USING HEURISTICS FOR ENTREPRENEURIAL DECISION-MAKING: A Real Options Approach

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Abstract

This paper examines how heuristics can be used for entrepreneurial decision-making under uncertainty, specifically by incorporating them as decision-making strategies that guide boundaries within real options theory. The study begins by establishing an overview of two mainstream approaches offering conflicting accounts on heuristics, with regard to when and how they should be used for decision-making. It is revealed that these differences are largely a result of conflicting perspectives on rationality, stemming from paradigms that are often viewed as rivals. The study posits that these paradigms need not exist as rivals, and that it is possible to establish a broader, more productive view of rationality. By recognizing both the liabilities and strengths of heuristics, it is argued that utilizing heuristics as a deliberate strategy can be a rational way of proceeding under particularly dynamic and uncertain conditions – especially ones in which it is not possible to model concrete, limited pathways with probability judgements. Furthermore, the study proposes that incorporating the use of ecologically rational heuristics to create rigid rules for real options decisions at the time of investment can be an effective way of overcoming a number of current issues with real options theory. Ultimately, it is argued that utilizing learned heuristics as part of a real options framework allows for a logical and structured approach towards entrepreneurial decision-making under (radical) uncertainty.
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1.0 Introduction

In both the practice of management and within academic debate, there exists an ever-increasing recognition of the fact that organizations must deal with high and growing levels of uncertainty. This uncertainty is especially prevalent within entrepreneurial decision-making, as entrepreneurs are often operating in environments where there is limited information available and a high degree of risk. As a result, entrepreneurial decision-making often requires a combination of creativity, strategic thinking, and risk assessment. Entrepreneurs must be able to identify and evaluate potential opportunities and threats, and make decisions based on incomplete or uncertain information. They must also be able to adapt to changing circumstances and pivot their strategies as needed.

This recognition of increasing uncertainty has led to a growing number of theories within strategic management and economics that move away from more systemized and rigid neoclassical assumptions, and instead emphasize flexibility and uncertainty of outcomes. One example of such an approach can be found within real options theory, which extends the application of valuation and decision-making with regard to financial options, to also encompass the decision-making relating to ‘real’ options – options pertaining to the undertaking of a number of different business initiatives. But as we move away from the world of quantitatively measured volatility and into the world of subjectively perceived uncertainty, there are differing beliefs with regard to what constitutes rational behavior within specific environments, as well as to which extent actors should still attempt to rely on more stylized and analytically disciplined models, as opposed to more open-ended and subjective decision-making methods.

While it is widely acknowledged that humans utilize heuristics and bias to make decisions under uncertainty, it has for a long time been the dominant view within strategic management literature that heuristics and bias should be avoided when possible, as they do not provide a rational foundation for decision-making. Instead, heuristics are often viewed as a second-best approach, that is only useful due to the cognitive limitations of humans. Meanwhile, heuristics have long been applied within machine learning and studies of artificial intelligence, as they have proven to be a useful tool for solving problems under certain conditions. Judea Pearl’s book,
'Heuristics: Intelligent Search Strategies for Computer Problem Solving', from all the way back in 1984 showcases how heuristics can still be utilized effectively, even when the cognitive limitations of humans are no longer applicable. Judea Pearl went on to win the Turing award partly for his work on heuristics, and more recent machine learning literature continues to emphasize the importance of the decision-making method.

It appears paradoxical and ironic that the dominant literature within economics and strategic management often continues to stress the need for classic optimization techniques and rigid models that avoid human bias, when researchers who work with artificial intelligence and machine learning instead strive to emulate human bias and heuristics when dealing with specific, uncertain environments and complex problem spaces. However, a growing stream of literature within strategic management has recognized this discrepancy between our understandings of human bias and heuristics, and aims to elucidate when heuristics can be applied effectively for decision-making.

Evidently, a gap is present between how heuristics and human biases are viewed within economics and strategic management. This gap largely stems from two key approaches employed in understanding economic decision-making, namely the ‘rational choice’ paradigm and the ‘bounded rationality’ paradigm. Furthermore, the thoughts and assumptions behind these paradigms have laid the groundwork for different approaches within real options methodology itself, creating a split between the methods applied in real options theory.

Consequently, this thesis aims to address and bridge this gap, with the intention of creating a framework for how heuristics may be used in an effective and ‘rational’ manner within the proper environments, combining the analytical discipline of one paradigm with the behavioral aspects of the other. Additionally, the thesis aims to investigate how such a framework might be affected by radical uncertainty or ‘unknown unknowns’, which are future contingencies that are yet to be categorized or conceptualized by the decision-makers, lacking an ex-ante description.
1.1 Thesis statement

The aim of this thesis is to study how heuristics can be effectively utilized for entrepreneurial decision-making under uncertainty. To achieve this goal, the following questions will be addressed:

- **What are heuristics, and how are they viewed within different paradigms of economics and strategic management?**
- **What constitutes a rational approach to dealing with (radical) uncertainty?**
- **How can heuristics contribute to entrepreneurial decision-making in combination with real options theory?**

1.2 Structure

To answer the three questions that are expressed in the above thesis statement, the thesis is effectively divided into three different primary parts. The first part consists of a general literature and theory review on heuristics, real options theory and uncertainty. The intent of this section is to establish a better overview of what heuristics are, and how they are viewed within two influential paradigms within economics and strategic management. Furthermore, an understanding of two central approaches to real options theory is also established, while a clear definition of uncertainty is characterized.

The second part aims to establish a broader view of rationality than that which is most frequently seen between the two “rival” paradigms with regard to rationality and heuristics within economics and strategic management. This section aims to first establish a clear understanding of human cognition through the dual-process theory of the mind, before demonstrating a broader view of rationality that can be utilized for entrepreneurial decision-making when dealing with uncertainty.

Finally, the third part of the thesis deals with the question of how heuristics can contribute to entrepreneurial decision-making when applied within a real options framework. The section first takes a deeper look into some of the problems that are currently present within real options theory, before delving into how these may in part be addressed by a different perspective towards rationality and heuristics. Ultimately,
an approach that is both systematic and structured, but also ecologically rational through the use of effective heuristics as deliberate decision-making strategies is put forth.
2.0 Literature and theory review

This section first covers two different approaches to rationality that are often used within economics and strategic management. These paradigms of rationality are often considered rival paradigms within the literature, and they have also played a major part in the two rivaling approaches to heuristics that will subsequently be covered. Finally, a clear definition of uncertainty for the purpose of the thesis is elaborated.

2.1 Two “rival” paradigms of rationality

When seeking to understand heuristics, the notion of rationality comprises a crucial element. In a general sense, heuristics allow individuals to make alternative decisions to the ‘rational choice’ when they are facing uncertainty with information, resource or time constraints. However, relying on heuristics may lead to suboptimal outcome through errors or biases. The intention of this thesis is, in part, to combine the notion of ‘rational choice’ with the notion of bounded rationality, wherein heuristics and biases are most frequently discussed and theorized. The ‘rational choice’ and ‘bounded rationality’ approaches constitute two mainstream but separate approaches to rationality within the economic sciences, with the two often being considered rival paradigms.

The approaches to heuristics even within bounded rationality are far from uniform, but before delving into the different views on heuristics and how these might be combined with ‘rational choice’, brief accounts of the ‘rational choice’ and ‘bounded rationality’ paradigms are first made.

2.1.1 The rational choice paradigm and instrumental rationality

The rational choice approach is seen in a large amount of especially neoclassical economic models. The rational choice theory is rooted in the ‘Savage paradigm’, as laid out by Leonard Savage in ‘The Foundations of Statistics’ (1954). Rational choice theory states that individuals have complete and transitive preferences to a number of available alternatives. Individuals are then expected to behave ‘rationally’ within the confines of available information, and pick the utility-maximizing choice through a cost-benefit analysis (Sen, 1987). The suggestion then, is that all possible alternatives within a given decision are considered for the acting agent, and that contingencies are
never unforeseen. As such, the rational choice theory operates under a notion of instrumental rationality, in the sense that individuals always make choices that are consistent with their goals and objectives to maximize their utility.

Savage himself speaks of “the practical necessity of confining attention to, or isolating, relatively simple situations in almost all applications of the theory of decision” (Savage, 1954, p. 82). Such an approach is indeed often seen within economic models, that often simplify the states of the world and alternatives in order to efficiently calculate value maximizing actions. Yet it is important to acknowledge that such an approach is very different from taking all possible alternative actions and contingencies into account in the real world.

Savage himself refers to the notion of the rational actor as an ‘extreme idealization’, which raises the question of when a simplified economic model presents an acceptable model of the real world. The answer, of course, is not when such a model considers all possible alternative actions and contingencies present in the real world, as that would be entirely unfeasible. Rather, Savage states that a problem is satisfactory if the utility judgements made with regard to alternative choices and contingencies within the ‘small world’ of the economic model remain unchanged when applied to the real world. As such, the small world should represent a (statistically) accurate ‘partition’ of the ‘grand’ or real world (Savage, 1954). Nevertheless, it is important to note that the use of rational-choice theory still rests on the need for problems to be defined in an adequately structured manner, to enable the employment of a utility-maximizing strategy.

2.1.2 The bounded rationality paradigm

The bounded rationality approach, offering an alternative to ‘rational choice’, is often seen within organizational or behavioral models of economics. Bounded rationality was coined by Herbert Simon, and it questions several of the notions of rationality from the ‘rational choice’ theory, by suggesting that agents are limited or ‘bounded’ in their rationality when making decisions; often leading to outcomes that are merely satisfactory rather than optimal (Simon, 1955). Bounded rationality represents a step away from the cost-benefit approach to rational decision making, by acknowledging
that humans are inherently not completely rational in their decision-making, as they are limited by elements such as the cognitive capacities of their mind or available time to make the necessary calculations (Simon, 1955). Instead of factoring in all possible calculations in their decision-making process, Simon argues that humans are content with ‘satisficing’, in which the decision maker settles for a decision that is ‘good enough’ rather than necessarily the best.

In his efforts to explain the limited rationality of individuals, Simon creates an ecological view of behavior, which he describes as a pair of scissors: “Human rational behavior (and the behavior of all physical symbol systems) is shaped by a scissors whose two blades are the structure of task environments and the computational capabilities of the actor.” (Simon, 1990, p. 7). According to Simon’s scissors analogy, internal explanations of behavior are inadequate by themselves, because they fail to take into account the impact the specific environments that the individual actors find themselves in.

2.2 Heuristics

The word heuristic is stems from the ancient Greek “εὑρίσκειν”, meaning to find or discover (Oxford English Dictionary, n.d.). In current times however, it is possible to find many different definitions for heuristics, with the word perhaps most frequently being associated with ‘rule of thumb’ or suboptimal but sufficient methods for reaching short term goals. Within psychology, such definitions are often associated with limits of human cognition, yet within machine learning Judea Pearl defines heuristics in the following way:

*Heuristics are criteria, methods, or principles for deciding which among several alternative courses of action promises to be the most effective in order to achieve some goal. They represent compromises between two requirements: the need to make such criteria simple, and at the same time, the desire to see them discriminate correctly between good and bad choices.*

(Pearl, 1986, p. 3)

The difference in understanding of what heuristics ultimately are, and how they can or should be utilized has been an ongoing debate for at least several decades. To
establish how heuristics can be used for entrepreneurial decision-making, it is first necessary to establish a better overview of what heuristics really are.

In an effort to understand what heuristics are, as well as how they are viewed within different paradigms of economic thinking, this thesis will cover the two most prominent approaches to heuristics within economics. As previously mentioned, both of these approaches are most widely used in behavioral decision theory, yet they differ considerably in how they seek to use or avoid heuristics. Furthermore, parallels can also be drawn to the ‘rational choice’ and ‘bounded rationality’ paradigms, with one stance being significantly less oppositional towards the notions of ‘rational choice’ than the other.

2.2.1 Heuristics avoidance

The first approach has been developed most prominently by Daniel Kahneman and Amos Tversky and is perhaps the most influential within behavioral economics (Cossette, 2014). This approach relies heavily on statistical decision theory, and the ways in which heuristics deviate from this ‘golden standard’ of rational decision-making (Grandori, 2013). While Kahneman and Tversky maintained that human rationality is not well characterized by unbounded rationality with completely rational actors, they heavily emphasized how the decisions and judgements of said actors deviates from the principles of probability theory and logic, and as a result deviates from rational behavior. As such, while the implications of bounded rationality remain, heuristics are nevertheless consistently measured against a notion of rationality that is instrumental, as present in the ‘rational choice’ theory. Unsurprisingly, this has led to a mostly negative view of heuristics, with them being viewed primarily as sources of biases that frequently impair more rational methods of decision-making (Kahneman & Tversky, 1982).

Writing about heuristics, Kahneman and Tversky state that “People do not follow the principles of probability theory in judging the likelihood of uncertain events. Apparently, people replace the laws of chance by heuristics.” (Kahneman & Tversky, 1972, p 431).

With heuristics largely being viewed as shortcuts that are frequently inefficient and dangerous for decision-making, a conscious effort has been made to build a repertory
of heuristics and biases, with the intentions of listing heuristics that should generally be avoided (Kahneman & Tversky, 1982). While this effort was first undertaken by Kahneman and Tversky, the idea of heuristics avoidance is widespread, and the repertoire of heuristics and biases has been greatly expanded since, most often with the underlying message of avoiding or correcting said heuristics (Grandori, 2013).

Many of these beliefs with regard to heuristic avoidance can be attributed to the accuracy-effort trade-off, which suggests that investing less effort leads to lower accuracy as a general rule. Broadly speaking, the heuristic avoidance approach can be characterized by the following three notions (Gigerenzer & Brighton, 2009):

1. Heuristics are always second-best
2. Heuristics are only used because of the cognitive limitations of individuals
3. More information, more computation, and more time always leads to better and more efficient decision-making

In their seminal work ‘Judgement under Uncertainty: Heuristics and Biases’ (1974), Kahneman and Tversky list three often-applied heuristics with negative biased associated with them. These heuristics are as follows:

The availability heuristic - a cognitive bias in which people estimate the probability of an event or the frequency of a phenomenon based on how easily an example or instances of that event comes to mind. This can lead to an overestimation of the likelihood of rare events because they tend to be more memorable.

The representativeness heuristic - a cognitive bias in which people judge the probability of an event or the likelihood of a phenomenon based on how similar it is to a prototype or a stereotype. This can lead to errors in judgment because it ignores the base rate or prior probability of the event.

The anchoring heuristic - a cognitive bias in which people use an initial value or a reference point as a starting point for subsequent judgments. This can lead to bias in negotiation, decision making, and valuation because the initial anchor can affect the perceived value of subsequent options.
These heuristics are just a brief list of what has now become a vast repertoire of heuristics that risk incurring negative bias, but they serve to give an overview of how cognitive biases and heuristics are generally viewed within this paradigm of thinking.

2.2.2 Ecological rationality and fast-and-frugal heuristics

After the heuristic avoidance approach of Kahneman and Tversky had begun to take hold in behavioral economics, Gerd Gigerenzer also built repertory of heuristics, which he would call the ‘adaptive toolbox’. But rather than focusing on heuristic avoidance, Gigerenzer believed that heuristics could actually be more efficient than other more complex decision-making methods (Gigerenzer et al., 1999). Like Herbert Simon, Gigerenzer places great emphasis on the notion of ecological rationality. He criticizes the experiments performed by Kahneman and Tversky for having been performed in labs, under conditions that do not reflect the environment that humans typically make heuristic decisions in (Gigerenzer et al., 2011). Returning to the analogy of Simon’s scissors, like it is impossible to accurately understand people’s behavior by solely looking at internal causes, Gigerenzer argues that it is also impossible to understand a heuristic by only looking at the heuristic itself, without incorporating the environment that it is used in (Gigerenzer et al., 2011).

Following the logic of Simon’s scissors, the effectiveness of a heuristic or optimization method is dependent on how well it fits with the environment in which it is being used. Heuristics and optimization methods are not inherently irrational or rational; their usefulness should instead be judged in relation to their environment. The question is then under which environmental condition a given heuristic will represent an efficient or inefficient decision method, which is the core of the notion of ecological rationality (Gigerenzer & Gaissmaier, 2011).

With Gigerenzer’s adaptive toolbox, he provides a framework for ‘nonoptimizing’ the visions laid out by Simon’s bounded rationality. Gigerenzer, being a staunch opponent of the idea of completely rational actors as seen in the ‘rational choice’ paradigm, labels the actors supposed to act within such paradigms as “demons” (Gigerenzer, 2001), mocking the suggestion of omniscient and omnipotent individuals with the ability to
factor in all options and contingencies\(^2\). Instead he puts an emphasis on ‘psychological plausibility’, which aims to model human behavior of bounded rationality on the “cognitive, emotional, social, and behavioral repertoire that a [human] species actually has” (Gigerenzer, 2001, p. 38).

![Figure 1: Gigerenzer's visions of rationality](Taken from Gigerenzer, 2001, p. 39)

Ultimately, Gigerenzer develops a number of ‘fast and frugal’ heuristics, which act as an alternative to the prospect of satisficing already present within Simon’s notion of bounded rationality. Notable fast-and-frugal heuristics as laid out by Gigerenzer include the take-the-best heuristic and the recognition heuristic, which are described below.

The take-the-best heuristic - a strategy in which people use the most salient and easily available information to make judgments. It suggests that people will choose the option that has the highest level of a single, positive attribute, rather than considering all attributes or options (Gigerenzer et al., 1999).

The recognition heuristic - a strategy in which people use the ease of recognizing an option as an indicator of its value. It suggests that people will choose the option that is

\(^2\) Such an interpretation of rational choice theory is in reality quite harsh in relation to the paradigm laid out by Savage, but perhaps less harsh in relation to the way in which a number of economic models operating under rational choice assumptions are applied.
more familiar or more easily recognized, rather than considering all options (Goldstein & Gigerenzer, 2002).

Again, these only represent a few heuristics that are considered ‘fast and frugal’, but in contrast to the heuristics laid out by Kahneman and Tversky, these heuristics represent decision-making methods that are meant to not merely be sufficient, but also effective under the right conditions.

With a general overview of how heuristics are viewed within different paradigms related to economics having been established, the next section will cover the concept of real options theory, along with different approaches to it.

2.3 Real options theory

The real options paradigm is vast and full of different approaches and theories. In this review, I will begin by looking at a more general view of real options, before delving into two main lenses within the real options paradigm, namely ‘real options valuation’ and ‘real options reasoning’. The intention is to establish a broader overview of the paradigm, before later establishing a more complete framework for how lessons from different approaches to heuristics can be incorporated into using real options theory for entrepreneurial decision-making.

In general, real options are a type of business decision-making tool that provides management with flexibility in their investment strategies. They allow a company to adjust its plans for a project, such as expanding, reducing, delaying, or abandoning it, in response to changing and uncertain market conditions. Real options pertain to management decisions about non-financial assets that can be exercised at a future time. Unlike financial options, which are tradable securities derived from underlying financial instruments, real options are not generally traded. Instead, they are a valuation or decision-making tool that a company can use internally to navigate uncertain circumstances. Much like financial options however, real options give a company the right to make a transaction or investment before the opportunity is no longer available, but without obligating them to do so. As the holder of a real option has the right, but not the obligation, to make a transaction or investment, they have
the freedom to decide against exercising the option and allowing it to expire (Koller et al., 2015).

Real options are termed as ‘real’ in reference to tangible, physical assets such as land, buildings or equipment that may be involved in projects undertaken by a given firm. However, real options theory nevertheless also covers intangible assets such as patents or technology or R&D investments (Schwartz & Trigeorgis, 2004).

Real options allow a company to change the timing, scope, and direction of its decisions in response to uncertain circumstances, providing flexibility in its operations and investment strategies. Options may include waiting, scaling, switching, expanding or abandoning a given position (Trigeorgis, 1996).

To understand the need for real options theory, it is helpful to understand common characteristics of investment decisions. In their book ‘Investments under Uncertainty’ (1994), Dixit and Pindyck lay out three such characteristics:

1. The investment is partially or completely irreversible
2. There is uncertainty over the future payoffs from the investment
3. The firm has some ability to delay their timing of investment to get more information (but never complete certainty) about the future

These characteristics form the initial foundation of the need for real options theory, with more straightforward evaluation tools such as discounted cash flow (DCF) and net present value (NPV) calculations failing to consider the importance of particularly uncertainty and flexibility in their valuations (see Figure 2 below).
As a result of these limitations, the real options approach was developed as an extension of financial option theory to better reflect the flexibility and adaptability needed in real-world business decisions, while still being based on financial option theory and using a similar set of models to analyze decision-making under uncertainty (Schwartz & Trigeorgis, 2004).

2.3.1 Real options valuation

Real options valuation relates to a more quantitative method of decision-making, which is typically used for general project management or resource allocation processes. The intent is to quantitatively measure the benefits of waiting before uncertainty is resolved, as well as the potential of partly reversing commitment (Driouchi & Bennett, 2012). Real options valuation represents a more neoclassical approach to real options, as a simplified, stylized model is created with quantitative inputs to output a concrete, final value of a given option. Nevertheless, within particularly uncertain environments, serious issues in obtaining relevant and accurate proxies for inputs to the model can arguably hamper the validity of quantitative options modelling with regard to entrepreneurial decision-making (Driouchi & Bennett, 2012). This is especially relevant when risk and uncertainty is difficult to model.

Real options valuation can be directly associated with the ‘rational choice’ paradigm, with the strong form of the valuation approach operating on the assumptions that actors are fully rational, and that markets function perfectly (Dixit & Pindyck, 1994;
Trigeorgis, 1996). Furthermore, as the mathematics from the valuation of financial options are being directly applied, it can be inferred that the assumptions associated with the methodology of valuing financial options similarly hold for the valuation of real options. Ultimately, the value assigned to the real option is given by the value associated with waiting until prospective uncertainty has been resolved (Trigeorgis, 1996).

2.3.2 Real options reasoning

Real options reasoning is a methodology that functions less as a valuation instrument, and more as a strategic tool to map out strategic decision options, allowing decision-makers to acquire the competencies and foresight needed to sequence their investment commitments in a more incremental and flexible manner (Driouchi & Bennett, 2012). As such, real options reasoning emphasizes the importance of proactive planning and the ability to consider multiple options in any planning and strategy formulation situation. Real options reasoning moves away from a more neoclassical approach, as the focus is not so much on optimization and value maximization, as it is in resource reconfiguration and value creation (Driouchi & Bennett, 2012). This also means that real options reasoning does not necessarily mean to be applied as a structured and specific planning method, but it can instead also be applied as a more metaphorical framework for intuitive decision-making.

The real option reasoning form of real options decision-making precedes the real options valuation method, but has grown increasingly less dominant in comparison to the more positivistic real options valuation method (Driouchi & Bennett, 2012). This possibly suggests that firms struggle with the less positivistic and quantifiable aspects of real options theory, indicating the need for a more structured approach while maintaining to ability to be useful within environments of high uncertainty.

The above sections cover the most prevalent views relation to real options theory within management and strategy research, in an attempt to clarify how the methods can be used within organizations. It also underlines that real options can be used both as an implicit or explicit method for both valuation as well as decision-making, or alternatively, as a thought process for strategic planning. Further limitations and
boundaries of real option theory within entrepreneurial decision-making will be discussed later, but first a greater understanding of uncertainty is established within the next section.

2.4 Defining uncertainty

When valuing financial options, referring to uncertainty often relates to what amounts to a negative or positive deviation from an expected outcome or return. Typically, the likelihood of such deviations will be quantified, with concrete probabilities assigned. When uncertainty can be measured and reduced to concrete probability, a better term for it is ‘risk’, as is seen with systematic and unsystematic risk within finance and economics. As an example, standard deviations is a measure of financial risk that is commonly used to assess the volatility of an asset compared to its historical price average over a given time period, producing a concrete, quantifiable outcome. It is then arguable to which extent past measurements of volatility are an accurate or useful assessment of future results, but it is nevertheless important to make a clear distinction between risk and uncertainty.

To distinguish the concept of risk from uncertainty, this thesis employs the concept of Knightian uncertainty, as first introduced by economist Frank Knight in 1921. As he put it:

\[\ldots\] uncertainty must be taken in a sense radically distinct from the familiar notion of Risk, from which it has never been properly separated. The term “risk” \[\ldots\] really covers two things which, functionally at least, in their causal in their causal relation to the phenomena of economic organization, are categorically different. \quad (Knight, 1921)

Unlike the quantifiable risk, probabilities cannot be effectively applied to uncertainty. Instead, it refers to situations in which the probabilities of different outcomes are unknown or fundamentally unknowable. As such, uncertainty is to be understood as a state of incompleteness or lack of knowledge about possible outcomes or their likelihoods, even when some information is available. It involves a deficiency, whether partial or full, of understanding or knowledge about a particular situation or environment (Knight, 1921). The implication is that consequences or future outcomes from chosen actions can be difficult or impossible to predict, due to the lack of perfect
information. As a result, high degrees of uncertainty can lead to a focus on robustness and flexibility rather than optimization, since it is not possible to know what the optimal decision is in advance. It may require taking a more exploratory and experimental approach, rather than relying on past data and models.

Beyond the explicated concept of uncertainty, the thesis makes a further distinction between Knightian uncertainty and what will be labelled as “radical” uncertainty, or unknown unknowns. The intent here is to clarify a term for an environment or situation in which probabilities for a given outcome or consequence are not just unavailable, but such outcomes or consequences are not even foreseen or conceptualized, and as a result have not been classified or discussed by relevant parties ex ante (Ehrig & Foss, 2021). Arguably the concept of Knightian uncertainty already covers such situations, but it is frequently misinterpreted as relative ignorance about lack of probability for an event (LeRoy & D Singell, 1987). Furthermore, Knightian uncertainty is also a broader concept that covers situations of even partial ignorance, and therefore a stronger statement about a complete lack of knowledge is needed, and it is given by radical uncertainty and unknown unknowns.

To summarize, risk differs from uncertainty in that concrete probabilities of outcomes cannot be assigned to a given situation where uncertainty is present. Uncertainty can still refer to situations in which there is partial information, and as such a stronger statement of a complete lack of knowledge is also made explicit, which throughout the thesis will be labelled as radical uncertainty or unknown unknowns. While both partial uncertainty and radical uncertainty gives rise to environments that favor further flexibility and robustness, they also have further implications for the rationality paradigms and the application of real options theory, which will be discussed later.
3.0 Research approach and methodology

This thesis has a theoretical approach, with an overarching intent of reviewing existing literature regarding rationality, heuristics and real options theory, and its applications to economics and finance, and more specifically to entrepreneurial decision-making under uncertainty. It is an inductive study (Babbie, 2013) to determine how heuristics can be applied in a beneficial matter to make entrepreneurial decisions within a real options theory framework.

For the purpose of this study, the ontological approach of critical realism is adopted. In critical realism, ontology is understood as the study of the underlying structures, causes, and regularities that shape the world. The belief is that that there is an objective reality that exists independently of human perception or interpretation, and this reality is composed of both observable and unobservable entities and their properties. Observable entities are those that can be directly perceived through our senses, while unobservable entities are those that can only be inferred through scientific explanation or theory (Saunders et al., 2018). As such, the empirical reality that we observe only makes up a small part of the actual events that are occurring, and this empirical reality can easily deceive the actors who observe it. Furthermore, ontology in critical realism emphasizes that reality is not static, but instead constantly changing and evolving (Saunders et al., 2018).

![Stratified ontology in critical realism](Taken from Saunders et al., 2018. p. 148)
These ontological considerations have important implications for the nature of how knowledge is acquired, i.e., the epistemology. As individuals only experience the empirical level of reality, they will have to “reason backwards” from what has been experienced, to understand the underlying reality of what is really occurring (Saunders et al., 2018). As such, abductive processes and causal reasoning are of particular importance, and it cannot be entirely reduced to statistical correlations or quantitative methods (Saunders et al., 2018). Furthermore, it is acknowledged within critical realism that knowledge is socially conditioned, which has two important implications: Firstly, knowledge cannot be understood independently of the social actors that inhabit the world, and secondly, the social actors within the world take part in affecting the structures of reality, just like they themselves are affected by the same structures (see Figure 4) (Buch-Hansen & Nielsen, 2014).

![Figure 4: Interplay between structures and social actors (Adapted from Buch-Hansen & Nielsen, 2014, p. 50)](image-url)

The above figure should be interpreted as a continual process, i.e., structural conditions lead to social interactions leading to structural development, which then again affects the structural conditions. This interplay between the structures of reality and the social actors within has important implications for the notion of rationality under uncertainty, and will be discussed further later.

The inability to directly observe reality means that it is at best possible to arrive at an approximation of the truth, and not the exact truth itself. This align with Karl Popper’s statement that no theory can ever be proven to be true, rather it can only be falsified. Popper, whose ideas have been very influential on the development of critical realism, similarly stated that in scientific discovery, it is usually not possible to ensure the highest likelihood of being correct, and it is even less likely to know that the best
possible outcome has been reached, as there are an infinite number and variety of possibilities (Popper, 2002). However, when there is a lack of current knowledge, it does not mean that knowledge cannot be rationally constructed. According to Popper, a rational actor is not one that has complete or infallible knowledge about the world, but rather one who is aware that no such thing as complete or infallible knowledge exists (Popper, 2002). Popper’s ideas of epistemic rationality play a significant role during the course of this thesis, especially with regard to discussing if heuristics\(^2\) can be utilized for rational knowledge construction, which will be delved further into later.

### 3.1 Limitations

The discussion of rationality and heuristics covers various issues across several different fields. This makes an all-encompassing exploration of the subject difficult, since there is no single framework that cover all of the primary assumptions or posits. Additionally, in line with the idea of ever-changing knowledge present within critical realism, the understandings of rationality and heuristics are constantly evolving, with key principles continuously being reevaluated and supplemented. The aim of this thesis is therefore not to provide an exhaustive account of the relevant concepts, but rather to attempt to unite and create a broader understanding of the most central ideas pertaining to strategic management and finance. As a result, the concepts presented in this thesis are merely a (qualified) selection from the vast body of work available.

The thesis has a focus on entrepreneurial decision-making, and assumes a certain (large) degree of flexibility in relation to the structuring of decision-making processes. As such, the scope of the study means that there may be a lack of generalizability with regard to extending the conclusions to larger, more established organizations. Additionally, while the study occasionally touches upon the impact different actors with different perspectives and biases may have within an organization, it nonetheless generally views organizations acting as a monolithic actor with regard to decision-making. Consequently, a number of factors with regard to the interplay of subjective knowledge, hereunder biases and heuristics, may not be considered.

\(^2\) Interestingly, Popper himself labels a “heuristic” as a method for discovery (Popper, 1989)
The nature of the thesis as primarily a theoretical study brings with it a number of limitations. First, while empirical data is cited on a number of occasions, it does not contribute with any original data. Furthermore, the thesis relies on a number of assumptions that, while popular within economics and strategic management, have not necessarily been empirically tested within the scope of the study. In the same vein, as an inductive study, thesis does not set out to test the validity of the conclusions that are drawn by testing the ideas and theories on the real world through a hypothesis.

Finally, consistent with the approach of critical realism, it must be acknowledged that the conclusions drawn within the thesis are neither a finite nor objective view of reality. Rather, it is an approximation of reality that is in part shaped by both subjective experiences and bias. As such, it must be emphasized that the knowledge herein is open to revision and improvement through further scientific inquiry.
4.0 Understanding human cognition and establishing a broader view of rationality

To understand how heuristics can effectively be applied with a real options framework, it is necessary to: (i) establish general conditions for human cognition, that can be applied to the decision-making process within real options theory and (ii) to create a clear notion of rationality for the framework to operate within.

To establish the general conditions for human cognition, a look into the dual-process theory of the mind as described by Daniel Kahneman in his book “Thinking, Fast and Slow” (2011) is undertaken. Kahneman makes the distinction between two separate theoretical systems to explain how the brain processes information and how people make decisions. He also argues that understanding the distinction can help us better understand the limitations and biases of human thinking, and how we can overcome them.

In an effort to bridge the gap between the different views on heuristics and rationality as presented so far, this thesis aims to build on the foundation of the dual-process theory as presented by Kahneman, primarily by shifting the rivaling views on rationality within the literature towards a broader, more compatible approach.

4.1 A dual-process theory of the mind

In the dual-process theory of the mind, Kahneman presents two theoretical systems that guide human cognition and decision-making. He labels these systems as ‘System 1’ and ‘System 2’.

4.1.1 System 1 – intuitive, biased, and error-prone

System 1 is characterized by being the fast, intuitive, and automatic thinking system that is responsible for our snap judgments, emotions, and perceptions. It operates automatically and quickly, with little or no effort and no sense of voluntary control. Kahneman describes System 1 as "fast, automatic, frequent, emotional, stereotypic, and unconscious.\textquotedbl, and claims that it is \textit{the origin of many of the systematic errors in your intuitions" (Kahneman, 2011, p. 58).
System 1 is responsible for producing intuitive responses based on past experiences. Intuition is considered valid when familiar patterns are recognized in new situations and actions are taken accordingly. However, when an individual overvalues their abilities and applies their current understanding to unrelated scenarios, this can lead to an intuition that is not valid or appropriate (Kahneman, 2011).

A crucial aspect of System 1 is the use of mental shortcuts, i.e., heuristics. These are experience-based methods that allow the mind to arrive at satisfactory, though often imperfect, solutions to complicated decisions. Kahneman does state that heuristics can be useful when navigating complexity, but he emphasizes that in their tendency to reduce information and cues to fit with previous experience and knowledge, they often lead to a number of biases that impact the decision-maker, deviating the outcome of the decision from an ideal, rational one (Kahneman, 2011).

System 1 operates as all time, meaning that cognitive errors for humans are an inherent and unavoidable fact of the human cognitive process. However, to keep such errors in check, System 2 can be utilized to actively monitor the thoughts stemming from System 1, in an effort to prevent irrational decisions (Kahneman, 2011).

4.1.2 System 2 – effortful and rational

System 2 is characterized as the slow, deliberative, and logical thinking system that is responsible for more complex thinking, problem-solving, and decision-making. It requires more attention, mental effort, and voluntary control. Kahneman describes this system as "slow, effortful, infrequent, logical, calculating, and conscious." (Kahneman, 2011).

It is when intuition fails that human can switch over to System 2, which is a more deliberate manner of thinking, but also one that requires much greater cognitive effort. As such, the two primary functions of System 2 are both to conduct conscious, deliberate cognitive evaluations, and to monitor System 1, over which System 2 has the ability to override thoughts and assessments (Kahneman, 2011). Furthermore, unlike System 1, System 2 is capable of adhering to rules, comparing different cues between objects, making conscious choices between different options and properly comprehending statistics (Kahneman, 2011).
Following the logic both of wishing to adhere to instrumental rational but acknowledging bounded rationality, Kahneman reasons that System 1 resorts to using heuristics to ease the mind from the burden of complexity, as the attention and cognitive effort required for the use of System 2 is in limited supply. Kahneman argues that System 2 acts in a “lazy” manner as a result of this, in an effort to control its limited energy (Kahneman, 2011). It is in acknowledging these limitations that Kahneman adheres to the bounded rationality of the human mind, but it is nevertheless measured with the axioms of rational choice as a normative frame.

To summarize, System 1 mainly operates through the use of heuristics, which are viewed as mental shortcuts that are fast and simple, but often inefficient and leading to errors due to the bias an actor might have from past experiences. It is the task of System 2 to monitor System 1 and prevent such errors from occurring, which it does through a more effortful and cognitively demanding mental process. Because the act of monitoring System 1 is cognitively demanding and humans have cognitive limits, humans are viewed as having bounded rationality. These cognitive limits make it impossible to monitor the heuristics used by System 1 at all times, which makes it more fruitful to recognize when System 1 might resort to these inefficient heuristics. It is precisely this line of thinking that led Kahneman and Tversky to building a vast repertoire of heuristics and biases that are best avoided.

4.2 Efficient heuristics and why bias isn’t always bad

As previously mentioned, in opposition to the approach towards heuristics by Kahneman and Tversky of building a repertoire of heuristics that should ideally be avoided, Gigerenzer instead set out to showcase a number of ‘fast and frugal’ heuristics, that would act as adaptive strategies to make effective inferences. Gigerenzer would label these heuristics not as irrational or inefficient behavior, but as “a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods.” (Gigerenzer & Gaissmaier, 2011, p. 454). These heuristics function by employing skills that have developed through the process of evolution, to efficiently and flexibly adjust to the characteristics of a given environment. The ability to act efficiently within a specific environment is what gives rise to the notion of ‘ecological’ rationality. This ecological
understanding of rationality differs from both the instrumental rationality present in the rational choice theory, and from Kahneman and Tversky's interpretation of bounded rationality. A primary factor for this is that fast and frugal heuristics neither function as nor are compared to stylized models of optimization, rather they are ‘simple rules’ that describe an efficient manner of problem solving within specific contexts. Furthermore, they also go beyond Simons heuristic of ‘satisficing’, in that within certain environments, these fast and frugal heuristics are proven to be able to outperform more complex decision-making models, instead of settling for a second-best outcome (Gigerenzer & Brighton, 2009).

Additionally, consistent with the approach of critical realism, it must be acknowledged that the environments that actors find themselves in should not be regarded as passive entities that are merely observed by the actors. Rather, the decision-makers find themselves in a social context wherein there is a reciprocal interaction between the actors being affected by the structures of the environment, and the actors in turn affecting the structures of the environment themselves. But while it is possible for actors to develop new heuristics in response to structural changes, it is unlikely that the cognitive structures of ecological rationality themselves are subject to significant change within a relevant timeframe, as these structures are rooted in an evolutionary development (Basel & Brühl, 2013).

To showcase how these fast and frugal heuristics can be effective within certain environments, and to further discuss how this applies to environments typical for entrepreneurial decision-making, the next section delves into the concept of data-fitting and the bias-variance trade-off.

4.2.1 Less-is-more and data fitting

Previously, the accuracy-effort trade-off was introduced, which is the common belief that decision-makers rely on heuristics due to computation and information being constrained by time and costs, suggesting that heuristics are less effective than strategies that gather more information over a longer time period. Ergo, there is a perceived direct trade-off causing less effort to lead to worse accuracy and predictive

3 “Effort” here being a function of the amount of information and computation employed.
ability. This belief does not always hold however, as under certain conditions the use of heuristics can result in more accurate inferences than strategies that expend more effort, i.e. utilize more information and computation (Gigerenzer & Brighton, 2009).

This leads to another (conflicting) belief, which is dubbed the ‘less-is-more’ effect, and it states that: “More information or computation can decrease accuracy; therefore, minds rely on simple heuristics in order to be more accurate than strategies that use more information and time.” (Gigerenzer & Brighton, 2009). Note that unlike the accuracy-effort trade-off, this belief is not considered a general law, but rather an effect that is present under certain conditions. Nevertheless, under certain conditions there is commonly a point when less-is-more, even if information and computation is assumed to be completely free (Gigerenzer & Brighton, 2009).

Consequently, the less-is-more effect is in direct opposition to the classical, instrumental notion of rationality as is present within the rational choice theory and that Kahneman and Tversky would consistently measure heuristics against; evidently it is not always superior to incorporate all (possible) information into the decision-making process. Naturally, this does not mean that making use of less information always leads to superior predictive ability, but it does mean that independent of costs, too much information and computation typically becomes detrimental after a certain point (Gigerenzer & Brighton, 2009).

Understanding how the concept of data fitting relates to predictive ability aids in understanding why heuristics can be useful when dealing with an uncertain future. When analyzing a situation or outcome ex post, it is unsurprisingly useful to incorporate as much information as possible, through utilizing all possible cues. However, doing so becomes problematic when attempting to predict future situations and outcomes ex-ante. A major factor in this is that when attempting to predict future patterns based on past data, a model runs the risk of incorporating a great amount of ‘noise’, which is information that has zero predictive ability and does not help the model.

Creating a model that incorporates too many noisy cues of no value is what is referred to as ‘overfitting’. In other words, the model has become too trained on past (noisy)
data, leading it to perform poorly when used to predict new, unseen data. To have good predictive ability, a model should ideally only be trained on underlying, systematic patterns that are generalizable to new data. This is exactly the point of heuristics, which are designed to avoid overfitting by using only the most relevant information, rather than trying to consider all possible information. As such, ignoring cues, weights, and dependencies between cues can be a beneficial decision-making strategy (Gigerenzer & Brighton, 2009).

![Figure 5: Data fitting versus choosing the right cues (adapted from Basel & Brühl, 2013)]

The concept of choosing the right cues to avoid overfitting, as represented in Figure 5, only makes up part of the explanation for how and when heuristics can work effectively within specific environments. Another important aspect is the bias-variance trade-off, which has long presented a known dilemma in machine learning.

4.2.2 The bias-variance trade-off

In their study of human cognition, Kahneman and Tversky measured to which extent humans would deviate from instrumental rationality. Any deviations from what would be deemed statistically optimal and hence rational, they would term as ‘bias’. As such, bias often came to be viewed exclusively as a term with negative connotations.

In machine learning however, there exists several examples of how introducing bias to an induction algorithm can improve its predictive ability over that of an unbiased algorithm (Hastie et al., 2009). An article published in 1992 by Geman, Bienstock and Doursat, titled ‘Neural Networks and the Bias/Variance Dilemma’, provides a
comprehensive account of the aforementioned trade-off between bias and variance. They recognize that prediction error is not solely dictated by bias, but also by noise and variance. As such, the total error can be expressed as:

\[
\text{Total error} = (\text{bias})^2 + \text{variance} + \text{noise}
\]

To understand the concepts of bias and variance, consider an induction algorithm trying to learn an underlying true function. The algorithm tries to learn this function by only using a sample of data, which may contain noise. The bias of the algorithm is then determined by comparing the true underlying function to the mean function estimated by the algorithm, across all possible data samples of a given size. The difference between the underlying function and the total mean function then represents the bias. As a result, if the underlying function is exactly equal to the mean function, zero bias is present (Gigerenzer & Brighton, 2009). Variance on the other hand measures the sensitivity of an induction algorithm to the specific data samples it uses. It is calculated as the sum of the squared differences between the mean function estimated by the algorithm, and the function estimated by the algorithm for each individual sample (Gigerenzer & Brighton, 2009).

It follows, then, that a completely unbiased algorithm, while being exactly equal to the underlying function, may still incur a high amount of variance due to the separate individual functions being affected by an overabundance of variance leading to a high degree of total error. The degree to which an algorithm is prone to bias and variance is determined by the underlying function and, crucially, the amount of data points available to observe and learn from this function (Gigerenzer & Brighton, 2009).

The overall point is that low bias is in fact not always something that should be sought when seeking to be predict future patterns, as variance can be a greater source of error when dealing with limited sample sizes, as might often be the case within uncertain environments. The bias-variance trade-off shows how introducing bias to a model can reduce variance, with the intention of reducing the total margin of error.

Flexible models that incorporate a greater amount of data are more likely to be affected by high variance, as they run a greater risk of capturing a harmful amount of noise along with the intended underlying pattern (Gigerenzer & Brighton, 2009). To
combat bias and maintain a low prediction error when operating with a wide set of problems, a model must necessarily accommodate a large amount of patterns, but it does not come without risk. It may intuitively seem sensible to utilize flexible models within environments that are uncertain and dynamic, but it hosts a problem when it comes with the risk of using unsystematic patterns to make predictions. The only way to minimize this risk is by making a bet on what kind of pattern may occur, which can be done through heuristics.

It should be mentioned that when working with a large amount of data, it is easier to identify and eliminate accidental patterns, leading to more accurate predictions without bias. However, when dealing with sparse data and uncertain environments, using flexible models that serve a general purpose often leads to poor predictions of the future.

The bias-variance trade-off as described above gives an insight to why sometimes ‘less-is-more’, and how the accuracy-effort trade-off does not always hold. An important point here is that the less-is-more effect frees us from the instrumental rationality assumptions, as it is evidently possible to make efficient decisions without complete knowledge about all relevant choices, outcomes or probabilities. Instead, by utilizing heuristics, it is possible to make quick decisions in uncertain environments with limited sample sizes, unknown probabilities, and dynamic environments where the relevant conditions and variables may change drastically in the future.

4.3 A broader view of rationality – dismantling the rivalry

So far, the thesis has given an account of the ‘rational choice’ paradigm as a sort of “unbounded” rationality, as well as an account of two separate views of heuristics within the bounded rationality paradigm. Within the paradigm of bounded rationality, we find two very different approaches to heuristics – One, which emphasizes the irrationality of humans through their limitations and biases, and another, which argues that humans are capable of making rational choices through fast and frugal heuristics. It is evident throughout the literature that a rivalry has developed between these two differing views on heuristics, not unlike the rivalry that is to be found
between the rational choice paradigm and the bounded rationality paradigm. One could argue however, that this does not necessarily need to be the case.

Widening our view on the two paradigms, one might establish a broader view of rationality; one which showcases both the liabilities and the strengths of human cognition and reasoning. It is clear that human bias does not always lead to second-best and irrational outcomes, but similarly it cannot be said that humans always act in a rational manner because they employ fast and frugal heuristics.

Returning once more to the analogy of Simon’s scissors, representing the need for an understand of human rational behavior to consider not only human cognition, but also the task environment, it should become clearer why a broader view of rationality is needed. Kahneman and Tversky, through consistently measuring human cognition not against the environment it typically finds itself in, but against structured problems in a lab, end up only representing one blade of the scissor. But one blade does not a scissor make, so incorporating the notion of ecological rationality should aid in establishing a more comprehensive view of rationality. Figure 6 showcases a broader view of rationality using the analogy of Simon’s scissors. The relation between cognitive capacities and task, a), showcases how a decision may be positively or negatively influenced by the cognitive abilities and limitations by the actor. Meanwhile, b) shows how the environment itself has influenced these cognitive capacities, while c) shows how the decisions themselves should be judged with regard to the environment that they must be made within (Basel & Brühl, 2013).

![Figure 6: Simon's scissors explicated (Taken from Basel & Brühl, 2013, p. 750)](image-url)
It is not fair, as Kahneman and Tversky have done, to measure human cognition in a structured world with complete knowledge about all relevant choices, outcomes and probabilities, as this is not an accurate portrayal of the environments in which they actually have to make decisions. However, humans are nonetheless clearly prone to making different avoidable errors, and they may also be influenced by bias in a negative manner and resort to heuristics that do more harm than good. As such, it should be evident that there is also merit to sometimes establishing structured, stylized models, which are able to utilize large amounts of information to aid in the understanding and decision-making with regard to certain problems. In the same vein, when Savage, in relation to the rational choice theory, states the need for “small world” stylized economic models to mirror the real world, he makes it clear to such models do not rely on omniscience. Instead, they present another decision making strategy that is more suited to environments that are less dynamic and uncertain. In other words, models operating under rational choice and instrumental rationality provide logically consistent and deductively correct manner to exploit knowledge that is already known, but they do not provide systematic and sound methods for generating new knowledge on which decisions are based (Grandori, 2010). Therefore, instrumental rationality represents only part of human rationality, and one that differs from a more epistemic rationality.

As a result, the paradigms covered in the thesis so far should perhaps less be viewed as rival paradigms, but more so be viewed as different decision strategies that are contingently effective based on the nature of the problem that they are dealing with.

4.3.1 Heuristics as deliberate strategies

Returning to the dual-process theory of the mind, if heuristics are used as a deliberate strategy within a rational context, one might conclude that they should be considered part of the more reflective and ‘rational’ system 2, rather than the intuitive and otherwise error-prone system 1 (Basel & Brühl, 2013). The table below shows the characterization of System 1 and 2, as described by Kahneman and Frederick (2004):
Table 1: Characterizations of System 1 and 2 (Kahneman & Frederick, 2004)

<table>
<thead>
<tr>
<th>System 1 (intuitive)</th>
<th>System 2 (reflective)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic</td>
<td>Controlled</td>
</tr>
<tr>
<td>Effortless</td>
<td>Effortful</td>
</tr>
<tr>
<td>Associative</td>
<td>Deductive</td>
</tr>
<tr>
<td>Rapid, parallel</td>
<td>Slow, serial</td>
</tr>
<tr>
<td>Process opaque</td>
<td>Self-aware</td>
</tr>
<tr>
<td>Skilled action</td>
<td>Rule application</td>
</tr>
</tbody>
</table>

Following the logical flow of the dual-process theory of the mind, heuristics can then be viewed initially as intuitive judgements, that may or may not be negatively influenced by bias. But importantly, heuristics that are proven to be ecologically rational can later be adopted into System 2 as deliberate strategies to aid in the decision-making process. Going forward, the thesis will be working with a definition of heuristics that considers them prediction strategies that accept some form of bias, but with the intent of making superior decisions than prediction strategies without bias. The optimal approach to rational decision-making is then no longer to avoid any heuristics and human bias, but rather to establish clearer boundaries and rules for when heuristics should be used.

4.3.2 The context of entrepreneurial decision-making

It has long been established that entrepreneurs rely on heuristics to a greater degree than managers in large organizations (Busenitz & Barney, 1997). The prevailing explanation for this has typically been that entrepreneurs operate within computationally intractable environments, which makes rational approaches such as using more analytical, stylized models for decision making difficult. As entrepreneurial opportunities extend beyond previous knowledge and experience on a regular basis, the risk of using a model that overfits the data and incorporates a great amount of noise is very real. Nevertheless, the dominant view on rationality and bias has led heuristics to most frequently be seen as something that entrepreneurs have had to resort to using, in lack of better, more rational strategies.

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4 Bias being understood as for example ignoring some available information
In reality, the fact that entrepreneurial decisions often have to be made with small sample sizes within complex and dynamic environments makes heuristics not only an easier, more convenient decision strategy, but likely also a more efficient one. Entrepreneurial decisions are often made on the precipice between the known and the unknown, making predictive ability and the bias-variance trade-off particularly important. A study done by Timo Ehrig and Jens Schmidt show that transferring outdated experience to a new or changed environment can indeed lead to systematic bias in predictions, but can also reduce the variance of prediction error (Ehrig & Schmidt, 2021). This is in line with the trade-off between bias and variance, where decision-makers must weigh the risk of outdated experience leading to incorrect predictions against the risk of inappropriate generalization from a small sample in the new environment. In changing environments, ignoring outdated experience can lower bias but increase variance, making it better to use biased experience if it reduces variance more than it increases bias. Consequently, being aware of the trade-off between bias and variance and the risk of inappropriate generalizations, while also paying mind to the specific environmental characteristics, can lead to better decision making through the use of heuristics that display greater predictive ability than more complex models (Ehrig & Schmidt, 2021).

To summarize, models for decision-making that rely on complete knowledge about the external reality and all choices, outcomes and probabilities in it, are largely not well suited when it comes to entrepreneurial decision-making. Entrepreneurial opportunities often present themselves on the precipice between the known and the unknown, and when these ‘unknown unknowns’ begin to become ‘known unknowns’, what may previously have been the optimal or rational choice between pre-specified alternatives are often no longer fitting or relevant. Instead, utilizing biased heuristics as deliberate decision-making strategies can be a more efficient manner to deal with environments that are dynamic, uncertain, and complex. The next part of the thesis delves into how this logic and the new notion of rationality can be applied within a framework for real options theory.
5.0 The application of heuristics within real options theory

To understand how heuristics can contribute to entrepreneurial decision-making when applied within a real options framework, it is first necessary to take a deeper look into some of the problems currently present within real options theory, which will be done within the first section of this chapter.

5.1 Uncertainty and real option valuation – a brief case study

As previously touched upon, attempting quantitatively value strategic real options can be particularly difficult. A number of mathematical models can be employed to attempt to derive a concrete value of a real option, but it is no easy task to pick a model whose assumptions match those required for the analyzed option. Furthermore, once a model has been picked, the required inputs are often difficult to come by, and proxy values frequently have to be used.

Bowman and Moskowitz (Bowman & Moskowitz, 2001) provide a case study of Merck, a pharmaceutical company, attempting to use the real options approach to justify an investment in an R&D project. Merck settled on the Black-Scholes model, which is a popular choice due to it being the standard for calculating the value of financial options (Brealey et al., 2020), but they faced a number of difficulties in their endeavor. In this section a brief summary of the problems associated with deriving a concrete value of a real option in a similar manner as a financial option will be covered, with the intent touching upon some of the limitations and common complications within current real options valuation. The inputs covered will be specific to the Black-Scholes model, but many of the complications are still relevant to any other quantitative form of modeling with the intent of deriving a concrete real option value.

The first issue Merck encountered was in calculating the stock price input for their model. Stock prices are easily observed for financial options, with a number of terminals providing accurate, up-to-date information about current market prices, and the high activity within the markets ensuring that stocks are generally sold at their current price. This is less so the case for real options, as active markets for options such as R&D projects do not exist in a similar fashion, as there is uncertainty about the outcome of such a project. As a result, there is no readily observable stock price, and
organizations will have to resort to more subjective proxies as inputs to the model. To calculate the stock price, Merck instead decided to do a classic net present value calculation, with a number of sensitivity cases based on different ‘probable’ outcomes (Bowman & Moskowitz, 2001). Such a calculation however presents another host of issues, as a number of subjective assumptions again have to be made, and probabilities as previously mentioned are difficult to assign under uncertainty. A similar problem is found when needing to input the volatility of the option, as again, unlike publicly traded instruments it is difficult to specific a concrete risk profile for a real option. This relates back to the notion of Knightian uncertainty, as opposed to more concrete and quantifiable risk.

Finally, a necessary input for the Black-Scholes model is the time to expiration. Again, this input is trivial for financial options, which have a set time and date for their expiration. With real options however, there is frequently simply no set time to expiration. In the case of a research undertaking as with Merck, the time period of the project could be extended for any number of reasons (Bowman & Moskowitz, 2001). Similarly, many investments related to real options open up for the possibility of undertaking other further incremental investments related to new opportunities, once again making it difficult to set a concrete expiration time. It is possible for the decision-makers to assign concrete boundaries for themselves, but in practice this can be difficult to do. The concept of when to assign boundaries for real options will be delved further into later.

As Bowman and Moskowitz (2001) conclude, the complexity present when attempting to value real options present a number of problems, making it difficult to specify errors within the analysis. Furthermore, the apparent need for subjective judgements on the model inputs create a risk negative bias by the decision making, leading for instance to overly optimistic estimates. Bowman and Moskowitz suggest that one way of solving these issues is by creating a more advanced, customized model to value the real option, that better fits the characteristics required for the specific real option (Bowman & Moskowitz, 2001). Such a response is perfectly in line with the typical assumptions of rational choice, but as the less-is-more effect and the bias-variance trade-off shows, it is quite likely that creating such a complex model would run the
risk of overfitting the data and incorporating too much noise, harming its predictive ability. Importantly however, Bowman and Moskowitz also conclude that a requirement for consistency can often provide more value to decision rules than a search for optimality\(^5\) (Bowman & Moskowitz, 2001).

In the next section, a more complex models that aims to address some of the issues raised in the case study will be covered. However, as will be discussed, more complexity does not necessary resolve all issues.

5.2 A “realistic” real options approach

Past attempts have been made to create a more realistic approach, most notably by incorporating strategic factor market theory and feedback learning theory (Leiblein et al., 2017; Posen et al., 2018). Incomplete markets are an important assumption within the strategic factor theory, and it also adds an important aspect to real options theory. By assuming that markets are incomplete, Leiblein, Posen and Chen recognize the need to not only calculate prospective uncertainty, but also contemporary uncertainty, i.e., uncertainty about the current value of a real option (Leiblein et al., 2017). Furthermore, with the notion of feedback learning, they recognize the need to transform data into information about the true value of an asset. Importantly, this means that the model is better tailored to uncertain and dynamic environments, where information may change over time. Essentially, the model operates under the assumption that an organization has an initial (subjective) belief about the value of a real option, but over time receives noisy feedback which it updates its beliefs in accordance to, changing the value of the option (Posen et al., 2018). As the feedback it receives is affected by contemporaneous uncertainty, bias by relevant actors then becomes an incorporated factor in the model.

Posen et al. emphasize the need for analytical tractability in their model, which leads them to, like Merck, develop a model based on the Black Scholes formula, but this time importantly linking it with a feedback learning model (Posen et al., 2018). By adding a number of “somewhat realistic behavioral and informational assumptions”, the model

\(^5\) Interestingly, a study they cite, titled ‘Consistency and Optimality in Managerial Decision Making’ conducted by Bowman back in 1963, finds that it is generally the variance in decision making rather than the bias that is harmful.
is able to infer a concrete real options price of a biased decision-maker under uncertainty (Posen et al., 2018). It is not the intent of this thesis to go into detail about the mathematics employed in the model, but rather to briefly touch upon a few issues with the used assumptions, especially with regard to rationality. Specifically, the model uses Bayesian inference to update beliefs about the (true) value of a real option. Furthermore, bias is incorporated as “misperception of the level of contemporaneous uncertainty.” (Posen et al., 2018, p. 1121), leading bias to always lead to a deviation from the Bayesian optimal rate.

5.2.1 Limitations of Bayesian inference in uncertain environments

The issue with such a model of “rational search” that operates under Bayesian inference is that they are best suited for relatively structured problems, where it is possible to assign probabilities in a logical manner (Grandori, 2013). When operating under high (Knightian) uncertainty or radical uncertainty however, the accuracy of such models become questionable. In Bayesian models it is presumed that all possible information must be taken into account to arrive at the conclusive decision or value. As such, within conditions for entrepreneurial decision-making, where environments are particularly complex, uncertain or dynamic, the model runs a real risk of utilizing too many cues, leading to overfitting or incorporating too much noise, and risking inferior rather than superior belief updating. Past studies have already shown how heuristics can outperform Bayesian inference in such environments (DeMiguel et al., 2009; Lee et al., 2002). Ultimately, there is no concrete method within standard probability theory for updating probability distributions when dealing with radical uncertainty or unknown unknowns. Probability theory allows for the understanding of deriving a marginal distribution from a known joint distribution by conditioning on an event, but this method is not applicable when a novel type of event is introduced to environment and no larger joint distribution that is already present can be updated (Ehrig & Foss, 2021). Ultimately, the use of Bayesian models becomes limited when operating within environments where all relevant information is already available ex-ante, which goes against the notion of radical uncertainty, where it is impossible or meaningless to assign probabilities to outcomes.
5.2.2 Rationality of heuristics in relation to real options theory

When delving outside structured problems from known environments and into unstructured problems in uncertain environments, it is useful to return to Popper’s logic of scientific discovery and epistemic rationality. Under such conditions, the number of ways in which the cause-effect correlations used could potentially be disproved is infinite, making the probability of any such relationship being true always zero (Popper, 2002). As a result, the ‘rational’ approach under such conditions is arguably not to attempt to assign probabilities at all. The argument here is not that Bayesian approaches to probability assessment should never be used, in fact they have plenty of applicability within certain (lower) levels of uncertainty. Rather, the argument is that it is not ultimately necessary to take a universal stance on which approach to apply, much like the case between rational choice and bounded rationality. Decision strategies should be contingent on the environments they are based in, and in conditions of strong uncertainty where it is difficult or impossible to foresee future contingencies, utilizing robust heuristics can often prove the better choice. Real options theory specifically deals with choices that are often made within high uncertainty, and as such, it presents a suitable framework for using heuristics within.

Ultimately, Leiblein, Posen and Chen do touch upon several important things with regard to real options theory. For one, they argue that superior information processing can reduce contemporaneous uncertainty, which will increase an organization’s competitive advantage by allowing them to execute real options more effectively (Leiblein et al., 2017). However, superior information processing need not mean being able to process more information effectively, rather the act of effectively processing noisy information may instead mean choosing to process less information, qua the bias-variance trade-off. This is especially relevant when samples sizes are low, as is often the case for entrepreneurial decisions. Furthermore, the potential for human bias to negatively influence real options decisions is a relevant concern raised by the authors, and an important issue that would be discussed in the next section.
5.3 A heuristic real options approach to decision-making under uncertainty

While remaining too dedicated to an analytically tractable approach towards entrepreneurial decision-making may lead to poor performances in highly uncertain conditions, adopting an approach that is too flexible and leaves too much continuous freedom for decision-making is also likely to lead to suboptimal outcomes. The next section covers how negative bias may still be avoided while utilizing heuristics as deliberate strategies.

5.3.1 The need for real option boundaries

As covered, one of the primary benefits of real option theory resides in the ability to take advantage of the flexibility that sequential investments bring. This flexibility largely emanates from the option of abandoning undertaken investment endeavors, which provides decision-makers with a greater degree of freedom in their project planning. As such, much of real options theory emphasizes making an initial investment under uncertain conditions, and then waiting until the level of uncertainty has decreased, as information about the relevant environment and characteristics are revealed over time through market signals. Figure 7 shows such an approach to real options theory.

![Figure 7: Structure of a Real Option (Taken from Adner & Levinthal, 2004)](image-url)
This approach is theoretically equivalent to that of a financial options, but it is made problematic by some of the issues with real options that have already been touched upon. Again, the true market value of a real options is not as easily derived as it is for a financial option. But perhaps more importantly, unlike the value of a financial option, the value of a real options is not completely exogenous to actions undertaken by the investor, i.e., it is possible for the owner of a real option to directly affect the value of the option through a number of ways. These differences between a financial option and a real option have a number of implications. The most obvious, perhaps, is that it is rarely completely clear when an option should ideally be exercised.

Clearly, it is difficult to establish concrete a priori criteria for when an option is profitable through a more traditional approach such as the Black-Scholes model, while more advanced models including Bayesian inference still risk performing poorly in highly uncertain settings. Nevertheless, negative biases such as the logic of sunk costs, escalation of commitment or overconfidence may lead to “option traps” that that impair well timed and appropriate option abandonment (Adner & Levinthal, 2004). Such biases become even more problematic because real options rarely have a set expiration date, which was also one of the main issues Merck ran into when valuing their R&D project. When the organization itself has to decide on an explicit expiration date, there is once again a serious risk of bias influencing the decision and the actors falling into an option trap. In fact, even while applying a real option reasoning approach, entrepreneurs have been found to suffer from psychological inertia, leading to suboptimal disinvestment choices (Sandri et al., 2010). Being aware of the biases laid out by Kahneman, Tversky and a large number of other authors as part of the ‘heuristic avoidance’ approach can be valuable under these circumstances. However, using effective heuristics with appropriate bias as deliberate decision strategies can also help guide the boundaries for when an option is best abandoned rather than continued.

Setting a priori criteria for abandonment must naturally be based on past experiences and information. But within uncertain and dynamic environments, where samples may be few and information may be unreliable and noisy, it is likely better to rely on few cues for decision making. Consequently, opting to ignore some of the (likely noisy)
information at one’s disposal when setting a priori criteria for real option abandonment may ultimately lead to better results than trying to model the uncertain environment through complex, analytical models.

Furthermore, under these uncertain circumstances, Karl Popper’s words on scientific discovery spring to mind once again. Real options endeavors can in many ways be perceived analogously to the process of scientific discovery. When undertaking a strategic investment in a real option, it is similarly unlikely to proceed in a manner that guarantees success, just like it is not possible to know when the best outcome has been reached, due to the vast number of contingencies that may affect the outcome. As a result, it may be useful to view real options similarly to a scientific hypothesis – as something that cannot be definitively proved, but only falsified. It may not be as easy to falsify the thoughts behind a real option in the same manner as that of a hypothesis in the natural sciences, but utilizing heuristics in an ecologically rational manner is possibly the best substitute.

5.3.2 The limits of flexibility with a real options approach

One of the key values of real option theory is that it provides a more flexible approach to decision-making, but this flexibility is not without limits.

Even when applying ‘rational’ heuristics to establish effective boundaries for real options, there is a risk of shutting down a project that could potentially be successful if allowed slightly more time, slightly more money, or a slightly different scope. In other words, a real option investment can only be demonstrably successful by achieving some certain market or technical requirements (Adner & Levinthal, 2004).

Put more clearly, if a R&D project like the one initiated by Merck was initially invested in and later abandoned, they might conclude that within their subjective time frame and with their chosen amount of resources invested, it was not possible to meet the technical requirements necessary for success. Likewise, they may find that the current result of their R&D project was not well received by the specific market. These can be the correct conclusion given the choices of the real option framework, but it would be wrong to ultimately conclude that the R&D project in itself could not be valuable under other circumstances. Perhaps if they project had received more funding, more time or
if it was situated within another market with different characteristics, it would have ended up being a big success.

The point here is that while the flexibility inherent in real option theory is seen as one of the big strengths of the approach, this flexibility is ultimately limited to the boundaries that are set before the investment. Any information that the decision-maker may receive after the initial investment in the real option may change the perspective on the initially chosen boundaries, but choosing to ignore these boundaries on the basis of the new (potentially useful) information increases the risk of the decision becoming subject to negative cognitive bias. Consequently, the boundaries that were set based on past experience and information may result in hampering innovation, regardless of whether or not they were based on the most rational decision strategy at the time of their inception.

5.3.3 Rigid flexibility – the true value of real options

It may seem somewhat paradoxical that a theoretical framework that underlines flexibility as one of its primary values would need rigid boundaries to perform ideally, but it is perhaps exactly within this combination that the true value of real option theory lies. The real options approach, with the use of heuristics as rational decision strategies, provides a systematic and structured decision-making approach that does not only set it apart from more traditional methods like NPV or Black-Scholes calculations, but also from more unstructured exploration methods that run a greater risk of being negatively influenced by bias.

To return to the discussion about rationality, the need for boundaries in real options represent a clear case for when both instrumental rationality and epistemic rationality are applied together. Part of instrumental rationality is the process of making decisions based on the ability to achieve a specific goal and how this goal is achieved, while epistemic rationality guides how to make rational decisions even with limited information and understanding of the world. In the case of real options, the theory itself represents a normative framework and an instrumental approach, while the application of ‘bounded’ but rational heuristics as a deliberate decision-making strategy provides an approach that maintains epistemic rationality.
In sum, utilizing effective heuristics as part of the real options framework can aid in structuring a more logical approach to entrepreneurial decision-making under uncertainty. Part of high uncertainty involves acknowledging that an investment endeavor can be affected by a near-endless number of factors, and as such can take far more different paths that can be conceived of ex-ante. Under such circumstances, decision-makers run a real risk of falling succumbing to negative bias and falling victim to option traps, leading to mistiming on the execution or abandonment of the option. As such, the flexible approach of real options in truth requires a great deal of rigidity, to set boundaries for which actions are logically sensible based on the experience and information available before the investment into the real option itself. Still, these rigid boundaries should ideally be set so as to allow a flexible selection of reactions based on a number of different contingencies. It is precisely under such conditions of strong uncertainty that the predictive ability of robust heuristics can shine.

5.3.4 Learned heuristics as deliberate strategies for real options theory

Part of utilizing heuristics in an ecologically rational manner lies in recognizing that effective heuristics are heavily dependent on the specific environment and context that they are used to make decisions in. While much of the research done by Gigerenzer and his colleagues is centered around how heuristics can solve specific problems, there is also evidence to suggest that organizations learn rational heuristics through experience from their environment (Bingham & Eisenhardt, 2011; Bingham & Halebian, 2012). Furthermore, it is clear that many of these heuristics are idiosyncratic to the particular organizations. Notably, such heuristics include boundary rules, priority rules and exit rules (Bingham & Eisenhardt, 2011). These rules encompass strategic portfolios of heuristics for decision-making that guide organizations with regard to which opportunities to pursue, the ranking of acceptable opportunities and when to drop given opportunities. Additionally, there is empirical evidence that suggests organizations that rely on opportunity-capture heuristics have higher-performing organizational processes (Bingham et al., 2007).

Using learned heuristics to set deliberate boundary rules and priority rules then represent an intriguing and likely effective method for structuring real options in a way that captures and prioritizes opportunities effectively in uncertain environments.
One Singaporean security firm was found to outperform a relevant industry counterpart on several parameters by employing rules such as rescripting its internalization to Asia, and employing a consultative sales approach that highlighted value over technology (Bingham et al., 2007). Additionally, similar learned heuristics about exit rules should help guide decision-makers with regard to when opportunities should be dropped, aiding in the rigidity of the real options approach and ensuring a lower risk of negative bias.

Such rules are likely to be especially important for entrepreneurs and growth-oriented firms, with evidence suggesting that new organizations often lack the control and direction that is provided by a more structured approach to decision-making, even when competing within dynamic markets (Bingham et al., 2007). In this regard, the real options framework should again prove beneficial, due to systematic and structured the mix of rigidity and flexibility.

Within entrepreneurial environments, it can also often be crucial to act quickly, in order to capture value before any potential competitors. As such, having a framework to make quick decisions, without having to rely on large amounts of information and processing, as well as without having to wait for uncertainty to subside, can be an important competitive advantage. In addition, adopting a ‘make and see’ approach rather than a traditional ‘wait and see’ approach to real options may help entrepreneurs not just in capturing opportunities quicker, but also gaining important knowledge about their environment. In other words, instead of investing in a real option and waiting for relevant market signals and for uncertainty to subside, real options can be perceived as conducting experiments that in themselves aid in receiving useful market signals. Designing such options in a structured, logical manner should make them analogous to a scientific hypothesis, and as such important conclusions may be drawn from their outcomes.

In summary, entrepreneurial decision-making should not be based on a passive investments that hopefully remain standing after the storm of uncertainty has died down, but rather as active investments that push and test relevant market and technical conditions. Nonetheless, a structured and logical approach is required to
prevent hopefully holding on to lost causes or falling victim to other negative bias; and a strategic portfolio of learned heuristics could be the key to such an approach.
6.0 Conclusion

This study aims to investigate how heuristics can be used for entrepreneurial decision-making within a real options approach. In this endeavor, three explicit objectives have been identified: (i) to create a greater understanding of what heuristics are, and how they are viewed within different paradigms of economics and strategic management, (ii) to establish what constitutes a rational approach to dealing with (radical) uncertainty with regard to entrepreneurial decision-making, and (iii) to ascertain how heuristics can contribute to entrepreneurial decision-making in combination with real options theory.

It has long been the mainstream view within economics and strategic management that heuristics represent mental shortcuts that offer individuals a quick but suboptimal approach to decision-making. Heuristics are shaped by the bounded rationality of actors, and as such the decisions made using heuristics have believed to often be negatively influenced by the cognitive limitations and biases that these actors inhabit. However, ‘fast and frugal’ heuristics are proven to be not just fast, but also efficient and logical methods for decision-making under dynamic conditions that include high uncertainty and low sample sizes. Such conclusions go against the traditional notion of instrumental rationality as present in the ‘rational choice’ paradigm, and what emerges is that a broader nation of rationality is desirable for establishing a greater understanding of decision-making using heuristics.

By recognizing that instrumental rational and bounded rationality need not exist as rival paradigms, and that the decision-making methods based on them are not mutually exclusive, it is possible to take steps towards a broader, more productive view of rationality. Instead of approaching such methods in a universalistic manner, it is better to recognizing them as contingent decision-making strategies that may each be more effective under certain conditions. A relevant question then becomes whether or not it is possible to model a problem in a structured enough manner to have concrete, limited options that allow for probability judgements. Under (radical) uncertainty where this may not be possible, using robust heuristics may prove a better solution through higher predictive ability and better outcomes.
While real options theory proclaims that much of its value stems from flexibility under uncertainty, the risk of succumbing to negative bias and falling victim to option traps nevertheless dictates the need for a certain degree of rigidity. As real options investment typically do not have an explicit expiration date, and it can be difficult to prove definitive failure in uncertain environments, it is necessary to set clear boundaries for when to abandon a real option at the time of the investment if negative bias is to be avoided. Consequently, a real options approach using effective heuristics as a deliberate decision-making strategy to set rules that aid in capturing opportunities, prioritizing certain characteristics and defining clear exit rules represent an approach that is both instrumentally and epistemically rational.

The structures and logical approach provided by real options theory is especially important for entrepreneurial decision-making, where a lack of control and direction can often lead to negative outcomes. Furthermore, the fast nature of heuristics allows entrepreneurial organizations to adopt a ‘make and see’ approach, in which they are able to capture opportunities faster than organizations that rely on more information and less uncertainty to act.

6.1 Implications

There is a clear divide on the perception of heuristics within much of the current literature in economics and strategic management – a divide that largely stems from different views on rationality. By establishing a broader view on rationality, and recognizing that a universalistic approach is not only unnecessary but often harmful, it should be possible to create more effective and holistic processes for decision-making. This has a number of both theoretical and managerial implications.

Much research would benefit from a broader view of rationality, as comparing rational behavior within a closed system through stylized model is clearly not a realistic benchmark with regard to generating epistemic knowledge. Similarly however, it is harmful to label models that operate under instrumental rationality and utility-maximization as always harmful, as they undoubtedly still have a use, even within open systems present in the real world. Ultimately, a question of rationality often comes down to whether it is realistic to model the context of decision-making with
finite options that have concrete probabilities assigned. Such models will of course never be an objective version of reality, but as Savage rightly posited, if the utility judgements covering the specific contingencies made within the model still apply to the real world, then the models still provide a useful method of making decisions.

On a practical level, recognizing that it is not always necessary or even optimal to incorporate all available information is an important implication for decision-makers within organizations. Additionally, acknowledging that it is possible to retain a structured and logical approach without assigning concrete values and probabilities will likely be helpful when dealing with high levels of uncertainty. Managers should actively seek to become aware of their biases – not just so that they can be avoided, but also so that they can be utilized if proven to be effective.
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