviation form by setting its mean to zero before squaring the centred variable or forming interactions to minimize these problems (Cohen et al., 2003, Cronbach, 1987, Marquardt, 1980). We also examined the correlations among the variables to check for multicollinearity. This examination revealed no evidence of multicollinearity. We also performed collinearity diagnostics to rule out concerns of multicollinearity. There is little concern of multicollinearity because VIF values are close to 1 and the condition numbers are below 10. All the independent variables and control variables, except firm age, were lagged by one year relative to the dependent variables.

RESULTS

Table 1 reports the descriptive statistics and correlation matrix for all the variables in this study. Table 2 shows the results of the regression analysis for knowledge usage, and Table 3 for firm financial performance.

(Insert Tables 1, 2, and 3 here)

The impact of failure on knowledge usage and exploration contingency. Hypothesis 1a proposes that failure experience in a focal firm has a positive impact on knowledge usage (KU). In Model 2 in Table 2, we add the failure variable. Results show that failure is significantly and positively related to KU, supporting Hypothesis 1a.

Hypothesis 1b states that the effect of failure experience on KU is more positive for firms with higher exploration in their product development than for firms with lower exploration in their product development. In Model 3, we add the exploration variable as the moderator. Results for exploration as a predictor for KU are significant and negative. In Model 4, the linear interaction term for failure and exploration is significantly and positively related to KU. This suggests that exploration moderates the linear effects of failure on KU. Figure 2 shows a plot of the effect on the lines for groups one standard deviation below the mean of exploration, the mean of exploration, and one standard deviation above the mean of exploration. The learning effect is strengthened when exploration is high rather than low. Specifically, for firms with high exploration, the rate of increase in KU associated with increasing failure is steeper than firms with low exploration, supporting Hypothesis 1b.

(Insert Figure 2 here)

The impact of failure on financial performance and exploration contingency. Hypothesis 2a proposes that there is an inverted U-shaped relationship between failure and firm financial performance. In Models 2 and 7 in Table 3, we add the linear term of failure variable. Results show that failure is not significantly related to market return (MR) or return on equity (ROE). We add the quadratic term to the regression equation in Models 3 and 8. As shown in the table, the squared terms for failure are significant and negative in both models, supporting Hypothesis 2a.

Hypothesis 2b states that the effect of failure experience on firm financial performance depends on various levels of exploration a firm has in its product development. In Models 4 and 9 in Table 3, we add the degree of exploration as the moderator. Results for exploration as a predictor are not significant for MR and significant for ROE. We add the linear interaction term and the curvilinear interaction term in Models 5 and 10. The linear interaction term for failure and exploration is significantly and positively related to both MR and ROE. The curvilinear interaction term for failure- squared and exploration is significantly and positively related to both MR and ROE. These suggest that exploration moderates the curvilinear effects of failure on firm financial performance.

To facilitate the interpretation of this effect, we plot the relationships between failure and MR, and between failure and ROE, for firms with high and low exploration. Figures 3 and 4 show plots of the effects on the curves for groups one standard deviation below the mean of exploration, the mean of exploration, and one standard deviation above the mean of exploration. Firms with low exploration benefit more from learning from failure than firms with high exploration, supporting Hypothesis 2b.

(Insert Figures 3 and 4 here)

The R^2 values for the models in Table 3 are low, and thus, that the models only explain a limited portion of the variation in the data. While low R^2 values clearly present limitations, this level of explanatory power is not uncommon in strategy and management research. Recent examples that report low R^2 include studies in this area of research (Allatta and Singh, 2011, Batt and Colvin, 2011, Godfrey et al., 2009, Hirst et al., 2011, Muller and Kraussl, 2011). Low values of R^2 should not undermine the significant relationships between failure experience and firm financial performance, as well as the moderating effect of exploration.

Robustness Tests

To examine the robustness of the findings in more detail, we conducted several post hoc checks. First, we considered alternative dependent variables to measure firm financial performance. We used return on assets (ROA), return on investment (ROI), and profit margin (PM) to re-examine Hypothesis 2. The data on these variables were obtained from Research Insight for the sample firms during the studied period. The regression analyses revealed that the original models using MR and ROE as the dependent variables returned better statistical fit than the models using ROA, ROI, and PM.

Second, we controlled for success in firms' product development by re-examining a number of subsamples. In the learning curve literature, there is a strong tendency to focus on success and to under-sample failure (Levinthal and March, 1993). An emerging research focusing on learning from failure (Homsma et al., 2009, Kim and Miner, 2007, McGrath, 1999, Minniti and Bygrave, 2001, Shepherd, 2003, Sitkin, 1992) argues that firms learn more from error incidents because failure provides valuable learning opportunities. We controlled for success by selecting three subsamples via three standards and re-examined the hypotheses. The three standards were (1) firms having fully launched drugs in any year of the studied period; (2) firms having positive sales of investment in any year of the studied period; and (3) firms' sales of investment greater than US $ 50 million in any year of the studied period. We expected that the learning effects would be stronger in the firms that experienced successes because successes generally represent positive learning outcomes.

In the first subsample, fully launched drugs refer to drugs whose development were effectively completed (Pharmaprojects, 2008). The data were obtained from Pharmaprojects. We show the results in Table 4. Hypothesis 1a is supported, and Hypothesis 1b is not supported in this subsample. Hypothesis 2 is supported. The second subsample contained firms that had positive sales of investment (SI) during the studied period. Data on SI were obtained from Research Insight. We show the results in Table 5. The results support Hypotheses 1 and 2. The third subsample contained firms with SI greater than US $ 50 million in the studied period. We present the results in Table 6. All the models report poor statistical significance. Despite this, Models 1 to 4 exhibit support for Hypothesis 1. The results generally exhibit stronger learning from failure effects in the subsamples. Although it may be improper to interpret the findings of these additional longitudinal studies as evidence that learning from failure results in success, it would suggest that learning from failure is an important aspect of firms' capabilities

(Insert Tables 4, 5, and 6 here)

Third, we examined the relationship between KU and firm financial performance. We did not find significant relationship between KU and MR or between KU and ROE.

DISCUSSION

This study introduces knowledge usage as a dimension of organisational learning outcomes and produces a positive relationship between failure experience and knowledge usage. This study further challenges the assumption that organisational performance increases automatically along with learning from failure because failure not only undermines organisational profit but also signals problems in an organisation's history. The results reveal an inverted U-shaped relationship between failure experience and financial performance. This study completes the model development by demonstrating the contingent roles that exploration in product development plays in the impact of failure experience on firms' knowledge usage and financial performance. Exploration positively moderates the relationship between failure experience and knowledge usage and negatively moderates the relationship between failure experience and financial performance.

Theoretical Implications

The findings have implications for research on organisational learning from failure. Prior research shows that firms learn by encountering problems (Cyert and March, 1992, Levitt and March, 1988). Scholars show that failure experience results in generation of new ideas and insights (Homsma et al., 2009) and reduced accident cost (Baum and Dahlin, 2007). These studies generally reveal a positive relationship between failure experience and organisational learning outcomes, following the traditional learning curve perspective (Argote and Epple, 1990, Thornhill and Amit, 2003). Advancing this stream of literature, we introduce an indicator of learning capabilities, knowledge usage, examined it in the context of R&D intensive firms, and revealed empirically that organisations learn from failure experience. Failure experience results in increased knowledge usage. The more failure experience an organisation has, the higher its knowledge usage in R&D.

Previous studies argue that performance improvement can be an outcome of organisational learning from failure in both quantitative research (Baum and Dahlin, 2007) and qualitative research (Cope, 2011). However, translating learning outcomes into financial improvement does not occur automatically. Recent scholarly findings imply that translating learning from failure into capabilities that enhances performance may not be direct (Desai, 2010). Learning is a necessary but not essential antecedent of organisational performance improvement. This is consistent with theoretical arguments that factors that enhance rent generation may not automatically enhance rent appropriation (Durand et al., 2008). This research reveals that organisational learning from failure resulting in financial gains may be an approximation in the context of low levels of failure. This is illustrated by the findings that both knowledge usage and firm financial performance increase along with increasing failure before the levels of failure reach a certain threshold. After this threshold, firm financial performance decreases, though knowledge usage continues its increasing trend. The inverted U-shaped relationship between failure experience and organisational financial performance implies that the process of value creation from failure experience is complex and not linear.

Prior research has highlighted the importance of understanding the boundary conditions governing learning theory and practice (Desai, 2010). Enriching this stream of literature, the present research portraits a different boundary condition, the moderating role of exploration in organisational learning from failure experience. This study shows how exploration strengthens and weakens the impact of failure experience on knowledge usage and financial performance, respectively. Specifically, organisations that make substantial changes in their search orientation following failure may not improve knowledge usage and financial performance simultaneously.

Practical Implications

This study presents several implications for managerial practice. Increases in knowledge usage may suggest the need for managers to encourage learning from failure. Although failure is associated with individual grief and organisational financial losses, learning from failure could make firms more capable of utilizing knowledge. Managers should not ignore failure but should treat it as invaluable information for learning. The results of this study suggest that organisations that use failure events as learning opportunities will gain high levels of knowledge usage in their product development.

Firms with high knowledge usage are not inherently more profitable than those with low knowledge usage. A second practical implication of this research is the non-linear process organisations face in translating learning from failure into financial improvement. The results of this study suggest that managers should control the levels of failure in product development because firm financial performance can decreases after certain thresholds of failure. Managers that motivate learning from failure on the one hand and pursue superior financial performance on the other hand may need to make trade-offs between the two. Although risk and failure should be supported (Baden-Fuller, 2005), high levels of failure do more harm than good to the firm's financial performance.

Conclusion

This study contributes to explaining how R&D intensive firms' knowledge usage and financial performance change along with increasing failure. Supporting theoretical arguments, the study finds that failure experience is positively associated with knowledge usage. This relationship is positively moderated by exploration in product development. Failure experience has an inverted U-shaped relationship with firm financial performance, which is negatively moderated by exploration in product development.

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Figure 1 Model: The Impact of Failure on Knowledge Usage / Financial Performance and Exploration Contingencies

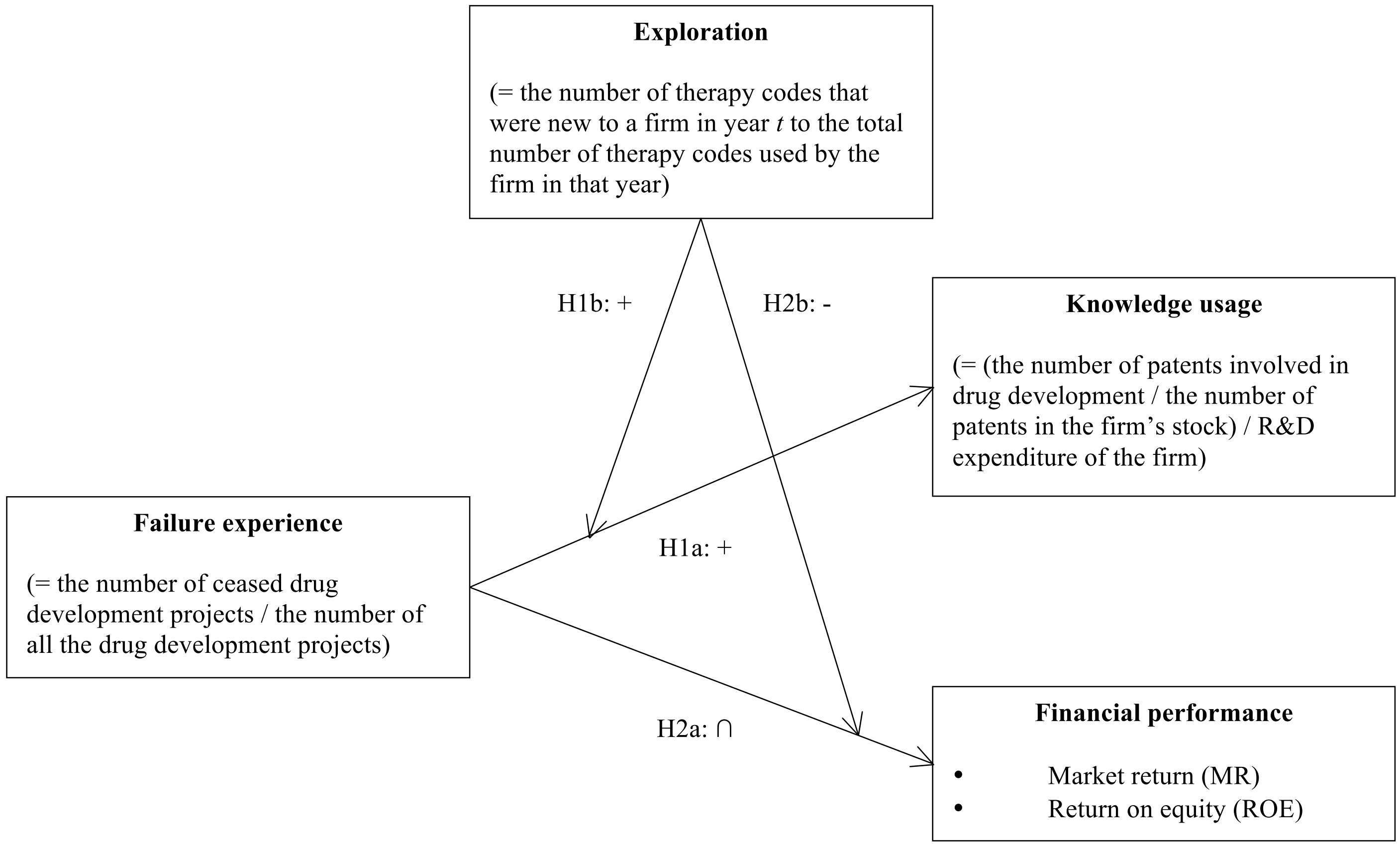

Figure 2 The Impact of Failure on Knowledge Usage and Exploration Contingency

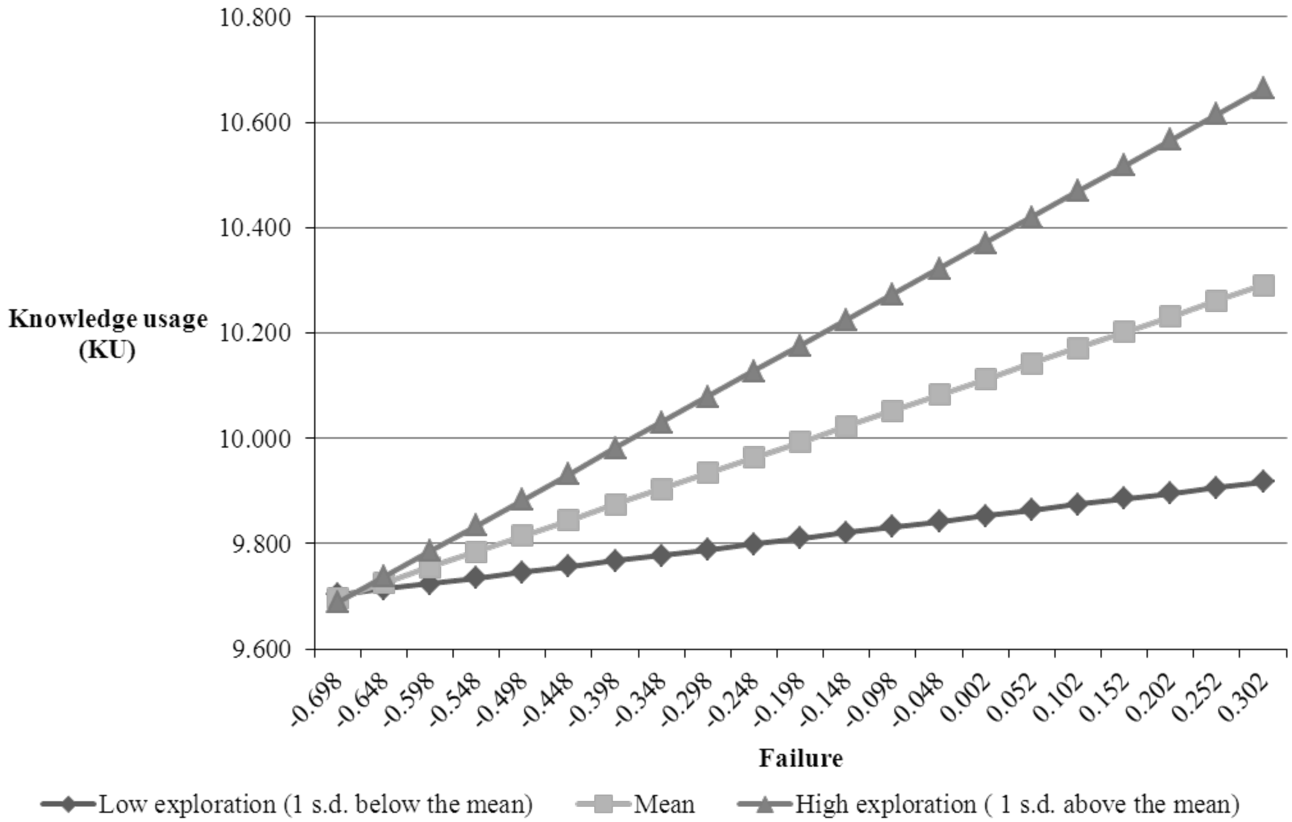

Figure 3 The Impact of Failure on Market Return and Exploration Contingency

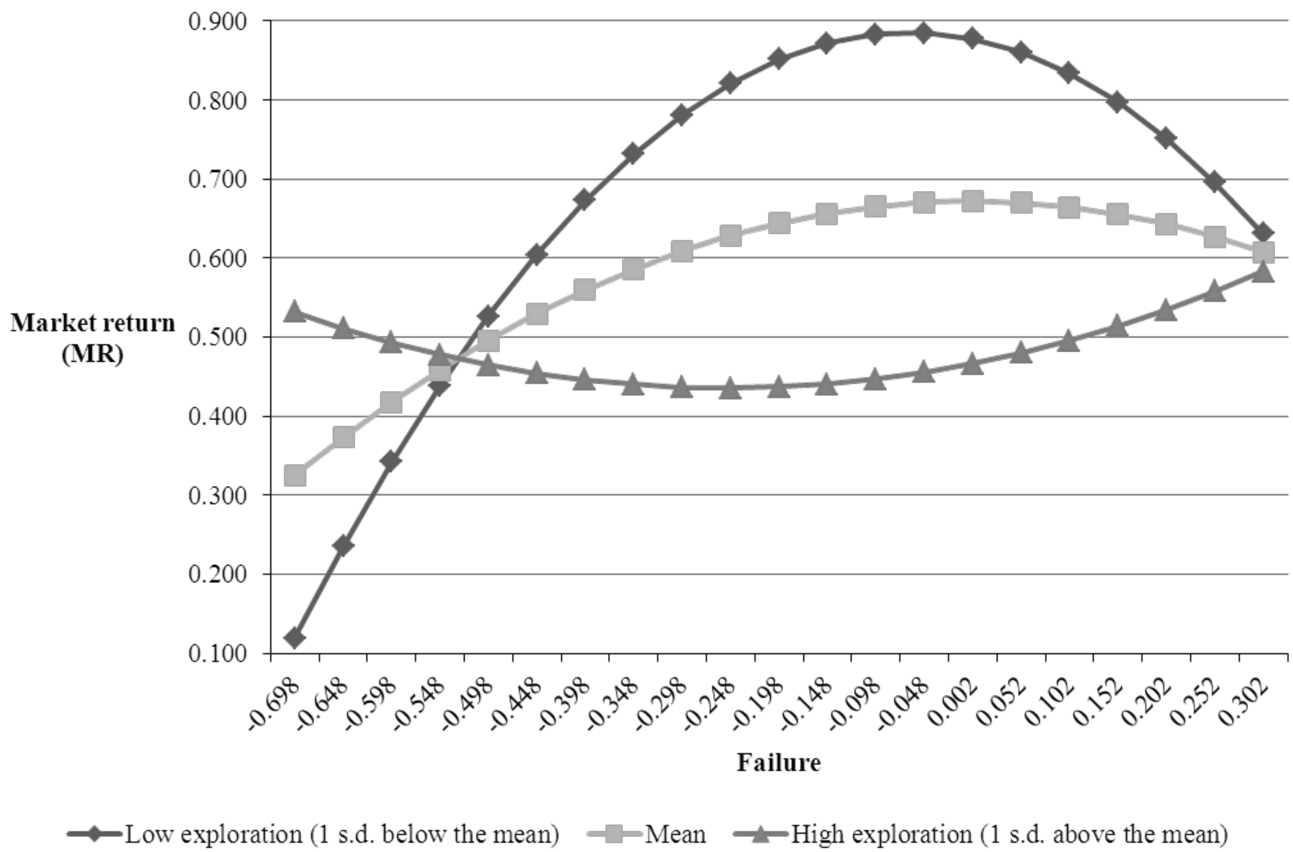

Figure 4 The Impact of Failure on Return on Equity and Exploration Contingency

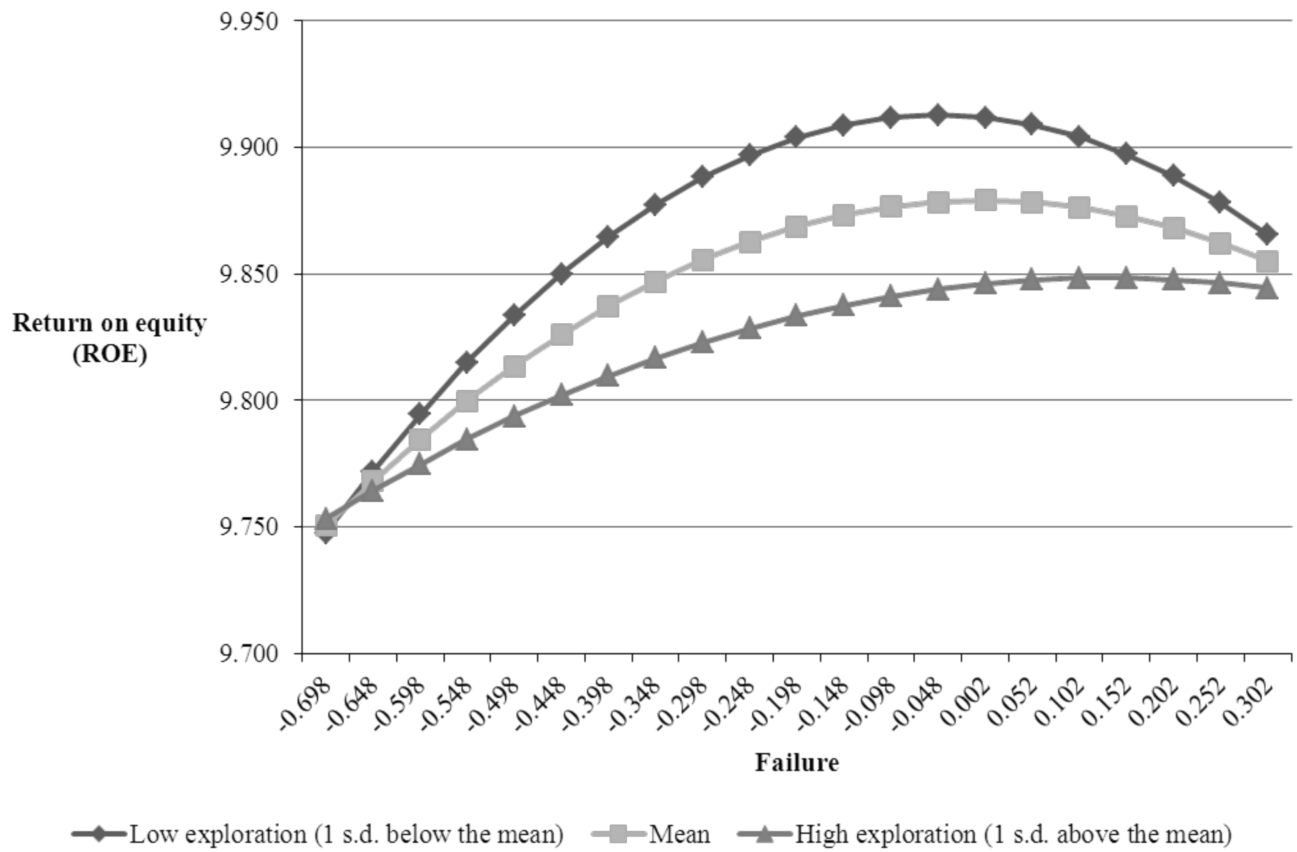

Table 1 Descriptive Statistics

Variables		**Mean**	**s. d.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dependent (DV)	1. Knowledge usage	9.595	1.496								
	2. Market return	1.776	.152	-.002							
	3. Return on equity	9.654	.107	-.020	.013						
Independent (IV)	4. Failure	.698	.378	.106	.086 ***	.033					
Moderator (m)	5. Exploration	.174	.211	.125 ***	-.040 *	-.001	-.160 ***				
Control (CV)	6. Alliance	.873	.930	-.138 ***	.009	.005	.081 **	-.234 ***			
	7. Cash burn	1.936	.202	-.207 ***	-.131 ***	-.035 †	-.016	.099	-.014		
	8. R&D experience	.187	.970	.092 **	.031	-.048 *	.076 ***	.018 †	-.292 ***	.025	
	9. Firm age	2.766	1.132	-.083 **	-.017	.024	-.017	-.034	.319 ***	-.119 ***	-.432 ***

N = 165.
Significance level:
† p < .10
* p < .05
** p < .01
*** p < .001

Table 2 The Impact of Failure on Knowledge Usage and Exploration Contingency

	Dependent variable (DV)	**Knowledge usage (KU)**			
	Models	**1**	**2**	**3**	**4**
Independent variable (IV)	Failure		.653 ***	.657 ***	.595 ***
Moderator (m)	Exploration			1.385 *	1.225 *
Interaction (Int)	Failure*Exploration				1.804 **
Control variables (CV)	Alliance	.321 ***	.315 ***	.292 ***	.274 ***
	Cash burn	.199 ***	.194 ***	.193 ***	.182 ***
	R&D experience	.075	.069	.089 †	.089 †
	Firm age	-.467 **	-.179	-.243 †	-.301 *
	Constant	10.577 ***	9.225 ***	9.450 ***	10.111 ***
	R^2	.088 ***	.124 ***	.133 ***	.144 ***
	ΔR^2		.036 **	.009 **	.009 **
	F	12.28 ***	14.41 ***	12.96 ***	12.19 ***

N = 132.
Significance level:
† p < .10
* p < .05
** p < .01
*** p < .001

Table 3 The Impact of Failure on Financial Performance and Exploration Contingency

	Dependent (DV)	**Market return (MR)**					**Return on equity (ROE)**				
	Models	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Independent (IV)	Failure		.039	-.108	-.119	-.139		.060	-.027	.046	-.016
	Failure^2			-.476 **	-.450 **	-.712 **			-.289 **	-.111 **	-.264 **
Moderator (m)	Exploration				-.206	-.976 *				-.032 *	-.156 **
Interactions (Int)	Failure*Exploration					1.150 †					.172 †
	Failure^2*Exploration					5.656 ***					.594 *
Control (CV)	Alliance	-.074 *	-.075 *	-.085 *	-.089 *	-.089 *	.008	.006	-.000	.013	.001
	Cash burn	.076 **	.076 **	.075 **	.086 **	.088 **	.002	.002	.002	.010	.001
	R&D experience	.038	.037	.013	.010	.013	-.001	-.003	-.017	.014	-.018
	Firm age	-.182 *	-.168 †	-.188 *	-.162	-.157	-.067 *	-.047 †	-.057 *	.037 *	-.067 *
	Constant	.647 *	.603 *	.738 *	.668 †	.672 *	9.846 ***	9.786 ***	9.859 ***	.114 ***	9.879 ***
	R^2	.025 **	.025 **	.028 **	.032 **	.051 ***	.007	.013	.025 *	.033 **	.040 ***
	ΔR^2		.000	.003 †	.004 †	.019 *		.006 †	.012 *	.007 †	.007 †
	F	4.00 **	3.23 **	3.02 **	2.87 **	3.65 ***	1.07	1.59	2.53 *	2.82 **	2.67 ***

For market return, N = 144. For return on equity, N = 142.
Significance level:
† p < .10
* p < .05
** p < .01
*** p < .001

Table 4 Robustness Test: The Impact of Failure on Knowledge Usage / Financial Performance and Exploration Contingency (Subsample 1)

	DV	Knowledge usage (KU)				Market return (MR)					Return on equity (ROE)				
	Models	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
IV	Failure		.791 ***	.806 ***	.814 ***		-.064	-.261	-.248	-.284		.002	.004	.005	.006
	Failure^2							-.658 *	-.566 *	-.807 †			-.006	-.005	-.004
m	Exploration			2.825 ***	2.840 ***				-.172	-.718				.002	.002
Int	Failure*Exploration				-.132					1.667 †					.009
	Failure^2*Exploration									5.561 *					.003 †
CV	Alliance	.305 ***	.299 ***	.259 ***	.260 ***	-.041	-.041	-.053	-.065	-.061	-.000	-.000	-.000	-.000	-.001
	Cash burn	.292 ***	.270 ***	.288 ***	.289 ***	.081 *	.080 *	.079 *	.103 *	.101 *	-.002 †	-.002 †	-.002 †	-.001	-.001
	R&D experience	.273 ***	.260 **	.305 ***	.305 ***	.002	.002	.002	.002	-.001	-.001	.002	.002	.105 †	.106 †
	Firm age	-.131	.218	-.162	-.159	-.210 †	-.233 †	-.259 †	-.291 †	-.231	.003	.004	.004	.005	.005 †
	Constant	9.594 ***	8.003 ***	9.076 ***	9.627 ***	.641 †	.710 †	.887 *	.988 *	.830 †	9.648 ***	9.646 ***	9.644 ***	9.644 ***	9.642 ***
	R^2	.129 ***	.180 ***	.218 ***	.218 ***	.029 †	.030	.035	.037	.051 †	.012	.014	.014 †	.013	.016 †
	ΔR^2		.040 *	.072 ***	.001		.000	.002	.002	.012 *		.002	.000 †	.000	.001
	F	8.92 ***	1.56 ***	11.10 ***	9.48 ***	2.22 †	1.81	1.76	1.57	1.67 †	.84	.75	.66 †	.49	.48 †

For knowledge usage, N = 103. For market return, N = 116. For return on equity, N = 116.
Significance level:
† p < .10
* p < .05
** p < .01
*** p < .001

Table 5 Robustness Test: The Impact of Failure on Knowledge Usage / Financial Performance and Exploration Contingency (Subsample 2)

	DV	Knowledge usage (KU)				Market return (MR)					Return on equity (ROE)				
	Models	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
IV	Failure		.765 ***	.741 ***	.586 **		-.023	-.124	-.109	-.098		.092 †	-.105	-.110	-.033
	Failure^2							-.339 †	-.312 †	-.409 †			-.702 ***	-.701 ***	-.589 **
m	Exploration			2.006 **	1.651 *				.139	-.055				-.154 *	-.403 ***
Int	Failure*Exploration				2.110 *					.087					.631 **
	Failure^2*Exploration									1.366 †					2.168 ***
CV	Alliance	.349 ***	.347 ***	.301 ***	.294 ***	-.013	-.013	-.022	-.025	-.024	.005	.004	-.015	-.012	-.014
	Cash burn	.195 **	.196 **	.203 **	.176 **	.051 †	.050 †	.048 †	.050 †	.051 †	.008	.011	.008	.007	.005
	R&D experience	.123 †	.096	.112 †	.117 †	.075 †	.061	.060	.059	.012	.013	.000	.001	-.006	.000
	Firm age	-.394 *	-.112	-.300	-.342 †	-.181 †	-.190 †	-.198 †	-.235 †	-.225 †	-.110 †	-.075	-.080	-.080	-.093 †
	Constant	1.156 ***	8.654 ***	9.376 ***	1.049 ***	.599 †	.629 †	.706 †	.829 †	.799 †	1.004 ***	9.886 ***	1.001 ***	9.986 ***	1.003 ***
	R^2	.099 ***	.143 ***	.163 ***	.177 ***	.024	.024	.026	.027	.030	.010	.017	.056 *	.073 **	.114 ***
	ΔR^2		.031 *	.020 ***	.010 *		.000	.001	.001	.003		.007	.039 †	.010 *	.030 **
	F	7.04 ***	8.57 ***	8.25 ***	7.78 ***	1.85	1.49	1.36	1.20	1.00	.71	.96	2.76 *	3.07 **	3.89 ***

For knowledge usage, N = 77. For market return, N = 93. For return on equity, N = 89.
Significance level:
† p < .10
* p < .05
** p < .01
*** p < .001

Table 6 Robustness Test: The Impact of Failure on Knowledge Usage / Financial Performance and Exploration Contingency (Subsample 3)

	DV	Knowledge usage (KU)				Market return (MR)					Return on equity (ROE)				
	Models	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
IV	Failure		.657 **	.608 **	.487 *		.235 †	.140	.168	.251		.001	.000	.001	.001
	Failure^2							-.338	-.307	-.666			-.002	-.002	-.001
m	Exploration			2.713 **	2.246 *				-.047	-.280				.001	-.000
Int	Failure*Exploration				1.946 †					-1.887 †					.004
	Failure^2*Exploration									1.448					.009
CV	Alliance	.456 ***	.473 ***	.392 ***	.382 ***	-.006	-.005	-.014	-.012	.008	.000	.000	.000	.000	.000
	Cash burn	.130 †	.143 †	.158 *	.121 †	.031	.043	.040	.045	.048	-.000	.000	-.000	.000	.000
	R&D experience	.116	.116	.142 †	.135 †	-.002	-.003	-.032	-.034	-.030	.000	.000	.000	.000	.000
	Firm age	-.386 †	-.152	-.509 †	-.484 †	-.224 †	-.148	-.166	-.159	-.164	.001	.001	.001	.001	.001
	Constant	9.744 ***	8.479 ***	9.876 ***	1.237 ***	.703 †	.435	.545	.515	.518	9.659 ***	9.658 ***	9.658 ***	9.658 ***	9.658 ***
	R^2	.123 ***	.159 ***	.198 ***	.209 ***	.015	.026	.028	.030	.066	.005	.009	.012	.018	.024
	ΔR^2		.036 †	.039 ***	.010 **		.010	.001	.002	.032		.001	.002	.005	.005 †
	F	5.58 ***	5.96 ***	6.46 ***	5.89 ***	.69	.96	.87	.78	1.37	.23	.31	.34	.42	.44

For knowledge usage, N = 58. For market return, N = 74. For return on equity, N = 66.
Significance level:
† p < .10
* p < .05
** p < .01
*** p < .001