
Sunk costs, uncertainty and market exit: A real options perspective

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In this article, we examine whether the option value of keeping an operation alive will deter firms from exiting an industry. We find that uncertainty dissuades firms from exiting an industry, but only when the sunk costs of entering and exiting that industry are sizeable. Moreover, we argue and find that sunk costs can be influenced by the technological intensity of an industry, by the extent to which a firm competes on the basis of innovation, and by the firm's diversification strategy.

1. Introduction

There is growing evidence that real managers take real options into account when making important investment decisions (Busby and Pitts, 1997). Even when firms lack formal option pricing techniques, managers will often employ relatively accurate "rules of thumb" to account for the value of real options (McDonald, 2000). However, almost all of the extant empirical research has focused on the decision to initiate an investment (Li *et al.*, 2007; Tong and Reuer, 2007). Despite being theoretically well developed (Dixit, 1989, 1992), the question of whether real managers employ real options logic when considering terminating an investment has received far less attention. Neglect of this topic leaves a distinct gap in the literature because many entry decisions can be characterized as mistakes (Vivarelli and Santarelli, 2007), and, consequently, many industries experience a surprisingly high rate of churn as firms enter but subsequently exit (Barteisman *et al.*, 2005). In this article, we explain how real options theory helps us to better understand the evolution of industries by illuminating the factors that influence the decision to exit from an industry. Furthermore, we examine how this perspective challenges entrenched notions about exit decisions, and we explore how firm strategy can affect the value of real options, and, hence, the probability of exit.

Real options theory yields significant insights into the exit decision because it challenges two common assumptions about industry exit. The first is that inertia

with regards to the exit decision is inefficient (e.g., Meyer and Zucker, 1989; Jensen, 1993), and possibly even a violation of real options logic (Adner and Levinthal, 2004). In contrast, real options theory demonstrates that uncertainty about future payoffs creates a zone of inaction where the wisest course of action is to wait until more information is gathered. Accordingly, scholars have drawn on real options theory to emphasize that “[i]f there is uncertainty about future payoffs, owners may be willing to accept low levels of performance with the hope that conditions will improve” (Gimeno *et al.*, 1997: 751) and that “under uncertainty, it is rational to keep options open, to hesitate when uncertainty is beyond one’s ability to influence it” (McGrath *et al.*, 2004: 99).

While the economic rationale of inertia in response to uncertainty has received some attention in the research on exit, very little attention has been given to how real options theory challenges a second common assumption about exit: The role of sunk costs. The option of exercising future managerial discretion is most valuable when investment decisions involve not just considerable uncertainty, but when those decisions also entail sunk costs (Coucke *et al.*, 2007). Irreversible investments represent sunk costs and traditional “[e]conomic analysis provides a clear-cut recommendation to the manager facing the sunk cost problem. . . . The amounts invested in the past are sunk costs; neither they nor their amortization are relevant to today’s decisions. Those who violate this rule are said to be ‘throwing good money after bad,’ leading to the popular label of the sunk cost fallacy” (Parayre, 1995: 418). Hence, scholars have interpreted evidence that people consider sunk costs when making an abandonment decision as evidence of biased decision-making (Staw, 1981; Ross and Staw, 1993), and responded by devoting considerable class time and textbook pages to teaching business students to ignore sunk costs (Friedman *et al.*, 2007). However, as we describe below, the sunk cost fallacy is premised on an outdated model of economic rationality. Real options theory shows that attention to sunk costs when considering exit is indeed entirely rational, and thus it has profound implications for theory, practice, and even teaching.

Absent any sunk costs, there is no economic rationale for persisting in an industry in the face of losses, as the firm could simply exit and re-enter later if conditions improve appreciably. However, in the presence of significant sunk costs, it is rational to persist and endure some amount of losses if there is some possibility that industry profitability may improve (Dixit, 1989). If conditions do improve, managers who decided to exit may very well regret that decision because the firm would have to incur those sunk costs all over again in order to re-enter. Thus, managers should consider how the confluence of significant sunk costs of (re)entry and the potential for improvement in the industry makes inertia optimal because persistence preserves the option of future profitable operations in the industry. While the economic logic of this real option has started to gain some acknowledgment (e.g., Bragger *et al.*, 2003; Tiwana *et al.*, 2006), most research still regards attention to sunk costs as an irrational commission of its fallacy. Even the popular finance textbook by

Brealey *et al.* (2007: 217) fails to consider the real options perspective on exit, and, hence, preaches under the heading “Forget Sunk Costs” that “Sunk costs are like spilled milk: They are past and irreversible outflows . . . they do not affect project NPV.” Such a view, however, fails to account for the option value of persistence, and the fact that exit is rational not when the expected net present value (NPV) of remaining in an industry falls below zero, but when expected losses exceed the value of this option.

To be clear, real options theory would concur with the preexisting literature that the sunk cost effect is real and robust; it would simply add that this effect is also quite rational. Friedman *et al.* (2007) recently concluded after examining the surprisingly scant published evidence of the sunk cost fallacy that when one adopts an appropriate economic model for evaluating sunk costs “. . . one can rationalize the choices featured in most studies and anecdotes” (p. 80), and that in many situations it may simply be that the subjects have a better intuition for the value of real options than the experimenters. Thus, consistent with the view that the decision heuristics we employ evolved to be there because they generally serve us quite well (Kihlstrom, 2004), the real options logic may be rationally embedded in the managerial intuition (Busby and Pitts, 1997).

In this article, we explore how real options influence real world exit decisions. Our empirical results indicate that while uncertainty generally dissuades exit from an industry, its effect is most pronounced in technologically intensive industries, which tend to be characterized high levels of investment irreversibility (Fichman, 2004). Furthermore, we also extend real options theory by exploring how the option value of persisting in an industry may be influenced by the firm’s strategy. Specifically, we contend that the sunk costs associated with industry exit and reentry, and, hence, the option value to persisting in an industry, will be influenced by both the extent to which a firm attempts to differentiate its products by investing in innovation, and by the firm’s diversification strategy. In addition to contributing to both real options theory and the broader literature on exit, these results also have weighty implication for practicing managers.

2. Theory and hypotheses

2.1 *The evolution of the real options perspective on exit*

The classical Marshallian view of economics (Marshall, 1920) presents a straightforward logic for making exit decisions: Exit an industry when price falls below the total average variable cost (i.e., when operating profits are less than zero). Jorgensen (1963) criticized this emphasis on current profits as too static, and emphasized that *expected* profits should be part of the calculus for investment decisions. According to this neoclassical perspective, managers should exit when the NPV of remaining in the

industry falls below zero. The neoclassical model is most typically operationalized via dynamic discounted cash flow (DCF) models, where decisions to proceed or halt an investment are updated every period by calculating revised NPVs.

While the neoclassical model has proven to be a powerful and useful framework for making investment decisions (Graham and Harvey, 2001), it has two major limitations. First, it fails to offer much insight into how uncertainty should influence investment decisions. The neoclassical model argues that only systematic risk matters, but since systematic risk may affect both the expected returns and the discount rate associated with a project, its net effect on NPV is ambiguous (Holland *et al.*, 2000). A second limitation is that it is unable to explain why sunk costs that have already been incurred may influence the exit decision. Forward looking but static DCF models fail to value the potential wisdom of a managerial change of heart, and, hence, treat sunk costs as irrelevant when computing the NPV of remaining in an industry. However, research has shown that sunk costs do matter, and firms may persist in an industry if they have made large investments in physical or intangible assets that cannot be recovered in the event of exit (Porter, 1976; Harrigan, 1981). If one assumes that the neoclassical model describes economic rationality, then a relationship between sunk costs and exit can only be explained by theories premised on irrationality (e.g., Staw, 1981; Shimuzo and Hitt, 2005). In contrast, real options theory demonstrates that when managers are uncertain about the future of an industry, it is perfectly rational to consider sunk costs when making the exit decision (Dixit, 1989).

Real options theory argues that it may be economically wise for even poorly performing firms to persist in an industry. Although precise valuation can be quite complex (Dixit, 1989), the intuition is not. Suppose a firm is considering abandoning an industry in which it is currently competing. As uncertainty increases, the distribution of possible future outcomes widens, the potential for significant improvement in industry conditions increases, and exiting the industry becomes less attractive. The options logic is pertinent here because the firm can always truncate the downside by exiting later if conditions either fail to improve or deteriorate. However, a firm that exits now may wish to subsequently re-enter the industry if conditions improve significantly. Unfortunately, a firm that exits now and re-enters later must re-incur all, or at least part, of the sunk costs of entry. Thus, a firm will be willing to incur some operating losses in order to preserve the option of future profitable operations should improve industry conditions (Dixit, 1992). In order to induce exit, the losses have to exceed the value of keeping this option alive.

2.2 *Real options theory and the sunk cost fallacy*

Although real options theory and the sunk cost fallacy make relatively similar predictions about the impact of sunk costs on exit, we offer six reasons why the real options perspective offers a superior framework for analyzing exit decisions.

First, research on the sunk cost fallacy has been driven by the premise that *any* attention to previously incurred sunk costs is irrational. Yet, as we have discussed, this premise is derived from an incomplete model of economic rationality (i.e., the neoclassical model) and is patently wrong. Real options theory shows that attention to sunk costs when making exit decisions is entirely rational. By Occam's razor, the real options perspective on sunk costs should be considered the default explanation because it is more parsimonious. That is, a real options explanation requires only a relatively simple assumption that decision-makers choose a certain course of action because it is wise to do so. In contrast, the sunk cost fallacy relies on the more complex assumption that people fail to act in their own best interests, which is contrary to arguments from evolutionary psychology that people generally employ useful decision-making heuristics (Kihlstrom, 2004).

Second, much of the research supporting the sunk cost fallacy is based on case studies (Staw, 1981; Ross *et al.*, 1993). However, anecdotes can only illustrate that errors occur and offer no evidence of a systematic bias in the error distribution. Accordingly, anecdotes can also be used to illustrate a *reverse* sunk cost bias (Heath, 1995). Third, as Friedman *et al.* (2007) explain, many of the supposedly fallacious choices highlighted in the extant research (including the aforementioned anecdotes) can be rationalized when one adopts an appropriate economic model for evaluating sunk costs. Fourth, although Friedman *et al.* (2007) were able to detect a sunk cost effect that exceeded appropriate rational models after considerable effort and manipulation in an experimental setting, they found it to be very small and erratic and relatively trivial in terms of explanatory power compared to variables pertaining to rational choice.

Fifth, numerous psychological mechanisms have been proposed to explain the sunk cost effect. However, a recent study by Biyalogorsky *et al.* (2006) demonstrated that, contrary to many previous explanations of escalation of commitment,¹ persistence is not driven by psychological involvement with the original decision. While an involvement effect would suggest that irrational biases are at work, the authors found instead that the only psychological mechanism driving persistence was biased belief updating. However, the authors did not account for the value of real options when labeling persistence as "biased." Indeed, in the experimental scenario for which project termination is presumably rational, there would appear to be significant uncertainty about the future of the product, uncertainty that is compounded by the fact that the industry is growing faster than anticipated. Thus, the only mechanism actually found to be related to the sunk cost effect is actually consistent with rational choice. Hence, while we concur with Biyalogorsky and colleagues that there are important psychological mechanisms and/or decision

¹The terms "escalation of commitment" and "sunk cost fallacy" are often used interchangeably. However, there are subtle differences, as escalation bias need not entail sunk costs, and under the sunk cost fallacy firms may simply maintain positions without escalation.

heuristics at work driving the tendency for managers to look beyond the simple NPVs presented to them, we also stress that these heuristics might generally serve us quite well.

Finally, even if a trivial sunk cost bias can be detected by laboratory experiments deliberately contrived to detect such an effect, it may be questionable whether it would persist in real world applications. Behavioral research has found that individual cognitive biases can be largely attenuated when subjects are motivated to be accurate (Kruglanski, 1980), feel that they will be held accountable for their decisions (Tetlock, 1992), take more time to make their decision (Webster, 1993), or even just by the routines of organizational decision-making (Burgelman, 1996; Tetlock, 2000). Certainly, cognitive biases may offer useful insights into the decision-making processes of individuals in many real-world situations. However, given the likely time, effort and diligence invested in major decisions such as exiting an industry, in conjunction with the fleeting and minor influence of any potential sunk cost bias, we believe that real options theory provides a superior framework for considering firm inertia with regards to exit decisions.

2.3 Existing empirical evidence

Despite the promise of real options to the study of exit, there has been surprisingly little empirical work to validate its predictions. Ansic and Pugh (1999) used laboratory experiments with students to surmise that the presence of sunk costs and exchange rate uncertainty has a negative effect on exit from foreign industries. Similarly, Tiwana *et al.* (2006) used a quasi-experimental survey to demonstrate that numerous types of real options could potentially dissuade termination of a project, although they did not consider the interaction between uncertainty and sunk costs. In terms of real world exit decisions, Moel and Tufano (2002) found that a real options model explained the opening and closing of North American gold mines between 1988 and 1997 better than the neoclassical model. However, this evidence only shows that real options can explain the decision to suspend operations, and not that real options can explain managerial decisions to exit from industries. Stronger evidence is supplied by Campa (2004), who examined whether real options could help explain the decision to cease foreign export activities. Unfortunately, he found only mixed evidence in support of the theory. We believe that his weak results may be due to his operationalization of uncertainty, which was based solely on exchange rate uncertainty. While this is certainly an important component in the exit decision, it is really total uncertainty which is pertinent. Hence, neglecting the uncertainty in the exported goods product market may result in an imprecise test of real options theory.

Ghosal (2003) provides probably the most comprehensive test to date of the tendency for real options to influence the decision to exit industries. However, his ability to control for alternative explanations was hampered by the nature of his data.

Ghosal (2003) only had data on the total number of firms in each industry, and thus could only assess net changes in the number of industry participants rather than true entry and exit. Also, lacking firm level data, he could not control for firm level factors (such as performance) that might induce broadly similar results.

Thus, while some evidence exists to support a real options perspective on exit, much more remains to be done. In particular, while existing evidence suggests that both uncertainty (Harrigan, 1981) and sunk costs (Porter, 1976) influence exit, and that stock markets value the real options associated with termination decisions (Berger *et al.*, 1996; Kumar, 2005), we lack empirical evidence demonstrating that the industry exit decisions of real managers are sensitive to the *interaction* of sunk costs and uncertainty, which is the true crux of the real options logic. Hence, we develop hypotheses below relating to the ability of real options to deter exit and we test our predictions on a large sample of business unit exits by public corporations.

2.4 Exit decision: Uncertainty, firm profitability and technological intensity

According to the neoclassical model, expected future performance should be the dominant consideration in the exit decision. It is thus no surprise that studies have found that current performance, which is one of the best predictors of future performance (Ball and Watts, 1972), is a powerful determinant of exit (Ravenscraft and Scherer, 1991). Real options theory is intended to supplement (not supplant) this view by emphasizing that it is not just *expected value* of future profitability that matters, but that the *distribution* of potential future cash flows also warrants consideration. With greater uncertainty, there is a greater possibility that struggling firms can turn things around. Conversely, if conditions deteriorate, the firm can always truncate losses by exiting later. Hence, greater uncertainty in an industry should, *ceteris paribus*, dissuade firms from exiting that industry because it increases the option value of persisting in the industry.

Hypothesis 1. Greater uncertainty makes it less likely that a firm will exit an industry.

Recent evidence suggests that real options are most salient to managers when other quantifiable benefits are negligible (Tiwana *et al.*, 2007). While this may represent biased decision-making in some situations (Tiwana *et al.*, 2007), this relationship is easily rationalized in the case of exit. When profitability is high, the option value to persisting in an industry is an immaterial consideration because it is unlikely that managers will be considering exit. However, as profitability falls, and the easily quantifiable benefits of remaining in the industry evaporate, the option value of persistence should become much more influential. Hence, we propose that the influence of the industry's uncertainty on exit will depend upon current performance.

Hypothesis 2. As a firm's profitability in an industry decreases, the negative impact of uncertainty on exit from that industry will become stronger.

Although uncertainty should generally dissuade exit, we have argued that sunk costs will play a critical role in moderating this relationship. If the capital committed to the industry was fully reversible, then a poorly performing firm could exit, re-deploy its capital, and reenter later if industry conditions improve. Conversely, if the capital committed to the industry is largely sunk, then the firm cannot costlessly reverse the exit decision. Thus, uncertainty about future conditions in the industry should matter most when entering that industry requires sunk cost investments. While sunk costs are not easily observed or measured, theory suggests that investments in technology are generally highly irreversible (Fichman, 2004). Arrow (1968) argues that intangible assets have little value outside their current application because they are likely to suffer from market failure, making trade on the open market difficult relative to physical assets. Competing in knowledge intensive industries requires large expenditures on R&D. While these investments in R&D create valuable knowledge-based assets, these assets are intangible, highly firm-specific (Long and Malitz, 1985; Friend and Lang, 1988; Balakrishnan and Fox, 1993; Helfat, 1994), tightly coupled to the firm's organization (Kogut and Kulatilaka, 2001), and, therefore, are largely sunk investments (Armour and Teece, 1980; Caves and Bradburd, 1988; Titman and Wessels, 1988; Gompers, 1995). Hence, firms that compete in technologically intensive industries should generally incur higher sunk costs. Accordingly, we propose

Hypothesis 3. The negative impact of uncertainty on exit will be stronger in technologically intensive industries.

2.5 Firm strategy and real options

Sutton (1991) pointed out that the sunk costs required for entering an industry may be influenced not just only by the exogenous nature of the industry but also by the strategy endogenously selected by the firm to compete in that industry. Regardless of the technological intensity of an industry (be it high or low), firms vary within industries in the extent to which they attempt to compete on the basis of innovation. Aspiring innovators not only have to incur greater sunk cost investments in R&D (Kochhar, 1996) but we argue that firms attempting to compete by building innovative capabilities incur additional "strategic sunk costs" if they exit an industry then later re-enter. Theory suggests that the stock of innovative capabilities is best built by steady, continuous investment over a period of time (Dierickx and Cool, 1989). Therefore, firms that leave and subsequently re-enter will be at a competitive disadvantage relative to other would-be innovators that remained in the industry and continued to build their capabilities. Just as Kulatilaka and Perotti (1998) point out

that delaying entry can entail strategic losses, we contend that the category of sunk costs should also encompass strategic losses associated with exit. Even if the capital committed to an industry is fully reversible, the competitive position of a firm that exits now and re-enters later may be significantly eroded because the firm would have been much more competitive had it not taken temporary leave. Whereas firms that compete on low cost by reaching economies of scale with fungible assets may suffer relatively small competitive sunk costs, these costs might be quite severe for aspiring innovators.

In addition to increasing sunk costs, innovation-based strategies may also moderate the value of the option to defer the exit decision by helping firms to learn about and act upon unfolding opportunities in the industry. While uncertainty increases the value of all options, Dixit (1992: 118) points out that “[t]he option value of keeping the operation alive is governed primarily by the upside potential.” Of course, distinguishing between an industry’s upside potential and total uncertainty is a moot point if outcome distributions are always symmetric. However, when faced with a turbulent environment, the upside of the uncertainty distribution might well be accentuated for innovators, relative to non-innovators. An industry that is characterized by considerable uncertainty is one, by definition, in which there is a significant possibility that conditions will undergo dramatic change. Although firms often have trouble adapting in a changing environment, innovators should generally be more capable of spotting opportunities and adapting to change (Cohen and Levinthal, 1990; Pisano, 1994; Windrum, 2005). Thus, innovators may be particularly well-positioned to capture a disproportionate share of the industry’s upside potential, and, hence, would be less likely to abandon such environments. If innovator firms incur higher sunk costs and also reap an accentuated upside to the distribution of potential outcomes, then uncertainty should be a greater deterrent to exit for these firms.

Hypothesis 4. The negative impact of uncertainty on exit will be stronger for firms that compete in the industry on the basis of innovation.

Firms expand in order to productively deploy underutilized resources (Penrose, 1959). Although those resources may sometimes be of use in unrelated industries, they will generally be most applicable to industries that are related to existing operations (Montgomery and Wernerfelt, 1988; Piscitello, 2004). Exiting an industry that is unrelated to the rest of the firm’s operations may allow a firm to refocus its operations and improve performance (Hoskisson *et al.*, 1994), and thus relatedness should have a negative main effect on exit. Furthermore, synergy across business units may help a firm better capitalize on an industry’s upside potential. Hence, a pure resource-based perspective implies that relatedness will amplify the tendency for uncertainty to dissuade exit. Curiously, a real options perspective suggests that this may not be the case.

Given little attention in the resource-based view (RBV) is the potential for relatedness to influence a firm's sunk costs. This is ironic because resource fungibility, a central tenet of the RBV, has close parallels to investment reversibility. It stands to reason that if resources can be leveraged across related segments when the firm expands, it should be possible to redeploy them from an abandoned segment into an ongoing segment if the firm contracts (Anand and Singh, 1997; Helfat and Eisenhardt, 2004). Resource fungibility should also allow the firm to re-enter the abandoned segment at a later time while undertaking fewer sunk investments. Furthermore, operating in another highly related industry should also attenuate the erosion of the firm's competitive capabilities, and, hence, reduce the competitive sunk costs of exit and reentry. To the extent that the firm can still monitor the industry, nurture its valuable capabilities, and learn from a proximate vantage point taking temporary leave from the industry may not induce a significant competitive penalty. Thus, relatedness actually reduces the sunk costs of exit and later reentry.

The above arguments suggest that the influence of relatedness on exit is ambiguous. Relatedness may amplify a firm's ability to capitalize on upside potential, thereby raising the option value of remaining in the industry and diminishing the probability of exit. However, it may also decrease the sunk costs associated with exit and re-entry, thereby reducing the option value of keeping the operation alive and increasing the probability of exit. While one might argue that it is an empirical question as to whether relatedness will have a greater affect on upside variance or sunk costs, we predict that the sunk cost effect will dominate. Persisting in an industry is only valuable to the extent that it avoids possibly re-incurring the sunk costs of entry. Thus, the option value of persistence is bounded by the total sunk costs of reentry, and, hence, even a greatly accentuated upside will become irrelevant as sunk costs become minimal. Therefore, even though industry uncertainty can provide powerful incentives to remain in an industry, the root of those incentives is largely undermined when a firm operates in other highly related industries. Accordingly, we posit that the influence of relatedness on sunk costs will generally overshadow their influence on uncertainty, and thus relatedness should attenuate the influence of uncertainty.

Hypothesis 5. The more related a business unit is to the firm's other business units, the weaker the negative impact of industry uncertainty on exit from that industry.

As an illustrative example of the ability of strategy to influence option values, consider the evolution of Intel's product market offerings. Burgelman (1994, 1996) offers a vivid account of how Intel decided to exit the market for DRAM memory chips in 1985, thereby evolving from being "the memory company" into being "the microprocessor company." Although the company had been built on its success in

RAM chips, that industry had matured into being a commodity industry with little room for differentiation. Thus Intel, a company that competed primarily by being first to market with innovative products that commanded a premium, found their capabilities ill-suited to the market and saw limited upside potential. While Intel did not *expect* a turnaround, there was great uncertainty about the future of the industry. With potentially massive sunk-cost investments in this industry, one might suspect that there would be significant option value to persisting for some time just in case unfolding conditions deviated from expectations. However, Intel's related product market presences may have actually usurped the option value of persisting in the DRAM market.

Burgelman (1994, 1996) describes how Intel was able to transfer critical manufacturing resources and R&D capabilities from DRAM to the highly related microprocessor industry. Thus, unlike many competitors who lacked a presence in microprocessors, Intel faced relatively minor sunk costs and, hence, trivial option value to persisting in the industry. While Intel did persist in the industry for some time after they began losing money, Burgelman (1994) points out that this was not "crippling inertia" but rather a function of the time it took to transfer critical competencies to other divisions. Empirically, this delay in exiting would relate to the strong negative main effect for relatedness on exit, while the interaction of relatedness with upside variance would reveal that the option value of persisting was likely not a significant consideration for Intel. Furthermore, Intel's innovative capabilities and proximate product market position did apparently bear an influence on upside variance, as Intel was able to enter and become a dominant player in the market for flash memory chips when that product market began to show significant promise (Reinhardt, 1996).

3. Methods

3.1 *Sample and data sources*

Our theoretical framework is concerned with the option value of remaining in an industry, a real option which is only fully extinguished by complete exit from the industry. One potential approach for studying this phenomenon would be to draw a sample of divestitures from a data source such as Thomson's SDC Platinum. However, such divestitures only tell us that a firm sold assets in a particular industry, and not that the firm fully exited from it. Furthermore, we require detailed information on the firm's performance in the industry. Therefore, we decided to draw our sample from the Compustat Business Segments database, which contains detailed financial information on each industry in which all public firms have significant operations (for more details, see Davis and Duhaime, 1992). In this database, firms may report up to 10 business segments, with each segment having a

primary and a secondary SIC code, as well as one primary SIC code for the firm. Thus, each year any firm could potentially report up to 21 SIC codes.

Although SIC codes are given at the four-digit level, we aggregated up to the three-digit level because early pilot runs indicated that performing the analysis at the four-digit level would result in both many missing values for our industry-level variables and many of the remaining values being based on a very small number of firms. Furthermore, we were concerned that the potential modest year-to-year variability in the reporting of SIC codes in Compustat (Davis and Duhaime, 1992) may introduce noise into both our industry-level variables and our measure of exit. These problems were largely attenuated, however, by moving to the higher level of aggregation. While we define an industry relatively broadly, it is worth stressing that the lines between industries are more clearly demarcated at higher levels of aggregation, and that defining an industry too narrowly may be more problematic than defining it too broadly. To the extent that an industry definition is overly broad, it should only result in less precise measurement of constructs and, hence, greater noise in the empirical tests. Thus, any bias induced by an overly broad definition of an industry would be a conservative one (i.e., against finding statistical significance).

Our initial sample included all 244,076 segment/year observations listed in Compustat from 1985 to 2003. Aggregating the segments up to the three-digit SIC level reduced the sample to 207,081 observations. As we cannot detect an exit the very first year a firm is listed, our effective test sample was further reduced to 185,085 observations. Excluding firms with the SIC code 999 (not elsewhere classified) left of sample of 184,238 segment/year observations from which we calculated exits. In order to avoid highly distorted financial ratios, we also excluded almost 16,000 observations from the final analysis that had assets of less than 1 million dollars. Because of occasional missing values, the final analysis encompassed 167,795 segment/year observations, representing 16,447 firms operating in 405 industries. Thus, our data represents a large sample of firms operating in many industries over a significant period of time. These qualities are advantageous since they should yield significant variation in both firm and industry-level factors.

Although Compustat has the advantages described above, there are two major concerns with using it (or any data source) to detect exits. The first concern is that we may fail to detect some exits. Given the nature of our data and our sample, we acknowledge the possibility that we may indeed miss some exits, particularly from industries in which the firm had very minor operations. This could mean that our results are describing not all exits, but rather just exits from industries in which a firm had previously made a nontrivial commitment. Although this may be a qualifying consideration, it is not a critical shortcoming as the results are still descriptive of an important phenomenon. Moreover, our theory is intended to describe how previous commitments induce inertia and therefore influence the exit decision. Thus, exit decisions in the absence of a previous substantive commitment

fall outside the realm of our theoretical framework. Indeed, to the extent that our data may exclude small commitment exits, it will reduce the variation in our sample, and should have the effect of making it more difficult to detect significant results. Thus, if any systematic bias exists, we expect it to hinder our ability to find results in support of our theory. A second concern is the possibility of erroneously recording some observations as exits. We believe that we minimized this second more serious concern through the construction of the sample of exits (described below). While we may miss some exits that entailed minimal previous commitment, we believe that all of our exits are legitimate exits.

3.2 *Dependent variable: Exit*

To construct the variable *Exit*, we took a two-stage approach. First, we searched the database for instances in which one of the firm's primary segment SIC codes in a given year is not listed the following year in any of the potential 21 places where the firm may report SIC codes. This procedure yielded 14,192 potential exits. However, an SIC code may disappear for reasons other than complete exit from an industry, such as structural reorganization (Davis and Duhaime, 1992). Thus, in the second stage, we restrict the sample of exits to firms that report income from discontinued operations in the year that the SIC code disappears. This data item represents the sum of income (or loss) from operations of a discontinued division and the gain (or loss) on the disposal of that division. Reporting standards require that as soon as management adopts a plan for the sale or disposal of a segment, the operations of that segment must be segregated on the income statement (White *et al.*, 1994: 167-168). Therefore, the year in which an SIC code disappears and the firm reports income from discontinued operations represents the year in which management decided to exit from the industry. This approach yielded a total of 4664 exits in the full sample and 4038 exits in the final test sample of 167,795 segment/year observations (implying a 2.4% probability of exit each year, on average).

It is worth noting that reports of income from discontinued operations are relatively rare, occurring in only about 8% of all firm/year observations. About 40% of such reports corresponded to the year an SIC code disappeared (i.e., a coded exit) and an additional 20% occurred the year after that SIC code disappeared (as disposal can sometimes take more than 1 year). Given that firms may sometimes close some operations (and, hence, report income from discontinued operations) but not completely exit an industry, these statistics give us confidence that our exit sample includes the large majority of complete industry exits that occur and that very few of our coded exits would represent erroneous classifications. However, one limitation of our approach is that we include both losing divisions that were abandoned and profitable divisions that were sold for a profit. Although our theory should generally apply to both cases, the option value of keeping an operation alive is

most salient for struggling divisions. Hence, in two unreported sets of analysis (results available upon request), we restricted our sample of exits to either (i) segments that reported negative profitability in the last year of record or (ii) exits where the reported income from discontinued operations (which includes any profit or loss on disposal) was negative. In both instances, the results were virtually identical if not stronger than the ones reported below. Thus, we believe our results are conservative estimates.

3.3 Primary independent variables

Although uncertainty has been modeled in many different ways, most approaches have been based on the volatility of some time series. Accordingly, we chose to model uncertainty based on the volatility of stock returns. The primary benefit of this approach is that the underlying series considers all expected future profitability, and all sources of uncertainty that may impact that profitability. Following many studies in finance and economics (Carruth *et al.*, 2000), we modeled the stock returns data using generalized autoregressive conditional heteroskedasticity (GARCH) models (Bollerslev, 1986). The main advantage to employing a GARCH model is that it produces a time-varying estimate of the conditional variance of a time series, controlling for any trends that might exist in the data. In order to generate measures of industry level uncertainty, we ran GARCH models (specifically, a GARCH-M[1,1] model) on the daily stock returns (adjusted for all splits and dividends, etc.) of every firm listed in the CRSP database from 1950 to 2003. This produced measures of stock volatility for every trading day and for every firm over this period. Our proxy for annual industry-level *Uncertainty* is the median standard deviation of stock volatility for all firms competing in the industry for the relevant year.

Our measure of industry *Profitability* is constructed by dividing total segment operating profit by total assets. As described later, we empirically account for the endogeneity of this variable. To assess whether or not an industry is *Technologically Intensive*, we created a dummy variable that classifies an industry as technologically intensive if the R&D to sales ratio of the median business unit competing in that industry is greater than 5% (Berry, 2006).

While *Technologically Intensive* assesses variation *across* industries in technological intensity, Hypothesis 4 is concerned with variation *within* the industry in the extent to which firms emphasize innovative capabilities. O'Brien (2003) argued that a firm's intensity of investment in R&D relative to other firms competing in the industry proxies for the extent to which a firm competes on the basis of innovation. That is, firms that invest in R&D at a much higher rate than their competitors are most likely *trying* to compete on the basis of innovativeness. Accordingly, we construct the variable *Innovator* by first computing R&D intensity (i.e., total R&D spending divided by total sales) for every business segment listed in our full sample, and then

comparing the R&D intensity of each segment to all business segments competing in the same industry (as defined by each segment's primary industry). The final value for this variable is the percentile rank for the business segment for R&D intensity relative to all other business segments competing in that industry. One limitation of this measure, however, is that in addition to proxying for the sunkness of investments, high levels of spending on R&D may also indicate that management is highly committed to remaining in the industry. While this possibility would suggest a main effect for R&D, it does not suggest any interaction with uncertainty, as we hypothesize. Furthermore, we empirically account for the endogeneity of this variable, and our results remain qualitatively identical even if we lag the variable *Innovator* for anywhere from 1 to 5 years, which alleviates concerns about near-term commitment.

To assess whether firms operate in highly related industries, the degree of relatedness between all pairs of industries was calculated by producing a list of all industries every firm competes in, and then calculating the likelihood that a firm operating in industry j will also operate in industry m , corrected for the expected degree of relatedness under the null hypothesis that diversification is random. This is similar to the measure proposed by Teece *et al.* (1994), except that our measure was recalculated every year to allow for changes over time. The degree of *Relatedness* between the focal industry and the remainder of the firm's portfolio of industries is the distance between the target industry and nearest other industry in the firm's portfolio.

3.4 Control variables

As financial slack will likely influence a firm's ability to maintain investments (Kovenock and Phillips, 1997), we include two controls for this construct. *Leverage* is the ratio of long-term debt to total assets, and *Cash* is the ratio of total cash and short-term investments to total assets. *Diversification* controls for how diversified the firm was prior to the exit decision by subtracting from one the sum of squared shares of each of the firm's business segments. *Advertising* is the ratio of total expenditures on advertising to total sales. *Size* is the natural log of the business segment's total assets. We also control for general industry conditions that might influence the exit decision. *Industry Profitability* is measured by the ratio of operating income to total assets for the median business segment in each industry.

Unless otherwise stated, all variables were derived from either the Compustat Business Segments database (for segment level variables) or the Compustat Industrial database (for firm-level variables). Industries were defined at the three-digit SIC code level. In occasional instances where an industry-level variable was missing at the three-digit level, or if it was based on less than five firms, we substituted in an industry value based on the two-digit SIC code. A Box-Cox procedure suggested nonlinearities in the relationship between exit and relatedness, as a natural log

transformation of *Relatedness* dramatically improved its ability to predict exit. Hence, we transform *Relatedness* by taking the natural log. Finally, the distributions of *Profitability*, *Leverage*, *Advertising*, and *Uncertainty* each contained some extreme outliers. Rather than drop the outliers, we winsorized these variables at the top and bottom 0.5% of their distributions.

3.5 Analysis

Testing our hypotheses presented a critical methodological consideration, as both *Profitability* and *Innovator* might be endogenously determined. In our model, *Profitability* and *Innovator* are observed one year, and the exit decision occurs the following year. Thus, the model is hierarchical (i.e., exit depends on performance but performance does not depend on exit). If the model were recursive (i.e., hierarchical with uncorrelated errors) the exit equation could be estimated without concern over endogeneity. However, even if the model is hierarchical, it is not reasonable to assume that the endogenous regressors (i.e., *Profitability* and *Innovator*) will be uncorrelated with the error term in the second equation (i.e., the exit equation) since any degree of model misspecification or measurement error will likely induce such correlation (Alvarez and Glasgow, 1999). Thus, traditional binomial regression approaches such as logit or probit estimation may lead to biased estimates of the coefficients due to the potential correlation between the error term and the endogenous regressor (i.e., omitted variables bias). Currently, there are two common approaches for modeling a dichotomous-dependent variable with one or more endogenous predictor variables: Two-stage probit least squares (2SPLS) and two-stage conditional maximum likelihood (2SCML) (Rivers and Vuong, 1988). Although 2SPLS is more flexible, we opted to use 2SCML because it fits the hierarchical structure of our model and because its standard errors are more accurate (Alvarez *et al.*, 1999).

To implement 2SCML, the continuous endogenous variables (i.e., *Profitability* and *Innovator*) are first estimated by normal regression techniques, then the residual from that regression is included in the second stage probit equation (i.e., on *Exit*). However, in order to be properly identified (and avoid perfect collinearity), the equation that estimates the endogenous variable must contain at least two independent variables not in the dichotomous variable equation. These instruments should be strong predictors of the respective endogenous variables, but weakly related to the dependent variable (i.e., *Exit*). Exploratory regressions indicated that a firm-level equivalent of the variable *Innovator* would serve as a valid instrument for the segment-level variable *Innovator*, while segment-level depreciation expenses (divided by total segment assets) would serve as a valid instrument for *Profitability*. Furthermore, if *Profitability* and *Innovator* are endogenous, it is likely that their respective interactions with *Uncertainty* may also be endogenous. Therefore, we also created instruments for the interaction terms by interacting *Uncertainty* with the

respective instruments for the endogenous variables.² Finally, it should be noted that since our data contain multiple observations per firm, the potential confounding influence of unobserved heterogeneity is a concern. Thus, all models used robust standard errors that account for correlation across the various observations for each firm/segment (Williams, 2000; Wooldridge, 2002). Results were similar if we incorporated random firm effects.

4. Results

Model 1 of Table 1 presents a base probit model that does not account for the endogeneity of *Profitability* and *Innovator*, while Model 2 presents the 2SCML estimate of the same equation. Both of the residuals in Model 2 are significant ($P < 0.001$), and the likelihood ratio test for Model 2 versus Model 1 is also significant ($P < 0.001$), thereby confirming that the variables are endogenous and 2SCML is warranted (Rivers and Vuong, 1988).³ Interestingly, the coefficients for *Profitability* and *Innovator* are several times larger in Model 2 versus Model 1, suggesting that failing to account for their endogeneity underestimates their true influence. Also noteworthy are the positive effect of *Diversification* ($P < 0.001$) and the negative effect of *Relatedness* ($P < 0.001$) on exit, which suggests that refocusing may be a prime driver of exit. In support of Hypothesis 1, *Uncertainty* had a significant negative ($P < 0.01$) main effect in Model 2.

Models 3 through 6 add in the hypothesized interactions with uncertainty. In each case, addition of the interaction(s) significantly improves the log pseudolikelihood ($P < 0.001$). While we sometimes add in the interactions in pairs for the sake of brevity, results are equivalent if we add them individually. Hypothesis 2 argued that industry uncertainty matters most when profitability is low. The significant positive coefficient ($P < 0.01$) for the interaction between *Uncertainty* and *Profitability* in Model 3 supports this contention. Model 4 tests Hypothesis 3 by introducing the interaction between *Uncertainty* and *Technologically Intensive*. As larger values of *Technologically Intensive* equate to greater sunk costs, the significant negative coefficient for the interaction ($P < 0.001$) supports Hypothesis 3 by indicating that uncertainty is a more potent dissuader of exit in technologically intensive industries.

Model 5 tests Hypotheses 4 and 5, which posit that strategy can also influence option values, and, hence, moderate the effect of uncertainty on exit. The significant negative ($P < 0.01$) coefficient for the interaction between *Uncertainty* and *Innovator* supports our contention that firms that compete through innovation will have higher option values than non-innovators. The significant positive coefficient ($P < 0.001$)

²We only include the residuals for the interactions if they were found to be significant in the relevant model.

³In unreported models, similar tests revealed that *Related* did not create any endogeneity problems.

Table 1 2SCML model results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Resid.						
Profitability	–	1.537 (0.41)***	1.986 (0.441)***	1.542 (0.41)***	1.903 (0.324)***	2.089 (0.323)***
Innovator	–	1.151 (0.287)***	1.178 (0.284)***	1.160 (0.287)***	1.319 (0.233)***	1.435 (0.231)***
Unc. x Prof.	–	–	–1.915 (0.846)*	–	–	–
Segment						
Profitability	–0.360 (0.022)***	–1.897 (0.409)***	–2.458 (0.438)***	–1.903 (0.409)***	–2.263 (0.323)***	–2.575 (0.327)***
Innovator	–0.412 (0.049)***	–1.538 (0.286)***	–1.566 (0.284)***	–1.546 (0.286)***	–1.476 (0.229)***	–1.622 (0.23)***
Relatedness	–0.830 (0.032)***	–0.852 (0.032)***	–0.850 (0.032)***	–0.854 (0.032)***	–0.986 (0.048)***	–0.972 (0.048)***
Size	–0.073 (0.004)***	–0.019 (0.014)	–0.015 (0.014)	–0.019 (0.014)	–0.006 (0.012)	0.001 (0.012)
Firm						
Divers.	1.475 (0.031)***	1.386 (0.037)***	1.398 (0.038)***	1.387 (0.037)***	1.380 (0.036)***	1.376 (0.036)***
Leverage	0.208 (0.033)***	0.091 (0.045)*	0.088 (0.045)*	0.092 (0.045)*	0.063 (0.041)	0.051 (0.041)
Cash	–0.304 (0.056)***	–0.220 (0.06)***	–0.205 (0.06)***	–0.216 (0.06)***	–0.188 (0.06)**	–0.173 (0.06)**
Advertising	–0.089 (0.246)	–1.067 (0.361)**	–0.948 (0.362)**	–1.073 (0.361)**	–1.290 (0.317)***	–1.362 (0.318)***
Industry						
Uncertainty	–0.254 (0.118)*	–0.330 (0.119)**	–0.278 (0.118)*	–0.319 (0.119)**	1.764 (0.422)***	1.541 (0.439)***
Tech. Inten.	–0.249 (0.033)***	–0.307 (0.037)***	–0.322 (0.037)***	0.255 (0.17)	–0.329 (0.035)***	0.197 (0.171)
Indus. Prof.	–0.111 (0.14)	1.621 (0.476)***	1.674 (0.474)***	1.595 (0.477)***	2.001 (0.379)***	2.158 (0.383)***
Interactions						
Unc. x Prof	–	–	2.557 (0.809)**	–	–	0.746 (0.212)***
Unc. x Tech.	–	–	–	–2.850 (0.847)***	–	–2.714 (0.854)***
Unc. x Innov.	–	–	–	–	–1.606 (0.544)**	–1.422 (0.576)*
Unc. x Relat.	–	–	–	–	1.139 (0.273)***	0.991 (0.278)**
Model						
Wald χ^2	3548.7***	3546.1***	3566.4***	3564.1***	3559.2***	3595.8***
Log PLL	–16,408.4	–16,400.9	–16,387.7	–16,395.0	–16,385.9	–16,370.8
LRT	–	14.974***	26.32***	11.804**	29.912***	60.216***

Numbers in parentheses are standard errors. For all models, $n = 167,795$. All models also included year fixed effects.

The Log PLL is the Log pseudolikelihood and the LRT is the likelihood ratio test.

+ $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$ (all tests are two-tailed).

for the interaction between *Uncertainty* and *Relatedness* supports Hypothesis 5, which argued that when firms operate in other highly related industries, sunk costs will be diminished and, hence, uncertainty will be a less powerful deterrent of exit. Although the negative main effect of *Relatedness* is consistent with prior research, we believe the interaction between *Uncertainty* and *Relatedness* addresses an aspect of relatedness that until now has not been explored. Our finding suggests that relatedness may lower the sunk costs required for re-entry, and thereby reduce the option value of remaining in an industry. Finally, Model 6 present a fully saturated model that includes all the interaction terms.

In order to evaluate the economic significance of our results, we calculated the predicted probabilities of exit and graphed these relationships in Figure 1. Panel A illustrates that the relationship between uncertainty and the probability of exit is heavily contingent on profitability. In fact, consideration of this interaction can potentially lead to an order of magnitude refinement in our ability to predict exit. Similarly, Panel B reveals that the relationship between uncertainty and exit is critically contingent on the level sunk costs. When sunk costs are high, uncertainty has a strong negative impact on the probability of exit, as moving from the 5th to the 95th percentile of *Uncertainty* results in an ~93% decline in the probability of exit. Conversely, when sunk costs are low, uncertainty appears to have a weak positive impact on exit. Speculatively, it may be that risk aversion dominates when sunk costs are low.

5. Discussion and conclusions

This article makes an important contribution to the real options literature by empirically demonstrating the power of real options to deter exit and by theoretically explicating how sunk costs can be impacted by both exogenous industry conditions and by endogenous strategic decisions. This article also makes an important contribution to the literature on managerial decision-making by challenging some traditional views on the nature of firm inertia. Furthermore, by arguing and demonstrating that firm strategy can influence a firm's sunk costs, we also enhance the applicability of the real options framework to the management and strategy literatures. Thus far, almost no work has considered how the value of real options may vary with a firm's strategy. If strategy is fundamentally about differentiating within an industry, then conditions that apply equally to all firms within industry, although potentially important, are not really "strategic" considerations. However, by considering differences in strategic positioning, we believe that we have extended real options theory into new areas. Our results also suggest that consideration of the sunk costs of these unique strategic positions, which is only fully appreciated through a real options perspective, is a significant and economically important element of strategy that has heretofore been ignored.

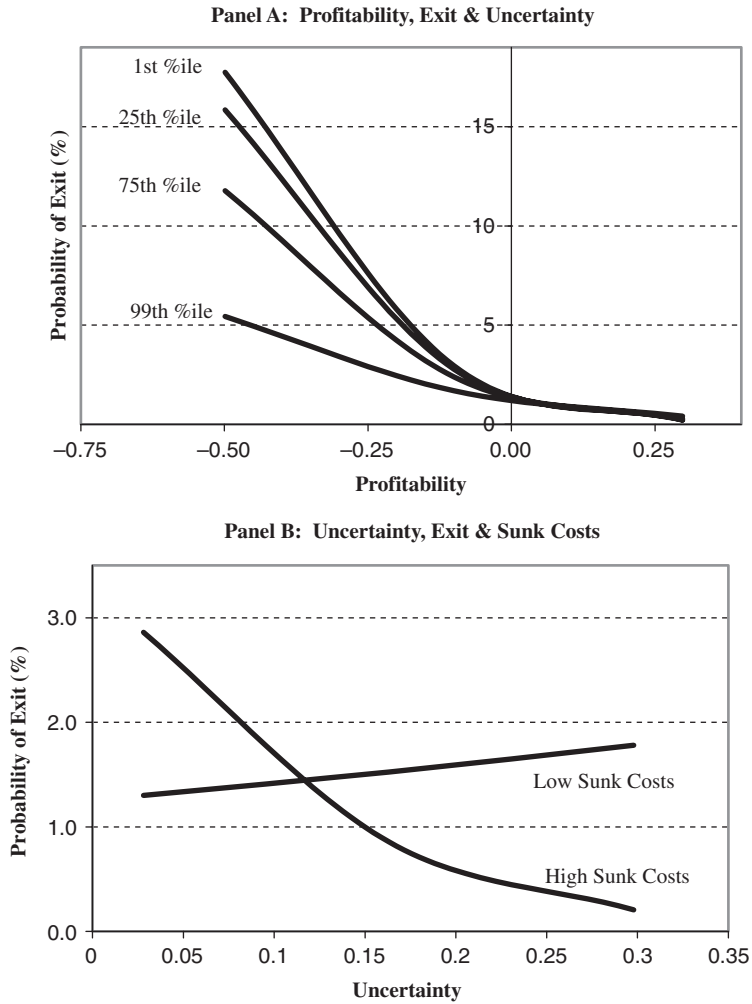


Figure 1 Predicted probability of exit. In each panel, the *y*-axis gives the probability of exit (as predicted by model 3 in Table 1 for Panel A, and by model 6 in Table 1 for Panel B); the *x*-axis plots the corresponding variable from the 5th to 95th percentile; all non-interacted variables were held constant at their mean. Panel A depicts the relationship between segment profitability and the probability of exit at varying levels of industry uncertainty. Panel B depicts the relationship between industry uncertainty and the probability of exit at varying levels of sunk costs. For the line labeled “low sunk costs”: *Technologically Intensive* was set equal to 0; *Innovator* was set equal to its mean minus one SD; and *Relatedness* were set equal to its mean plus one SD. For the line labeled “high sunk costs”: *Technologically Intensive* was set equal to 1; *Innovator* was set equal to its mean +1 SD; and *Relatedness* were set equal to its mean -1 SD.

One of our most interesting findings pertains to the role of relatedness in the exit decision. Consistent with prior literature, our results suggest that firms are more likely to exit industries that are unrelated to the rest of their portfolio of operations. At the same time, however, we find that the option value of keeping an operation alive is lower for related industries. This result draws important attention to the fact that relatedness influences not only a firm's ability to leverage its resources but also how it might do so. Apparently, firms can enter and exit related industries more freely than unrelated ones, without the same degree of sunk costs. We also emphasize that our results suggest that relatedness seems to influence sunk costs more than it does the upside potential of remaining in an industry. If relatedness influences sunk costs more than upside variance, then this suggests that the benefits of related diversification may derive largely from the ability to move around valuable resources from one application to another in response to fluctuations in industry cycles. This finding may of considerable consequence to the diversification literatures in economics, finance, and management.

The results of this study also have implications for a recent critique of real options research offered by Adner and Levinthal (2004). We tend to agree with two of their main contentions: That the real options framework has sometimes been over-extended and that real options are often impossible to precisely value in real-world contexts. However, we also concur with the retort that this framework may nonetheless provide useful insights into the economic logic of real behavior processes (McGrath *et al.*, 2004). A real options framework may be useful whenever a decision involves considerable uncertainty, the possibility of exercising future managerial discretion, and substantial irreversibility. Inspection of our results suggests that real managers do generally recognize and employ the economic logic suggested by this framework, even if precise valuation is infeasible.

Our results have weighty implications for the nature of firm inertia, as they suggest that persistence in the face of low profitability need not be linked to poor governance or irrational behavior. Rather, our results are consistent with the view that industry competition helps to drive out such maladaptive influences (Williamson, 1988). If firms resist exiting because of poor governance (Jensen, 1993), then one might conjecture that managers would tend to use industry uncertainty as an excuse for improperly remaining in an industry. Presumably, managers could use uncertainty as an excuse even if sunk costs were minimal. However, the finding that uncertainty only dissuades exit in the presence of sunk costs casts doubt on this perspective. Furthermore, our results also have strong implications for the supposed irrationality of the sunk cost effect. Earlier, we presented six reasons why a real options perspective provides a superior framework for evaluating the influence of sunk costs on exit decisions. Based on our results, we would add a seventh reason. The overall pattern of our results is more readily explained by real options theory than by the sunk cost fallacy. Figure 1 suggests that uncertainty does not dissuade exit when sunk costs are low, and that sunk costs are not necessarily associated with

a reduced probability of exit when uncertainty is low. While this interaction is congruent with real options reasoning, it is not easily explained within the framework of the sunk cost fallacy. Since real options suggest that attention to sunk costs and persistence despite low profitability can be economically rational, this framework and our results help to illustrate how “some behaviors that have been criticized as irrational turn out to be quite sensible” (McGrath *et al.*, 2004: 99).

In conclusion, we wish to emphasize the managerial significance of our results. Contrary to decades of managerial education, we found that in practicing managers generally have continued to rationally consider sunk costs when making exit decisions. However, some managers may have allowed their education to override their intuition. Some may have followed their intuition but felt guilt or been decried by financial analysts or boards of directors for committing the “sunk cost fallacy.” It is thus critical to spread the word of the real options logic, and to educate practitioners about the rationality of attention to sunk costs. It is also important that managers appreciate how strategy may impact these sunk costs. Attempting to differentiate ones products in the industry via innovation may result in becoming locked into the industry because of high sunk costs. Conversely, operating in highly related industries may provide an out by reducing the sunk costs of the commitments made to another industry.

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