

WHY DO FIRMS USE OPEN SOURCE STRATEGIES?: AN UNCERTAINTY REDUCTION THEORY

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ABSTRACT

Recent academic inquiry has questioned the traditional assumptions that successful market competition among profit-driven firms must be done in a closed manner to avoid competitors benefiting from knowledge spillovers by demonstrating that an open source strategy can be successful as well. Yet, it is still not well understood why firms choose an open source strategy when they have an array of more traditional strategies at their disposal. I argue that firms select an open source strategy to reduce the impact of different types of uncertainty that impede the clarity of their strategic options. An open source strategy allows firms to accept, disarm, share, compartmentalize, survive, and select uncertainty, reducing the negative impact of discontinuous change, transaction costs, loss of control, resource allocation problems, environmental selection, and poor fit. This choice means that firms are not stuck with strategies requiring high-stakes bets, hedging practices, or luck in order to reduce uncertainty. Instead, they can select an open source strategy that best reduces the types of uncertainty that they are facing.

Keywords:

Uncertainty; open source; behavioral theory of the firm; discontinuous change; environmental fit

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Bounded rationality limits strategic choices (Simon, 1991). The primary reason for the limitation is the impairment the decision maker suffers due to uncertainty of what lies outside her cognitive frame (Gavetti & Levinthal, 2000). This uncertainty is equivalent to a lack of information about all of the factors that impact strategic choices and the interconnections between these factors. The literature on strategy making has carefully considered how strategic managers make decisions in the face of uncertainty. They use tactics such as simplification (Schwenk, 1984), satisficing (March & Simon, 1958), trial and error (Alchian, 1950), framing contests (Kaplan, 2008), or imitation (Henisz & Delios, 2001) to cope with cognitive limitations (Simon, 1991).

Another way of looking at the impact of uncertainty is to consider the content of enacted strategies of firms. In turbulent, rapidly changing environments (Bourgeois & Eisenhardt, 1988), uncertainty is a serious constraint on strategy as planning (Mintzberg, Ahlstrand, & Lampel, 2008). Firms must implement strategies that include a variety of tactics such as sensing (Haeckel, 2004), forming alliances (Kanter, 1994), mergers and acquisitions (Walsh & Ellwood, 1991), and shaping the environmental structure (Lecocq & Demil, 2006), while walking a careful line between exploration and exploitation (March, 1991) to find the optimal value peak in their competitive landscapes (Gavetti & Levinthal, 2000).

On the one hand, decision making strategies help reduce the complexity of uncertainty by creating a set of processes that can be applied to novel circumstances, preventing strategic paralysis, but running the risk of being applied to contexts in which they are a poor fit. On the other hand, enacted strategies allow firms to adapt to a changing environment continuously as

they make strategic choices, promoting fit, but reducing replicability and requiring resource allocation bets that can be difficult to undo. Each type of strategy has advantages and shortcomings and new strategies are continuously emerging to address issues pertaining to specific environments, idiosyncrasies of firms, and the limitations of existing strategies. One such emergent strategy is open source strategy, and it does not cleanly fit into either of these two categories. Instead, it is a deliberate, replicable strategy that enables firms to adjust course as the environment shifts, maximizing the benefits of both approaches and minimizing the weaknesses.

In this paper, I argue that firms use open source strategies as a deliberate means of coping with uncertainty because open source strategies permit a simultaneous flexibility and replicability that is not possible with traditional strategies. First, I begin with a literature review of open source strategies and the existing explanations for firms selecting them. Second, I list and discuss the different types of uncertainty that firms face, and the traditional strategies that firms select to address them. Third, I discuss how open source strategies address uncertainty in ways that existing strategies cannot and develop propositions for further empirical examination. I conclude with a discussion of the implications for management research and strategic management practice along with suggestions for future research directions.

OPEN SOURCE STRATEGY

Open source strategy leverages the concept of peer production, a loosely organized means of cooperative production that is different from markets, hierarchies, and networks (Demil & Lecocq, 2006). In this form of organization, firms self-identify for participation in the production, and select themselves which tasks they will perform depending on what is most useful for them (Benkler, 2002). Participants are loosely tied to one another, with little or no hierarchical control, and governance systems that are designed to ensure that participants with

diverse goals can maintain equal footing. This production model has been called a bazaar (Raymond, 1999), open innovation (Chesbrough & Appleyard, 2007), private-collective innovation (von Hippel & von Krogh, 2003). The most common example of leveraging an open source strategy is participation in open source software development.¹ Open source software production has emerged in the past two decades as such a successful production strategy that it has become strong competition for proprietary software development strategies such as the methods used by Microsoft, Adobe, and Apple. Market penetration of open source software exceeds 90% in some areas such as embedded devices, network infrastructure, and high-performance servers (LinuxDevices.com, 2007; TOP500.Org, 2010).

Research into open source strategies has mostly focused on the incentives to participate. At first glance, it appears that firms contribute the time and effort of their employees to open source projects without obvious returns. But looking more deeply, research has shown that firms select open source strategies in order to reduce the transaction costs related to exchanging, defining, and protecting property rights (Foss & Foss, 2005). It has also been suggested that open source strategies may increase the value of a firm's complementary assets and may develop trust relationships between firms in an ecosystem to their mutual advantage (Lerner & Tirole, 2002). Finally, firms can use open source strategies to escape the traditional prisoner's dilemma context of joint innovation efforts, resulting in learning effects, network effects, reputation

¹ Some communities have strong feelings about the choice of words used to describe them. Some insist that "free", in the sense of liberty as opposed to at no cost, is the only apt description. Others prefer the use of "open" to avoid ambiguity. These discussions, while important to the communities in question, are beyond the scope of this paper. The term open source used in this paper should be read as a general term and not taken to refer to a specific sub-model of production or development method.

effects, and positioning effects for the firm that could not efficiently be obtained by other means (von Hippel & von Krogh, 2003).

One common element in the existing explanations for firms selecting an open source strategy is that, because the outcome of production is explicitly usable by all participants for whatever purposes might suit them, this shared product becomes a resource for complementary value creation and acquisition (von Hippel & von Krogh, 2003) for firms that participate in the effort. The shared product can take on characteristics of technological platforms upon which different firms build their own value-added component (Economies & Katsamakos, 2006). It can take on the form of a reference standard used to drive collective innovation (Osterloh & Rota, 2007). It can act as a means of changing the locus of value of a competing resource outside the open source project, realigning the value to be more readily acquired by the participants (Chesbrough & Appleyard, 2007).

Yet, while these examinations of firm incentives reveal some motivations, they do not fully account for the explosive growth of the number, quality, and penetration of open source projects and the increased levels of firm participation. At current count, there are nearly 300,000 distinct open source projects, each with distinct characteristics, communities, norms, needs, and types of participants (Sourceforge, 2011). Most projects start small with just a few contributors or a single sponsoring firm. Over time, in some cases over a decade or more, they can grow into incredibly complex organizations that look very much like large, decentralized firms. These open source projects are of such strategic importance that major companies such as Microsoft have explicitly listed them as strategic threats in their quarterly filings with the Securities and Exchange Commission (Galli, 2003). This recent explosion in strategic relevance has defied conventional analysis in the strategy literature, with classical models unable to clearly account

for how open source strategies can be so useful to firms. As Chesbrough and Appleyard (2007) put it, "if we are to make strategic sense of [these] innovation communities [...] and their implications for competitive advantage, we need a new approach to [investigate] strategy". This new approach, I argue, isn't to invent new theories that treat open source strategies as novel, but rather to try to understand what is different about open source strategies from well-understood first principles such as bounded rationality. From this theoretical perspective, open source strategies are novel because they agglomerate the advantages of several traditional strategic responses to environmental uncertainty into a replicable strategy that has fewer downsides than existing strategies. To better understand how open source strategies address uncertainty, it is important to have a clear picture of different forms of uncertainty and how they affect firm decision making.

FORMS OF UNCERTAINTY

Uncertainty is a "feature of organizational decision making with which organizations must live" (Cyert & March, 1963). The concept has been broken down in different ways by different researchers. Table 1 summarises the types of uncertainty described in the literature.

Insert Table 1 about here

One way of conceptualizing uncertainty is to divide it into unpredictability of the environment and complexity of the environment (Heiner, 1983; Suh, Key, & Munchus, 2004). Part of the boundary between firm and environment is a notion of understanding of what goes on within the firm that acts as a separation of available information from the chaos outside the boundary in the environment in which the firm operates. Firms exist, in part, because they are able to make sense of and coordinate internal factors because they are a limited subset of all the

factors in the environment. Firms face uncertainty when they must interact with the environment beyond the boundaries of the firm, as the environment is variable; what was before may not be so at a later decision point. For example, firms in a given environment come and go; government regulations are introduced; the availability of capital investments varies. Many of these factors that affect firms are unpredictable. Some can be the result of natural disasters. Others are the result of radical political shifts. There is an element of randomness to the unpredictability that cannot be eliminated from the perspective of the firm. Unpredictability can be largely due to the related concepts of variability (Alchian, 1950), and instability (Schoemaker, 1990) in that, for whatever reason, subsequent mappings of the environment will yield different results, hindering decision making.

Complexity can be represented by the number of factors that a strategic manager has to consider in order to make a given decision. By definition, the environment is vastly broader than any given firm, and simply counting all of the factors that affect a firm's course is a daunting task, let alone understanding them all. Complexity can also be represented by the properties of the factors, such as how readily they can be understood, how many distinct properties there are, and how those properties relate to the decision. For example, a factor that relates to environmental complexity could be the state of innovation in a particular product space. One of the properties of the factor is the limitations for the advancement of the development of the product. Understanding the limitations may require an advanced degree in chemistry, if the product is related to the oil and gas industry, or it may require an understanding of political science, if the product is used in election data mining. Even the most intelligent firms cannot hope to delve deep enough in the complexity of a given environment in order to fully understand it.

Environmental unpredictability and complexity mirror two of the constraints of bounded rationality (Simon, 1986), namely information availability and processing ability. Assuming a critical realist perspective on the environment, unpredictability is due to the amount of information an actor has about the underlying nature of the environment and access to that information. Firms cannot possibly have full information on the underlying nature of the environment, and so the environment changes in ways that cannot be predicted from its perspective. The complexity of the environmental information limits the firm's ability to process it to extract the underlying factors. As firms have limited processing ability, the complexity of the environment further constrains their understanding of the environment, producing another form of uncertainty.

An additional source of uncertainty stems not only from the unpredictability and complexity of the environment, but also from the interaction between the two factors. The interaction effect is distinct from the individual effects and suggests that normative strategies for dealing with uncertainty need to consider the implications of these factors as four distinct states representing the 2 x 2 grid of both complexity and uncertainty as either low or high (Suh, Key, & Munchus, 2004). This interaction effect is effectively a form of uncertainty of its own, especially given that it changes normative implications for decision makers.

Uncertainty can also be looked at across levels of analysis. If the environment is unpredictable and complex, firms have differing abilities at untangling the information availability and processing challenges. This ability has been referred to as a firm's "perceptual ability" (Heiner, 1983). The premise is that even if perfect information is available and processing is possible, firms will always, to a degree, have a skewed perception of the factors in the environment, effectively introducing a certain amount of error into decision making. Firm

perceptual ability moderates the effect of environmental uncertainty on decision making such that it is equivalent to representing its own source of uncertainty as a firm cannot understand the degree to which its perceptual abilities are skewed; otherwise, it would simply correct the errors.

The external environment is not the only source of uncertainty. Firms can experience internal uncertainty in forms such as technology (Fleming, 2001), subjectivity of estimated certainty probabilities by decision makers (LeRoy & Singell, 1987), and its experience dealing with specific contexts (Henisz & Delios, 2001). Technology uncertainty arises when a firm attempts to use new, unfamiliar components as internal production factors. As compared to existing components, new components have uncertain performance, fit for particular uses, and stability under varying conditions. Until firms use them, there is uncertainty in how the components will impact production efforts. Uncertainty also arises when attempting to use new combinations of existing components. The interactions between components in systems can radically affect the functionality of the system. Even when components are well known, changing their use, configuration, or interface with other components can to unpredictable results. In both cases, firms have to try out the new components or new combinations in order to reduce the uncertainty they create, as the usefulness of the outcomes are often not clear until attempted. (Fleming, 2001).

In separating the concepts of risk and uncertainty, Knight (LeRoy & Singell, 1987) argued that uncertainty is the critical factor that leads to profit, and firms that better navigate uncertainty will be more profitable. Risk, he argued, was distinct from uncertainty in that the probabilities for success or failure in any given context were well defined. Risk is what one takes when betting at a roulette table. Uncertainty, by contrast, is when the odds are unknown, or unknowable. Yet, strategic managers have a subjective view in uncertain situations of what, in

their minds, the risk of the decision is. This subjective view is not based on hard odds such as those found at a casino. Rather, it is a factor of internal firm uncertainty that resides within the perception of strategic managers. Bearing uncertainty has costs, and the uncertainty imbedded in the subjective estimation of the probabilities of making a profitable decision dramatically impacts these costs, acting as a distinct, internal form of uncertainty.

Internal uncertainty also arises when trying to estimate the match of a firm's capabilities to a given context. For example, a firm's lack of experience in a given market could lead to success in that market, if it brings radical new ideas that revitalize the market, or could lead to failure in the market, if it is poorly adapted to the idiosyncrasies of the market and cannot meet its needs. This lack of experience is distinct from the properties of the context itself in that it is more about fit than about the actual configuration of factors in the given context (Henisz & Delios, 2001). Figure 1 attempts to untangle the different perspectives on uncertainty and map out the effects between firm and environment based on different types of uncertainty.

Insert Figure 1 about here

Untangling types of uncertainty is a first step in selecting strategies to address them, yet much complexity still remains when determining how to address them. To address this problem, Milliken (1987) argued that all forms of uncertainty can be reduced to three distinct forms, state, effect, and response uncertainty. These forms assume that the strategic context for decision making is a closed system (Thompson, 1967) where strategic decisions are inputs to the system. State uncertainty is the actor's uncertainty about what state the system is currently in at the time a decision is being made. Effect uncertainty is the notion that a firm does not know how a state

transition in the system will affect the firm. Response uncertainty encompasses the way the environmental system changes subsequent to a firm action. By assuming the strategic context is a closed system with a finite number of states that transition from one another based on a set of rules, the number of strategic responses to uncertainty can be more readily bounded. The underlying epistemological assumption for is that the firms operate in a system that is knowable. But what if that assumption is incorrect and the system is in fact open and unbounded? Whereas closed systems allow strategic determinism by the possible states of the system, open systems assume uncertainty, effectively potential unboundedness in terms of states, effects, and response, and focus on adaptation to stimuli from the environment (Thompson, 1967). In the open case, narrowing down specific strategies that will address the uncertainty is problematic because each strategy can only address a particular bounded uncertainty problem and certain traditional strategies are more efficient in some contexts than others.

STRATEGIES FOR DEALING WITH UNCERTAINTY

Firms will select and execute strategies to cope with uncertainty depending on how they conceptualize the uncertainty and the approaches to dealing with it. Table 2 describes some of the traditional strategies and their advantages and disadvantages.

Insert Table 2 about here

One strategy for dealing with uncertainty is to accept that the uncertainty is unavoidable, either because it is unknowable uncertainty, or because there is a mismatch between the firm's ability to reduce or process the uncertainty and its complexity. The firm takes the uncertainty as a given and sets out to deal with it by interacting with its environment in a way that allows

constant correction. It constantly evaluates environmental stimuli and uses them as input to iterative feedback cycles for its strategic decisions. The iterative strategy can take the form of incrementalism (Quinn, 1980) where the firm makes small, deliberate, and carefully selected commitments over time. The firm engages in a cycle of sensing, evaluation, and readjusting between each small commitment, attempting to ensure as close a fit as possible between the firm's strategy and the needs of the environment. The iterative strategy can also be broken down in terms of firm functions instead of investment size. Firms may choose to move certain functions to different jurisdictions as the environment shifts instead of attempting to determine the best static placement for a given function. This form of adaptation as conditions change can allow firms to deal dynamically with changes in the environment that are out of their control, such as jurisdictional factors (Kogut & Kulatilaka, 1994). The net result is that firms effectively hedge their bets by making a number of smaller investments across a broader range of investment possibilities. Those that pay off can be iteratively developed, while those that fail can be discarded at low cost (Courtney, Kirkland, & Viguerie, 1997). The advantages of this strategy are a simplification of the strategic factors from the perspective of the firm which can reduce uncertainty paralysis. However, the increased focus comes at the cost of slower adaptation to large environmental changes that are not detected by the continuous feedback and incremental movement processes. To be effective, the feedback must come from continuous scanning behaviour that can also be costly for a firm.

If uncertainty is conceptualized as necessarily separate from a firm's perspective, another approach is to disarm the uncertainty by imposing certainty on the environment. Contracts can be used to create agreements between actors in the environment that reduce the potential harm that a potential future might have on the focal firm (Cyert & March, 1963). Contracts don't

reduce uncertainty in the sense that certain outcomes become more likely. However, they do disarm the uncertainty by helping make sure that regardless of the outcome, the firm is prepared and will not unexpectedly suffer a negative consequence. Firms can also design their internal procedures in such a way that uncertainty is planned around. Routines can normalize the impact of uncertainty by distributing it across areas of the firm, across time, or across accounting measures (Thompson, 1967). The result is a strategy akin to real options in finance (Kogut & Kulatilaka, 2001), where firms make investments in capabilities that permit it to best respond when opportunities emerge. The impact of an uncertain selection on the firm is disarmed to the election of a different option from a portfolio that the firm has at its disposal. Uncertainty in some environments is also effectively disarmed when a firm develops an ability to move much faster than the environment in which is embedded (Pich, Loch, & de Meyer, 2002). A firm can out-pace the uncertainty by making sure that by the time the impact of a particular previously unclear outcome takes place, the firm has already executed its strategy under the previous environmental conditions and moved on to a new strategy along strategic dimensions no longer related to that particular uncertain factor. Such a strategy is especially viable in slow-moving or niche industries where the rate of environmental change is very different from the firms embedded in them, leading to uncertainty having a limited impact relative to firm decision and execution speed. This strategy allows a measure of predictability for strategic managers. As a result, firms can increase their resilience to the unexpected. However, this predictability brings with it increased transaction costs to craft and impose order. Further, it is difficult to disarm uncertainty in the case of large disruptions as disarming it requires a measure of understanding of all the possible outcomes. Accounting for more possible outcomes necessarily requires

increased costs, which affects the scope of information availability and, subsequently, decisions (Walker & Weber, 1987).

Instead of facing uncertainty alone, firms can share uncertainty to distribute its effects across them, effectively reducing the uncertainty between them, through pooled interdependence. Uncertainty is reduced for all participants because each firm contributes a different perspective from its connection to the environment to a cooperative effort. Firms engage in the cooperation because it creates a commitment between members to exchange capacity to reduce uncertainty (Thompson, 1967). The cooperation can take the form of alliances where firms work together towards some shared goal of mutual benefit that doesn't naturally emerge as a consequence of the concentration of firms in the particular environment (Pfeffer & Salancik, 2003). Firms will seek out different alliance partners depending on the type of uncertainty in the market (Beckman, Haunschild, & Phillips, 2004), the degree of complementarity between them and potential partners (Brush, 1996), and the power relationships they have with other firms (Courtney, Kirkland, & Viguerie, 1997). The sharing of uncertainty can also be involuntary from the perspective of some firms in the case of competitive imitation (Farjoun & Levin, 2011). Imitation can be conceptualized as a form of cooperative reduction of uncertainty where one firm is setting the strategy and another firm is binding itself to the fate of the decision of the first, leading to a both-win or both-lose scenario. The uncertainty is shared in that the outcome is shared much in the same way as if both firms had agreed to take the same course, as is the case when firms engage in standards development. Pooled dependence built around standardization may be "the least costly [strategy for dealing with uncertainty] in terms of communication and decision effort" (Thompson, 1967), and it enables a larger number of firms to engage in the cooperation relative to a dyadic alliance, reducing a larger portion of the environmental

uncertainty, rather than only reciprocal uncertainty between alliance partners. However, individual firms must deal with power relationships that might affect their ability to extract value from the uncertainty reduction. The different players in a pooled interdependence arrangement rarely share equal power, and the more powerful members can influence the course of less powerful firms that lose total control over their own direction (Pfeffer & Salancik, 2003). Firms must be aware of power issues and only enter into pooled interdependence arrangements that are structured such that they will not be subsumed by another a more powerful firm.

Firms can deal with uncertainty internally by adjusting the firm structure to compartmentalize the uncertainty such that certain divisions of the firm are created to deal with uncertainty while other divisions focus on exploiting the crucial contingencies that allow a firm to generate and appropriate value (Thompson, 1967). This approach requires internal structural flexibility and accounting procedures that allow for certain parts of the firm to absorb the impact of uncertainty, while others are burdened with keeping the firm afloat. Such arrangements can make compensation and human resource management challenging. As such, only firms of certain size, with established and isolatable crucial contingencies, can deal with uncertainty in this way. The classic example is a separation of research and development for new products as a distinct division of a firm that focuses on reducing technological uncertainty (Fleming, 2001). This approach allows portions of the firm to focus on reducing uncertainty without distraction from its day to day activities. The assignment of a dedicated internal structural component of the firm can sometimes, over time, lead to a loss of firm-wide strategic awareness of uncertainty issues. When uncertainty isn't forefront in the mind of all firm actors, dealing with it can be less clear to the decision makers who control the resources, who might reduce or eliminate funding for the part of the firm responsible for this critical activity. Every research and development

department director has felt these pressures and must make sure to explain the importance of exploration in a manner that ensures that his or her department isn't considered a liability on the financial spreadsheets.

If firms cannot address uncertainty proactively, they can use a strategy of surviving uncertainty. This approach accepts that environmental uncertainty will lead to an evolution-like selection of firms that have particular properties that might not be knowable to the firm. Firms can create multiple, varied spinoffs that have different properties, aligned along the range of the uncertain possibilities. Uncertain discontinuous events in the environment will progressively eliminate certain variations while the firm survives with the variations that are a fit for the new environment, and creates new variations in anticipation of the next discontinuous event (Pich, Loch, & de Meyer, 2002). This strategy is distinct from an options strategy in that the spinoffs can also generate and appropriate value for the parent firm before the discontinuous event. Effectively, the execution of the option is in the hands of the uncertain environment, rather than the strategic decision maker, and the environment effectively decides when an option is “exercised” by eliminating the other options. The underlying assumption is that discontinuous change happens in waves and that firms can prepare and recover in between waves. If discontinuities happen too frequently, firms may have insufficient time to generate spinoff with varying traits and may be selected out in the next wave. Even if there is pacing between the waves, the process of continuous structural readjustment can be costly for a firm, especially if many of the spinoffs don't end up creating and acquiring value for the firm.

Finally, firms can select uncertainty indirectly even when they can't control the environment or the uncertainty it imposes by selecting the environment in which they choose to operate. Different industries have different characteristics and different degrees of uncertainty.

Firms can select environments that have lower uncertainty, such as those with established standard practices (Cyert & March, 1963). Niche industries can be less uncertain for firms that focus on value creation along the lines of the niche market needs. If markets change, firms can also select uncertainty by exiting the markets when uncertainty arises (Pich, Loch, & de Meyer, 2002). Uncertainty shifts can be selected against by moving across markets to areas where uncertainty is lower and the firm can compete (Kogut & Kulatilaka, 1994). This strategy is distinct from accepting uncertainty in that the range of strategic options crosses industries rather than within single industries. The scope of the choices is based on a macro level assessment of idealized industries rather than the feedback received from interaction between a firm and the industry in which it is embedded. The advantage of this approach is that firms can control their link to their environment and can leverage it for cost advantages and consistent focus. But, as a result, the type of such firms is necessarily limited and must have a structure that matches with a particular industry. It can be also difficult to recognize changes in an environment when a firm is isolated. The degree a firm is insulated may be inconsistent or incorrectly assessed. Further, niche industries can be susceptible to obsolescence, taking their firms down with them. Firms must be careful when selecting uncertainty to ensure that the selection is actually as stable as it appears to be, and periodically verifying its assumptions.

Given the diversity of options for strategic responses to uncertainty, and the orthogonal nature of the benefits and downsides of choosing one strategy over another firms are forced to try to find ways to combine the advantages of certain combinations of strategies while minimizing the downsides. It is in this context that open source strategies emerge.

DISCUSSION

Firms can address uncertainty by mixing and matching strategies as appropriate, internally, externally, depending on the context and environment. The aggregation of different strategies can form a strategy of its own if such a strategy balances the strengths and weaknesses of different strategies by selecting those best suited for addressing different types of uncertainty and different uncertainty situations, and, the strategy is replicable. This meta-strategy acts as an additional abstraction of analysis for uncertainty strategies. The second order consideration necessarily introduces additional level to the analysis, but allows for a balance of firm and environment idiosyncrasies, flexibility, and sensing that can be used to address contextual challenges. Firms must make sure that the combination of strategies isn't simply an aggregation of tactics. Instead, an aggregation strategy must address the same underlying issues related to uncertainty that arise from bounded rationality, and do so in a more efficient way than any of the individual strategies alone. Open source strategies are just such strategies that aggregate the benefits of the base strategies of accepting, disarming, sharing, compartmentalizing, surviving, and selecting uncertainty.

Open Source Strategies and Accepting Uncertainty

One of the main advantages of the traditional accepting uncertainty strategy is that it ensures that firms aren't overwhelmed by the complexity or degree of uncertainty. Open source strategies leverage iterative feedback cycles to allow firms to focus their growth and production on the areas that are most useful for them without making large bets. An open source approach can be built into the production activities of firms as an extension to existing strategies instead of a replacement. It brings with it benefits of environment scanning, through interaction with other participants, without the usual higher costs of environment scanning. The open source

production environment is a feedback system of its own that can channel information to the participating firm that might have been costly for it to obtain otherwise from the external environment. Discontinuous change is also less problematic because open source projects can typically be more readily repurposed and redirected through forks and aggregation of projects such that the efforts invested are not wasted relative to fit with a new environmental situation after a discontinuous event (Bonaccorsi & Rossi, 2003). The result is a web of strategic options for the firm, where the web can sense environmental vibrations long before the impact reaches the firm that resides at a central place in the web. This discussion leads to the first proposition.

***Proposition 1.** Firm use of open source strategies has a negative relationship to the harmful impact of discontinuous change in the firm's environment*

Open Source Strategies and Disarming Uncertainty

Open source strategies effectively act as an options strategy, disarming uncertainty by allowing firms to develop a core competence without the limitations that come from modeling specific cognitive representations. Instead, firms use open source strategies as a heuristic options strategy that allows fast response to changing situations and that mitigates errors in misapplication of strategy and inertia (Kogut & Kulatilaka, 2001). The selection of an open source project is equivalent to the "heuristics of investing in exploratory search" (Kogut & Kulatilaka, 2001: 744) where the value of such investments is determined at a later date, often when paired with a complementary asset (von Hippel & von Krogh, 2003). Because the complementary pairing is not known to the firm at the time it selects an open source strategy, the particular technological combinations that will yield the most value (Fleming, 2001) are not visible in the current cognitive representation of the firm (Gavetti & Levinthal, 2000). Firms benefit from the base disarming strategy in that they get a measure of predictability that is

embedded in the progress of the open source project's governance mechanism and contractual arrangements. They also improve their resilience to uncertainty as they learn from other participants. They create a portfolio of options that can be exercised at a later time, and while they wait for the complementary asset to become clear, they focus on developing their capabilities for adaptation, which yields base benefits as well. The base strategy downside of high transaction costs is mitigated with an open source strategy because most of the transactions are already standardized and do not require between-party arrangements. Firms "buy in" to the governance model through participation and do not need to spend money developing thorough contractual agreements from scratch. Even when firms start their own open source projects, they can select from an array of previous governance arrangements and pick one that is tailored to their needs and objectives, having the benefit of the history of which arrangements were the most successful in which contexts (O'Mahony & Ferraro, 2007). These existing governance arrangements do not hinder the firm because successful open source projects governance structures incorporate modularity principles by design to improve the usefulness of the project to firms with a plurality of needs (Bonaccorsi & Rossi, 2003). This discussion leads to the second proposition.

***Proposition 2.** Firm use of open source strategies has a negative relationship with the transaction costs of its production arrangements*

Open Source Strategies and Sharing Uncertainty

Open source strategies can also be usefully conceptualized as pooled interdependence arrangements. Most open source projects are loosely organized alliances, where the terms of the alliance are determined by the governance mechanism. The project itself acts as a standardized platform around which participants base their strategy and build complementary features and

products for their idiosyncratic needs (von Krogh & von Hippel, 2006). The platform acts as a shared uncertainty in that the fate of all the firms who choose to leverage the platform in their production activities will be affected by environmental changes that affect the platform. In a sense, firms are engaging in imitation by choosing a shared building block for their individual activities. The result is that there is reduced uncertainty between the firms that are participating in the open source project. Given the predominance of the openness principle in open source projects (Benkler, 2002), firms that participate share information with each other to improve their collective knowledge relative to the external environment, with each firm benefiting from the increased information availability. The governance system of the open source project effectively mitigates the power relationship downside of the standalone sharing uncertainty strategy as it ensures equal standing of participants relative to the platform. Power dynamics can be responsible for shifts in some projects, but firms can always take the existing platform at the time of the shift and continue working on it along a dimension that suits them if they don't want to follow the concentration of power in the projects. Such project forks are relatively uncommon, however, and unlike the case of failed alliances or aborted standards, rarely lead to firms being put in an untenable position. Further, because the locus of value for a firm is related to complementary assets, not the open source platform itself, any issues surrounding the platform are unlikely to cause a firm to lose control over its own strategic direction. Firms get the benefits of sharing uncertainty and pooling effort without the typically resulting power and control downsides. This discussion leads to the third proposition.

Proposition 3. *Firm use of open source strategies has a negative relationship to the loss of control of strategic direction*

Open Source Strategies and Compartmentalizing Uncertainty

Firms effectively compartmentalize uncertainty through the use of open source strategies by separating the part of their firm that will focus on complementary value creation and the part that will focus on advancing the collaborative open source project. Usually, there is divisional situation, with research and development focusing on the broader platform, and product design teams focusing on the complementary extensions. In this manner, product development teams operate in a reduced uncertainty environment as they can depend on the platform from the open source effort. Research and development efforts that focused on uncertainty reduction in the traditional model would run the risk of losing strategic prominence. However, participation in open source projects can be strategically valuable to firms in other ways such as brand development (Pitt et al., 2006) and learning (Grand, et al., 2004). As such, it is less likely that the activity will fall out of strategic prominence and be subject to reduced resource allocation until it is no longer viable. Further, firms can engaged in mixed participation in multiple open source projects that collectively reduce uncertainty by triangulating different factors that the firm needs for value creation and appropriation. This discussion leads to the fourth proposition.

***Proposition 4.** Open source strategies are less likely to fail due to loss internal resource allocations than other strategies*

Open Source Strategies and Surviving Uncertainty

Open source strategies incorporate elements of the survival strategy as open source projects can be viewed as multiple, varied spinoffs in terms of environmental selection traits. By participating in multiple projects, firms are effectively hedging their bets relative to the broader environmental uncertainty. As firms don't have to create the spinoffs themselves, continuous structural readjustment of the firm is not required (in part because of the compartmentalizing

strategy's complementarity), and the costs of using the survival strategy are drastically reduced. Further, little build-up time is required between waves as firms can jump ship between projects quickly with little inertia. As a result, the strategy can viably be used in high-velocity environments, even with frequent discontinuous change, without firms being selected out. Firm continuity also isn't relegated purely to environmental selection as firms always retain a measure of control over their survival through their complementary assets. In short, open source strategies increase firm resilience in the face of selection forces without the need for substantial investments into variation. This discussion leads to the fifth proposition.

***Proposition 5.** Firm use of open source strategies has a negative relationship to the firm being selected out of the environment*

Open Source Strategies and Selecting Uncertainty

Finally, firms can select uncertainty with open source strategies by choosing to participate in the open source projects that generate the most information related to the type of uncertainty that they are facing. Much as firms can control the firm-environment link when using the base selection strategy, firms can select the best match of open source ecosystem for their uncertainty situation. For example, if the environmental uncertainty focuses on the means of addressing a particular user need, firms can join open source projects that are designing platforms that provide a framework for a solution that can be a stepping stone for multiple, diverse specific approaches for addressing particular user needs. The result is that firms don't have to design full solutions each time they test out a particular way of addressing a user need. Instead, they reduce technological uncertainty (Fleming, 2001) by selecting a project that increases a particular type of certainty for a part of the production process. Open source projects can also be selected for cost advantage or focus reasons. Firms can select projects that are designing or have already

solved parts of the value proposition that would be costly for the firm to produce on its own. In this manner, firms reduce uncertainty related to their cost position. If firms use a more enacted strategy, focus on a particular direction can help the firm reduce its uncertainty as it enacts that future. Selecting particular open source projects can focus firm effort in the direction that will serve their vision best. The result is a change in perception- and subjectivity-based uncertainty for the firm. The traditional limitations from the base selection strategy are mitigated as firms do not have to change their type, structure, or industry to participate in open source projects. Firms of all types, structures and industries participate in the major projects and each firm benefits in different ways. This cross-pollination of types, structures, and industries also reduces the difficulties in recognizing changing environments that arise in the base strategy. By participating with different firms in an open source environment, firms reduce their information uncertainty and have access to cues about the environment changing earlier and with more clarity than they would if they were to scan their local industry and competitive landscape alone. They also can develop relationships with firms in other industries to develop knowledge about those industries that they can leverage in their own industry. The key is to select the project that has the best mix of the particular type of uncertainty reduction that the focal firm needs. This discussion leads to the sixth proposition.

***Proposition 6.** Firm use of open source strategies has a positive relationship to firm-environment fit*

SUMMARY AND CONCLUDING REMARKS

This paper began by untangling uncertainty and classifying it into different, overlapping types. Firms that understand differing types of uncertainty will be better prepared and will improve the outcome of their strategic choices. The different strategies that firms can use to

cope with uncertainty were then enumerated and their strengths and weaknesses discussed. This exposition examined the range of traditional approaches from which firms composed their strategies and highlighted the circumstances where certain approaches were likely to be more successful than others. The paper then examined the nature of open source strategies from the perspective of reducing uncertainty and explained how firms select these strategies to maximize the benefits and minimize the downsides of extant strategies.

This paper makes a contribution to the academic literature on uncertainty and strategic choice by examining how open source strategies affect uncertainty relative to traditional strategies. The typology ties together disparate streams of literature into underlying principles that could be considered in more depth to advance the research agendas of each stream. The typology also serves to standardize some of the vocabulary used in the extant literature on uncertainty by focusing on the first principles and tying them directly to selected strategies.

This paper makes a contribution to the open source literature by offering the novel theory of uncertainty reduction as a motive for firm use of open source strategies. Propositions were generated to promote further empirical research. It would be fruitful to explore the contexts in which a given open source strategy is more or less successful for a firm, including firm- and industry-level factors. Empirical research could evaluate open source strategy success by examining the returns that firms see on resource allocations into open source efforts as opposed to other, more traditional resource allocations.

This paper also makes a contribution to strategic management practice by providing a novel explanation for the increased use of open source strategies in enterprise. Explaining the implications of open source strategies at the firm level gives managers an additional repertoire of

strategies to leverage. A key takeaway from this paper is that open source strategies offer an alternative in turbulent, high-velocity markets where traditional strategies are difficult to pick from. Open source strategy has emerged as a way of keeping a strategy-level focus by using different modeling approaches and combining strategies in a way that provides the best balance of uncertainty reduction for a given firm, while minimizing the costs that each strategy, used on its own, would entail.

Further research into firm selection of open source strategies should consider their impact on the boundaries of the firm. It is the nature of the firm to place its boundaries around crucial contingencies for its production (Thompson, 1967), and it is clear that with the right conceptual framework, open source strategies do exactly that. By definition, the outcome of an open source project itself is not a crucial contingency and firm boundaries remain around the complementary factors necessary to generate and acquire value. The strategic advantage comes in the decision to participate, which is effectively an extension of the firm boundaries around all participants in the open source project--producers who are not employees of the firm and who would be prohibitively costly to all bring within the firm (Goldman & Gabriel, 2005)--without the cost of traditional firm boundary extension. This representation of pluralistic firm boundaries for strategic analysis has been considered previously in the literature (e.g. Pfeffer & Salancik, 2003), but has not been evaluated in the context of turbulent, high-velocity markets. The future of open source strategy research lies in this conceptual direction.

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TABLE 1

Types of Uncertainty

Type of uncertainty	Example reference
Unpredictability	Heiner, 1983
Complexity	Suh, Key, & Munchus, 2004
Information availability	Simon, 1986
Perception	Heiner, 1983
Technology	Fleming, 2001
Subjectivity	LeRoy & Singell, 1987
Institutional	Henisz & Delios, 2001
Risk	LeRoy & Singell, 1987
State	Milliken, 1987
Effect	Milliken, 1987
Response	Milliken, 1987

FIGURE 1

Untangling Uncertainty

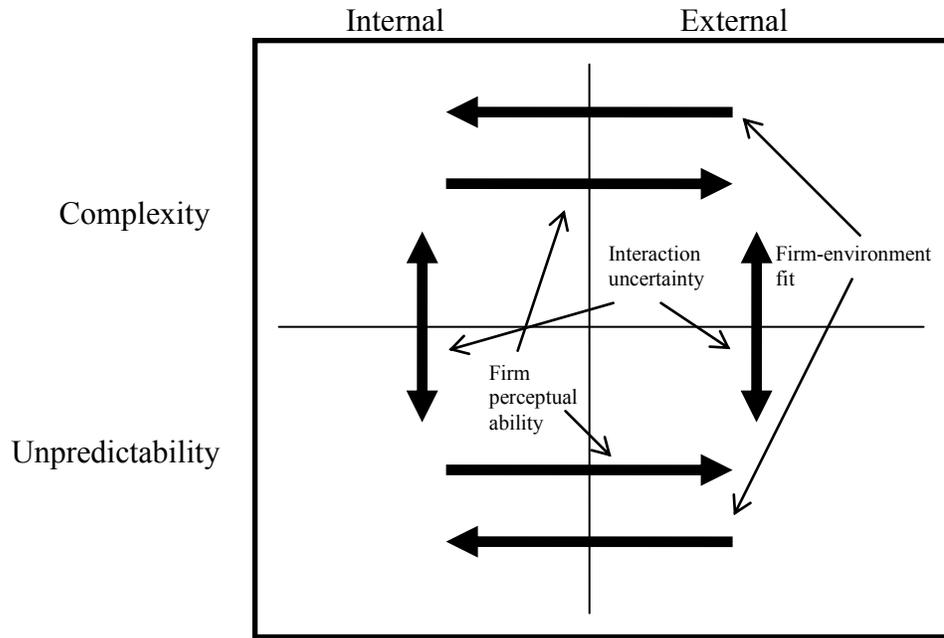


TABLE 2

Strategies for Dealing with Uncertainty

Strategy	Examples	Pros	Cons	Select References
Accept Uncertainty	Constantly evaluate environment; Iterative feedback cycles; Dynamic adaptation	Simplification; Direction	Discontinuities problematic; Scanning costs	<i>Quinn, 1980; Courtney, Kirkland, & Viguerie, 1997</i>
Disarm Uncertainty	Contracts; Routines; Options; Move faster than environment	Measure of predictability; Resilience	Transaction costs; Disruptions	<i>Thompson, 1967; Kogut & Kulatilaka, 2001; Pich et al., 2002; Walker & Weber, 1987</i>
Share Uncertainty	Pooled interdependence; Alliances; Imitation; Standards	Reduced between-firm effect of uncertainty; Increased information availability	Power relationships; Loss of control over firm direction	<i>Thompson, 1967; Beckman, et al., 2004; Brush, 1996; Courtney, et al., 1997; Farjoun & Levin, 2011</i>
Compartmentalize Uncertainty	Divisional separation; Separate operations and research	Actors focus on reducing uncertainty	Addressing uncertainty can lose strategic prominence	<i>Thompson, 1967; Fleming, 2001</i>
Survive Uncertainty	Multiple, varied spinoffs; Diverse selection traits	Hedging bets; Firm continuity	Costly; Continuous structural readjustment; Discontinuities might not come in waves	<i>Pich et al., 2002</i>
Select Uncertainty	Established industry practices; Niche industries; Shifting markets	Control of firm-environment link; Cost advantages; Focus	Limits firm type, structure, industry; Difficulty recognizing changing environment	<i>Cyert & March, 1963; Pich, et al., 2002; Kogut & Kulatilaka, 1994</i>