

**Strategic Decision Making Using Real Options Reasoning Under Uncertainty – What
Uncertainty**

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ABSTRACT

Strategic decision making in management is clouded by uncertainty, and to deal with that, real options approach is advocated. Scholars have examined extensively the typology of real options available to managers but not the prominent typologies of uncertainties. The inability to discriminate between different types of uncertainties lead to partial understanding of real options and consequently the suboptimal and biased creation and management of real options. In this paper we apply three types of uncertainty (state, effect and response) of Milliken (1987), to real

options reasoning. This results in better theoretical understanding of strategic decision making using real options reasoning.

INTRODUCTION

Decision making under uncertainty is a fundamental problem for complex organizations, and coping with uncertainty is the essence of the administrative process [37]. Uncertainty is sought out as a source of innovation, and the ability to handle uncertainty through flexibility is a competitive advantage in the theories of strategy management, organization, innovation, entrepreneurship and international business [8,15,18,23,31].

When uncertainty resolves itself, people will reevaluate and may want to change their choices. When such change occurs, effective responses can be due to serendipitous managerial actions or due to managers availing themselves of flexibility that was deliberately preserved [8]. The flexibilities created and preserved deliberately to enable future changes are formally viewed as real options, based on real options theory [42]. Real options theory proposes that firms can benefit by investing in options to respond to an uncertain future and by managing the investments in a sequential fashion as uncertainty is resolved [12,19].

In trying to handle uncertainties, one needs to know first which kinds of uncertainties one is currently facing [15]. While uncertainty in a financial option is clearly defined by the volatility of the stock price, uncertainty on real options in the real world requires further understanding. A

clear understanding of the differences between uncertainties in financial options and real options, as well their implications in management settings are essential in prescribing real options reasoning in both theory and practice.

While flexibility has been examined in details by its types, some of the most important typologies of uncertainty have been left unconnected with real options. Such theoretical development is needed to advance the understanding of real options and to improve our management of uncertainty. In this paper, we expose real options by three types of uncertainty [32] in organizational settings: state, effect and response uncertainty.

The three types of uncertainty form a concrete, intuitive and useful framework, relating action and environment across time and to explain many real world phenomena. As Kreiser & Marino [20] noted, while scholars from various fields have proposed various definitions and categorizations of uncertainty, they generally agree that the important thing is to choose one that fits the nature of the questions studied.

This paper is the first, to the best of our knowledge, to apply Milliken's categorization of real world uncertainties [32] to real options. This study contributes to the theory development of real options by highlighting effect and response uncertainties, which are non-existent in financial options and often ignored in the real options found in the literature. This paper also rebuts the common 'higher uncertainty, higher options value' findings, and points to uncertainty reduction as the source of options value and the key for management actions. The perception and management of uncertainty and real options form a heterogeneous competitive advantage of the firm on the edge of chaos.

MATERIALS AND METHODS

Real Options Reasoning

A real option is a decision that creates the right, but not the obligation, to pursue a future decision¹ [41]. Options make sense under conditions of uncertainty, where it is difficult to predict the state of the environment in the future. Hence the value of “buying time” for the decision maker to be in possession of new information that will help him decide better later (i.e.: exercise the option or not).

Real options have been applied to investment decisions [11,12], strategic decisions [3] [25], entrepreneurship [10,18,21], research and development [17,23,24], technological innovation [9,46], international business [39], and market entry [14].

Real options have also been prescribed as a way of thinking and reasoning, using which ‘strategy is seen as a process of organizational resource-investment choices, or options and therefore a firm can be viewed as a portfolio of options [6]. Real options reasoning argues that it is a rational survival strategy to use flexibility to reduce downside risk and increase upside opportunities [28,35]. It has been developed as a systematic strategy framework to inform strategic decision making under uncertainty [27,41].

While real options analysis is widely considered a promising line of research [42,44], with important practical implication, its actual use has not been smooth [1,5]. The possible reasons are varied, such as the lack of understanding of option pricing models and the difficulty of framing real options in parameters of financial options [35].

¹ Here we introduce real options as defined in the literature of strategy, organization, and entrepreneurship.

Three types of uncertainty

Despite the theoretical significance of uncertainty in management, the construct “has generally yielded inconsistent and difficult to interpret results due to poor reliability and validity of measurement instruments, and no clear evidence of a relationship between objective characteristics of the environment and perceptions of uncertainty” (Milliken, 1987: 135). Milliken [32] synthesizes the lament of many scholars of uncertainty that “the extant conceptualizations of uncertainty in management research do not distinguish between the types of uncertainty an individual experiences”. Thus, Milliken suggests three distinct types of uncertainty: state uncertainty, effect uncertainty, and response uncertainty.

1. State uncertainty: “Administrators perceive state uncertainty when they perceive the organizational environment or a particular component of that environment, to be unpredictable”.

State uncertainty is present when one does not understand how components of the environment might be changing and/or when there is an incomplete understanding of the interrelationships between elements of the environment. “For example, one might be uncertain both about the likelihood of deregulation as well as the likely behavior of competitors if deregulation occurs. Thus, in this case one knows neither the probability of deregulation nor the probability of a price war if deregulation occurs”.

2. Effect uncertainty: “...is defined as the inability to predict what the nature of the impact of a future state of the environment or environmental change will be on the organization”. Milliken gives the example of “knowing that a hurricane is headed in the general direction of your house does not mean you know how it will affect your particular house”.

3. Response uncertainty: "...is defined as the lack of knowledge of response options and/or an inability to predict the likely consequences of a response choice". Milliken adds: "Administrators would be most likely to experience response uncertainty either in the course of choosing from a number of possible strategies or in the course of formulating a response to an immediate threat of the environment".

According to Milliken, theorists that define environmental uncertainty as "an inability to assign probabilities as to the likelihood of future events" are referring to State uncertainty. Those who define it as "A lack of information about cause-effect relationships" may be referring to Effect and Response uncertainties, while "An inability to predict accurately what the outcomes of a decision might be" seems to adjust to the definition of Response uncertainty.

Each of these uncertainty types considered together define the nature and character of uncertainty that surrounds a given decision [32]. Explicit in Milliken's thinking is that there is heterogeneity between individuals with regard to how uncertainty is reflected in the perceiver's decision policies.

Milliken's uncertainty framework has been used for extending or reframing the theoretical assumptions on the role of uncertainty, such as in new product development [33], transaction cost theory [36], entrepreneurial action [29,30], leadership [43], social networks [16], and marketing [4].

Real Options reasoning under uncertainty

The general method of this paper is to apply the typology of uncertainty defined by Milliken to both financial and real options. We propose the following model for illustrating the logic:



T_0 is the moment in which an option is bought (in the case of financial options, as illustrated by a typical European option) or created (in the case of real options), and T_1 is the moment in which the decision of whether to exercise the option is made. As we will see when we discuss the results, there may be State, Effect and Response uncertainties both at T_0 and at T_1 , and each are labeled SU_{T_0} , EU_{T_0} , RU_{T_0} , SU_{T_1} , EU_{T_1} , RU_{T_1} .

An important point to be made is that all uncertainties are regarding the state of the environment at T_1 . The State uncertainty in T_0 is expressed as the difficulty to predict the State of the environment at T_1 , not at T_0 . The Effect uncertainty at T_0 is about a lack of understanding of the effect of the state of the environment at T_1 on the organization, and the Response uncertainty at T_0 is about a lack of understanding of the consequences of the organization's responses on the environment at T_1 . State, Effect and Response uncertainties in T_1 are obviously regarding the State at T_1 as well, indicating that decision makers still have uncertainties at T_1 about the state, effect or effect at present.

RESULTS

The three uncertainties in financial options.

First of all, it is illustrative to analyze the different uncertainties we have defined in financial options, where the relevant State is the price of the stock.

SU_{T_0} : Due to its volatility, it is difficult in T_0 to predict the price of the stock in T_1 . Hence $SU_{T_0} > 0$.

EU_{T_0} : Regardless of the State (stock price) in T_1 , the owner of the option, at T_0 , have certainty about its effects on the organization. In other words, it is known at the time of purchase of the option that, once the price of the stock in T_1 is fixed, it will establish beyond any doubt the value of the investment. Hence $EU_{T_0} = 0$

RU_{T_0} : Regardless of the State (stock price) in T_1 , it can be predicted in T_0 that the responses available for the organization in T_1 will be understood, as well as the consequences of each response. In other words, it is known at the time of purchasing the option that, once the price of the stock at T_1 is fixed, the possible choices in that scenario will become clear as well as the consequences of each of those choices. Hence $RE_{T_0} = 0$

SU_{T_1} : Due to the transparency of information in financial markets, there is certainty in T_1 that the owner of the option has access to all the relevant information about the environment (stock price in this case). Hence $SU_{T_1} = 0$

EU_{T_1} : Just as in T_0 , there is no uncertainty about how the current price of the stock affects the organization. Hence $EU_{T_1} = 0$.

SU_{T_1} : Just as in T_0 , once the price is known, there is no uncertainty on the possible responses and the consequences of each. Hence $RU_{T_1} = 0$. The responses (exercising or not) and their consequence can be calculated with certainty.

From this analysis we can deduce that:

- i. In a financial option the only relevant uncertainty is State uncertainty (the stock price). Effect and Response uncertainties are zero.
- ii. There is State uncertainty only at the moment of purchasing the option. At the moment of exercising, State uncertainty is zero (because the price is known). Since there are no Effect or Response uncertainties, once the State uncertainty is resolved at the moment of exercising, all uncertainties become zero.
- iii. Since the only prerequisite for the state of the environment to be defined (for the stock price to be known) is to complete the time lapse until the point in which the exercising decision must be made, it can be said that the mere passing of time is all that is required to resolve all uncertainties.

The three types of uncertainties in real options.

To make this analysis easier, we will illustrate with an example. Startup W is planning to install a plant in Patagonia (Chile) for the production of premium mineral water. Since the country's GDP per capita (PPP) is growing fast, Startup W is considering to focus on domestic market. But, even though PPP is growing, the Chileans preference for premium mineral water is unknown, and W determines that the demand for premium mineral water is an important source of uncertainty. Because of that, it decides to start the business in a small scale with a real option (through acquiring a production technology) to allow quick scaled up production if the startup decides to do so later.

SU_{T_0} : It is difficult to predict in T_0 the demand for premium mineral water in T_1 . It is also difficult to predict in T_0 that, once T_1 arrives, W will be sure about the completeness of its information on the demand of premium mineral water. Hence $SU_{T_0} > 0$.

EU_{T_0} : It is also difficult to predict in T_0 what will be the effects of all possible market scenarios in T_1 on Startup W. For example, if market demand keeps low, it may mean that there will not be enough clients who want to buy W's product. But it may also mean that there will not be many competitors interested in entering the market, so, although the total market size is few, a large share of them will be willing to buy W's water. Hence $EU_{T_0} > 0$

RU_{T_0} : If the demand for premium mineral water is large in T_1 , W may anticipate in T_0 that, if it increases production in T_1 , sales would grow. But it may also make W's water look less premium and more massive than what the public may have perceived, and profit may decrease. Hence, $RU_{T_0} > 0$.

SU_{T_1} : Now W is standing at T_1 and needs to make the decision whether to scale its production or not (exercising the option or not). But even then there will be uncertainty about the State, for many reasons, for example, the demand for mineral water is not easy to measure. There may always be perception that the knowledge about the State is incomplete. Hence $SU_{T_1} > 0$.

EU_{T_1} : W is in T_1 and the State is (more or less) known: demand for premium mineral water has increased. But that does not necessarily mean that demand for W's water has increased as well. Maybe Chileans want more premium water, but it is important for them that this water is from a recognized brand rather than a startup, or produced abroad rather than in Chile. The only way to be sure of the demand for W's water (i.e.: the effect of an overall increase in demand of premium mineral water on startup W) would be to increase production and see. But that would be after exercising. In T_1 , at the moment of exercising, although the State is known, its effect on the company is not well understood. Hence, $EU_{T_1} > 0$.

RU_{T_1} : In T_1 , once the State is (more or less) known, the consequences of exercising the scale option or not can still be hard to predict. In fact, the same examples used in SU_{T_0} still prevail. Demand may be high, but increasing production may or may not mean more sales. Hence $RU_{T_1} > 0$.

From this example we can deduce three propositions:

- i. While in financial options only state uncertainty is present, in real options all three types of uncertainties are relevant.
- ii. The three types of uncertainty may be present at the moment of option creation as well as at the moment of exercising.
- iii. The mere passing of time is not enough to resolve the uncertainties involved in real options.

Implication of the findings

A new light into incomplete uncertainty reduction

Real options deal with uncertainty by embedding flexibility to alter decisions at a certain time in the future. Often implicitly assumed is that uncertainty will be reduced by that time and better decisions can be made. For that reason,

- If there is higher uncertainty reduction between the moment of option creation and that of exercising, real options are more valuable.
 - If uncertainty will be zero in the future, the higher the uncertainty at the moment of option creation, the higher the uncertainty reduction and the higher the value of real options.
- Most of the literature assumes uncertainty will be zero by the time of exercising, and

therefore, the literature proposes, higher is the uncertainty (at the time of option creation), more valuable is the real option.

In this sense, a financial European option is a special case -an ideal and simplified type option, because the initial uncertainty is only regarding state and will become zero at the moment to exercise the option.

Real options depart from this ideal situation in the fact that, three types of initial uncertainty exist and their reduction is not guaranteed, because of:

1. Incomplete uncertainty reduction in State uncertainty: State uncertainty is defined by two sources (i) the difficulty to predict the state of the environment, as well as (ii) the difficulty of the owner to determine the completeness of the information about the environment available.

Just like in financial options, in real option the first source is present at the moment of option creation but disappears at the moment of option exercising (there is nothing to predict). But unlike financial options, where information is perfectly transparent and the second source is never present, in real options the second source of uncertainty is not only relevant at the moment of option creation but may be there at the moment of exercising. Hence uncertainty reduction may not be complete.

2. Incomplete uncertainty reduction in Effect and Response uncertainties: as we have seen, effect and response uncertainties, which are absent in financial markets, exist in the real world and may be present at the moment of option creation as well as at the moment of option exercising. This is the second reason why uncertainty reduction may be incomplete in real options.

Time is not (necessarily) money

Effect and response uncertainty are not necessarily dissolved by the mere passing of time. That happens because they depend primarily on the state of the environment, not on time. Time may resolve them, but only because time defines which is the state of the environment at the moment of exercising. The questions at the moment of exercising are:

- Do I have all the information required about this State?
- Do I understand the effect of this State on my organization?
- Do I understand the responses available and their consequences in affecting this State?

Similarly, the questions at the moment of option creation are:

- For the State that will be established at the moment of exercising, will I have complete information?
- For the State that will be established at the moment of exercising, will I know its effects on my organization?
- For the State that will be established at the moment of exercising, will I understand the responses available and their consequences?

For the first element of State uncertainty (the difficulty to predict the state of the environment), instead, the questions are simpler and are not mediated by any other element than time.

- At the moment of option creation: What will be the State in T1?
- At the moment of exercising: What is the State now?

This may be a bad news: in real options, time does not bring complete certainty. But there is a bright side: since a large part of uncertainty in real options is not directly linked to time, but is mediated by the state of the environment, then efforts can be made to reduce uncertainty ahead of time, preparing the conditions for the moment of exercising.

This of course, is implicit when we are told that real options allow the decision maker to “buy time” to gain access to new information, and this new information, specially under “act and see” strategies, would probably include actions to reduce the uncertainties that may still be present at the moment of exercising. If that is the case, then being able to discriminate which uncertainties we are dealing with in terms of the feasibility of such uncertainty reduction, would surely be of great help.

These findings as well as the improved understanding of real options concept have fundamental implication on the areas that real options have been used, including strategy, organization, entrepreneurship, international business, etc.

DISCUSSIONS

Applying the typology of state, effect, and response uncertainties to real options reveals a number of previously-hidden mismatches between financial and real options. These include: the presence of effect and response uncertainties in real options, the significance of uncertainty reduction, the incompleteness of a prescriptive “wait and see” or “let time resolves it” strategy often see in real options reasoning, and the opportunities to reduce uncertainty irrespective of time.

Without recognizing effect and response uncertainties, many real options valuation literature, such as Luehrman [22], do not contemplate the fact that uncertainty may not be resolved at the moment of exercising, but assimilate the uncertainty of real options to that of the financial market.

None the less, even without that conceptual recognition, researcher from other perspectives such as organization studies, behaviors, knowledge management, have noted the importance of uncertainty reduction on options management, including aspects such as the “degree to which the option lifetime is used for gathering and processing information that could reduce uncertainty surrounding the focal point” [5,18,40]. However, we theoretically advance such arguments through fundamentally improve the understanding of the concept and definition of real options. Using that lens we establish that a central value driver of real options is uncertainty reduction, which has been mentioned so far as complementary strategies to real options, such as in [26] and [5].

Our findings also contrast with the investment school viewpoint that the value of real options is exogenous to the investor’s activity and independent of the investor’s behavior. On the opposite, we consider that “uncertainty resolution is endogenous to firm activity”. Should organization want to increase the value of options, they cannot passively wait for the uncertainty to resolve – an area that is often ignored in real options literature [1]. Our viewpoint is therefore also in accordance with resource dependence theory that explains how organizations link with and shape their environments [34]. Organizations do not react to or act upon given realities, but they enact their environments, including its many facets of uncertainty.

While strategic management acknowledges that ‘uncertainty about the firm’s future is the core of strategy’ and suggests to use strategic planning to tackle the uncertainty [2], our view is that under very high level of uncertainties, the firms, rather than plan for the future, should reduce state uncertainty through forecasting and intelligence, effect and response uncertainty through small scale experiments and discussion with customers, echoing Brown and Eisenhardt [8].

The improvement of real options reasoning contributes towards the development of multiple perspectives of strategic decision making analysis, which are advantageous because the different perspectives act as a check on each other [7].

The future work includes the development of a better real options framework based on the improved understanding and new insight from this work based on the type of uncertainties. Other typologies of uncertainties on real options should be explored.

CONCLUSIONS

At the core of real options reasoning, lies a set of heuristics and tools to evaluate and deal with the uncertainty that pervades strategic decisions [41]. Breaking down the uncertainties based on Milliken [32] increases the understanding and leads to a better use of such heuristics and tools. People creating and using real options need to consider the dynamism between real options and the environment under the evolution of different types of uncertain factors. Failing to do so may result in misuse or suboptimal use of real options.

Our analysis has contributed to the theory development of real options by scrutinizing it in light of types of uncertainties. The differences between real options and financial options in effect and response uncertainties cannot be ignored in the creation and management of real options, but many real options models, directly borrowed from financial options model, failed to take account of them. Because of that, those models may have also overestimated the performance implication of real options. Putting back into the picture these two types of uncertainties, which are very real in the management of real options, helps to explain why the use of real options reasoning is more complex than it was once thought to be, and helps to explain why real options have not spread as pervasively as it was once imagined. Therefore, we also contribute to a series of alternative

explanations exploring why real options have not been used extensively, such as attention based view [5], bounded rationality [38,45], or the potential for misuse or suboptimal usage [25].

Whereas literature has found that the higher the (state) uncertainty, the higher the real options values, we point out that the reduction of uncertainties (all three types) are key to real options values. This points to uncertainty reduction as the key driver for obtaining benefits from real options creation. In many cases, one not only can reduce state uncertainty (such as through forecasting and intelligence) but also effect and response uncertainties (such as through experimenting). This is in contrast of the 'wait and see' approach prescribed by earlier real options papers. This calls for new approaches from management in the perception of uncertainties, and in the process of creation, maintenance, and exercising of real options.

Heterogeneity exists in people's perception of uncertainties as well as in the behavior of firms in dealing with uncertainties. There is also large heterogeneity in the behavior of firms regarding real options, which have been identified as possible determinants of option value and therefore performance heterogeneity [13]. Towards that end, we contribute towards a better appreciation of managing uncertainty using real options, which is a source for better strategic decision making for competitive advantage.

Various managerial implications can be derived from our study on real options reasoning.

First of all, the fact that real options value may require not only merely passive uncertainty through passage of time but also involve actively uncertainties reduction is informative for managerial actions. A clear implication is that the creation of real options needs to consider whether uncertainty reduction is deemed to be significant.

Understanding the types and relative weights of the uncertainties involved is needed to analyze the expected uncertainty reduction because, while state uncertainty tends to be harder to reduce and control and people have traditionally focus on it through forecasting, intelligence, learning and etc, reducing effect and response uncertainties could be overlooked for real options practices.

Finally, the interactive nature of effect and response uncertainties helps to define the activities that can be developed to actively reduce uncertainty. Since they are not directly dependent on time, but mediated by the state of the environment, testing and experimentation of the effects of different states of the environment on the organization, as well as of the consequences of possible actions taken by the organization, can be pursued systematically before the moment of exercising an option. This is reflected the very recent trend of customer development and lean startup in entrepreneurship around Silicon Valley.

Hence, all the phases of real options lifecycles are influenced by the application of different types of uncertainty: option creation should favor options associated to uncertainties that will passively or can actively be reduced before the moment of exercising. Option maintenance should involve the active reduction of uncertainties, especially those related to the interaction between the organization and the environment. And option exercising should evaluate if all the relevant uncertainty have been reduced to a level to make the irreversible exercising decision.

While this paper introduces new understanding of real options through applying Milliken and discusses in detail its managerial implications on real options reasoning, the focus of the paper is limited to managerial issues around real options reasoning, even though the improved understanding of real options also have fundamental implications on real options valuation.

In this paper we use a typology of uncertainty that fits the nature of the question studied, based on the recommendation of Kreiser and Marino [20], but we have not examined every possible typologies of uncertainty, and there are certainly others that may be interesting to be applied to real options.

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