

# Chapter 2

## Literature Review

### 1 A Review of the Theory of Decision Making

The following sections review the main literature on the topics of choice and decision making. The main theories are reviewed first, followed by some considerations that may provide different contexts and explanations for them.

#### 1.1 *The Bounded Rationality Model*

For Simon (1955) and March, Simon and Guetzkow (1958), reality is complex, but the human cognition is limited. Consequently, decision makers do not have exhaustive knowledge of all the possible alternatives, and they won't have all the necessary knowledge to adequately rank the alternatives and calculate their respective costs and benefits: rationality is bounded. On this basis, the decision maker does not attempt to find the optimal solution to a problem or the optimal choice for the organization; he will rather search a satisfying choice.

Simon (1979) also shows that often the goal of an organization cannot be connected directly to its operations. This will lead to the identification of a subordinate goal, what Simon calls "subgoal identification." Often, a subgoal is not unique, and its definition will be subject to the decision maker, his experience, knowledge, and the environment in which he evolves. And as complexity increases, decision making is often divided up among many specialists and their work coordinated through communication and authority relations.

## ***1.2 The Incrementalist View***

Lindblom (1959) argued that means and ends are intertwined. Decision making is not a discrete event; rather, it becomes a step-by-step process, considering incremental changes from the status quo toward problem solving rather than decision making toward the achievement of a specific goal. For him, decision making is an evolutionary process, not a revolutionary one. The incrementalist view is also akin to “learning by doing” (E. Carayannis and Stokes 2000). It puts emphasis on the implementation of a decision rather than the analytical step that precedes the decision but focuses on continuous learning from the decision implemented and multiple feedback loops and decision adjustments, so as to reach the intended goal.

## ***1.3 The Organizational Procedure View***

For March (1978), decisions are viewed as the output of an organization’s standard operating procedures rather than a specific and stand-alone decision-making process. In this context, Krabuanrat and Phelps (1998) highlighted the use and benefits of codified organizational experience so that decision-making input (whose understanding is common to everyone in the organization) can move through the standard operating procedures and lead to a decision. Codified organizational experience will ensure that everyone understands the rational and outcome of the decision-making process.

However, Das and Teng (1999) referred to the organizational procedure view as the “avoidance mode.” They consider that a systematic decision-making process, such as standard operating procedures, can take away the thinking piece of decision making. They fear that in this type of environment, decision making is made at the cost of innovation.

## ***1.4 The Garbage Can Model***

Cohen et al. (1972) argued that the decision-making process is really a meeting point of multiple actors, multiple goals, and multiple views. They define the garbage can as “the meeting point of a problem in search of a solution, a solution in search of a problem and actors whose attention is divided, who come and go, but who happen to be at the meeting place of the problem and solution.” As a critique, Mayer (2007) argued that the main drawback of the garbage can model is that since the decision point is really only a meeting point, it is impossible to adjust a decision made, and consequently, it is impossible to adjust the organization as a whole.

### ***1.5 The Individual Differences Perspective***

The individual differences perspective places the emphasis on individual decision making, rather than on organizational or group decision making. Keen and Morton (1978) showed that managers use different methods and come to different conclusions, not based on a rational choice but because of their personality, management style, and experience. As most decisions are perceived to emanate from a group decision-making process and a process that could be “standardized” for use within an organization, so as to have it move in one direction, this strings if research has not received as much attention as other decision-making theories and perspectives.

### ***1.6 Naturalistic Decision-Making Perspective***

Experience is the nexus of the naturalistic decision-making perspective. Klein (1999) argued that the decision-making process does not follow a rigorous method of solution identification, which is a key phase of the mainstream decision-making theories. Klein posited that the context in which the problem is posed is fundamental. Decision makers recognize a particular situation, its context, its possible outcomes, and the solution. As such, experience is key because the more experienced the decision maker, the easiest the recognition of the problem. Once the situation is recognized, the decision maker forms a scenario, which will then be tweaked until the decision maker is comfortable with it.

### ***1.7 The Multiple Perspectives Approach***

The multiple perspectives approach claims that all problems can be perceived from different angles. Mitroff and Linstone (1993) argued that no matter how rigorous the decision-making process, it will always be tainted by the perspective of the actors involved in the decision-making process. Thus, to reach a decision that is as comprehensive as possible and includes organizational, technical, and individual views, several stakeholders should be consulted.

### ***1.8 The Effect of Speed on Decision Making***

Kedia et al. (2002) claimed that traditional decision-making theories recommend that when facing uncertainty, decision makers should search for additional relevant information (Eisenhardt 1989; Milliken 1987; Simon 1987). By doing so, they delay the decision making and consequently alter actions and performance results.

Eisenhardt (1989) showed that the faster the decision-making process, the better. His work showed that the more successful companies analyze more relevant data, consider multiple alternatives simultaneously, and make faster decisions. Supporting his evidence, Baum and Wally (2003) also concluded that faster decision making has a positive impact on profitability and growth.

## ***1.9 Conclusion***

Decision-making theories can be broadly divided in to two schools of thoughts: the analytic and the experiential (incremental) schools of decision making. Both schools follow the three main steps in decision making: (1) problem definition, (2) identification, evaluation and selection of alternatives, and (3) implementation. The main difference between the two schools resides in how they weight the different steps. The analytic school focuses more heavily on the first two steps, and implementation is a simple execution of the carefully selected alternative, while the experiential schools focus more on the implementation of an alternative and feedback loops to adjust it as necessary.

## **2 Growth of the Firm**

The following sections review the main theories of the growth of the firm – traditional but mostly endogenous (Paul Romer), new growth of the firm based on increasing returns.

### ***2.1 The Resource-Based View of the Firm***

Before Penrose, most of the literature considered the firm as an equilibrium model. Penrose (1959) proposed a view of the firm based on its productive resources, both physical and human. Penrose made clear that the resources are not themselves factors of productions, but that they rather produce a set of services. “The services yielded by the resources are a function of the way in which they are used – exactly the same resource when used for different purposes or in different ways and in combination with different types or amounts of other resources provides a different service or set of services. The important distinction between resources and services is not their relative durability; rather it lies in the fact that resources consist of a bundle of potential services [...]” (Penrose 1995, p. 25). The theoretical perspective of the firm as a learning organization confronts and combines the resource-based view (E. Penrose 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi et al. 1992).

Penrose (1959) not only redefined the firm, but she also identified elements of the growth of the firm, interested in knowing how much a firm can grow. She established that firms can grow either through diversification or through mergers and acquisitions. In each case, Penrose analyzed what the growth prospects were and concluded that after a period of growth, the firm would inevitably enter a period of decreasing returns.

## ***2.2 Technology-Driven Firm Growth***

Romer (1986) proposed a model of firm growth based on endogenous technological change. He adopted a neo-Schumpeterian growth model that focused on intentional and purposeful innovation. His main contribution was to move away from all the diminishing return models and offer a model in which growth rates can be increasing over time. For Romer, the long-term growth of the firm is primarily driven by the accumulation of knowledge. His model revolves around three elements: externalities, increase return on output production, and decreasing return on knowledge production.

## ***2.3 Conclusion***

When moving away from the traditional models of the firm, the two main theories are the resource-based view of the firm (Penrose) and the technology-driven firm (Romer). The main difference between the two theories is that Romer's model actually argued the existence of sustained growth rates for the firm.

# **3 Innovation**

The following sections review the literature about innovation and how creativity, heterogeneity, and diversity can foster innovation. Here, we will understand innovation as “an invention successfully and sustainably brought to market” (E. G. Carayannis 2000–2009).

## ***3.1 Incremental, Generational, Radical, and Architectural Innovation***

The literature flourishes with a number of notions about innovations: whether they are incremental, generational, radical, architectural, continuous, discontinuous, and disruptive or not. Carayannis et al. (2003) proposed the following definitions of terms:

**Table 2.1** Process/content/context/impact innovation framework

Process	Content	Context	Impact
Evolutionary innovation	Incremental innovation	Continuous innovation	Nondisruptive or disruptive innovation
Evolutionary innovation	Generational innovation	Continuous innovation	
Revolutionary innovation	Radical innovation	Discontinuous innovation	Nondisruptive or disruptive innovation
Revolutionary innovation	Architectural innovation	Discontinuous innovation	

- “Incremental innovations exploit the potential of established designs, and often reinforce the dominance of established firms. They improve the existing functional capabilities of a technology by means of small scale improvements in the technology’s value-adding attributes such as performance, safety, quality and cost.”
- “Generational or next-generation technology innovations are incremental innovations that lead to the creation of a new but not radically different system.”
- “Radical innovations introduce new concepts that depart significantly from past practices and help create products or processes based on a different set of engineering or scientific principles and often open up entirely new markets and potential applications. They provide ‘a brand-new functional capability which is a discontinuity in the ten-current technological capabilities’.”
- “Architectural innovations serve to extend the radical-incremental classification of innovation and introduce the notion of changes in the way in which the components of a product or system are linked together.”
- In evolutionary innovations, “technological change appears to follow a process of natural selection.”
- In revolutionary innovations, “the change appears as a break or non-continuous change in the course of the technology.”

Carayannis et al. (2003) also proposed to frame these various notions along four dimensions of process (of development, diffusion, and adoption), content (specific nature), context (environment), and impact (resulting socio-technological changes). Their proposed framework is shown in Table 2.1 and illustrated in Fig. 2.1.

Incremental innovations lead to incremental changes in the market (Christensen 1997; Tushman and O’Reilly 1996). Incremental innovations are based on learning how to better exploit exiting capabilities (Ireland et al. 2003). Although they don’t lead to the exploitation of new entrepreneurial opportunities, incremental innovations are important “to help the firm derive maximum value from the firm’s current capabilities” (Ireland et al. 2003).

Radical innovations lead to revolutionary changes in the market (Christensen 1997; Tushman and O’Reilly 1996). Disruptive innovations are based on exploiting new opportunities through a new combination of resources results in Ireland et al. (2003). Current market leaders often focus on improving their processes, as well as on the products and services they currently produce. They don’t particularly feel

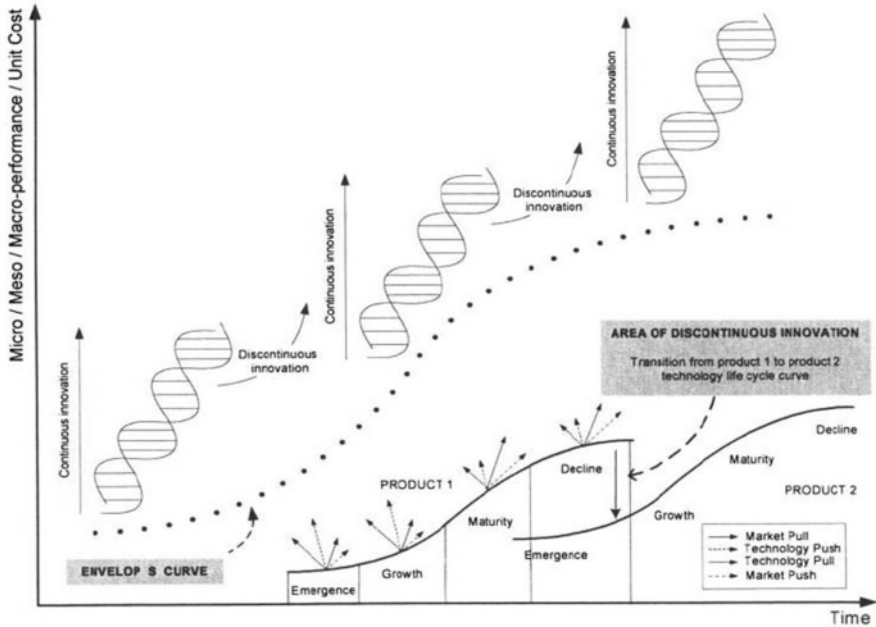
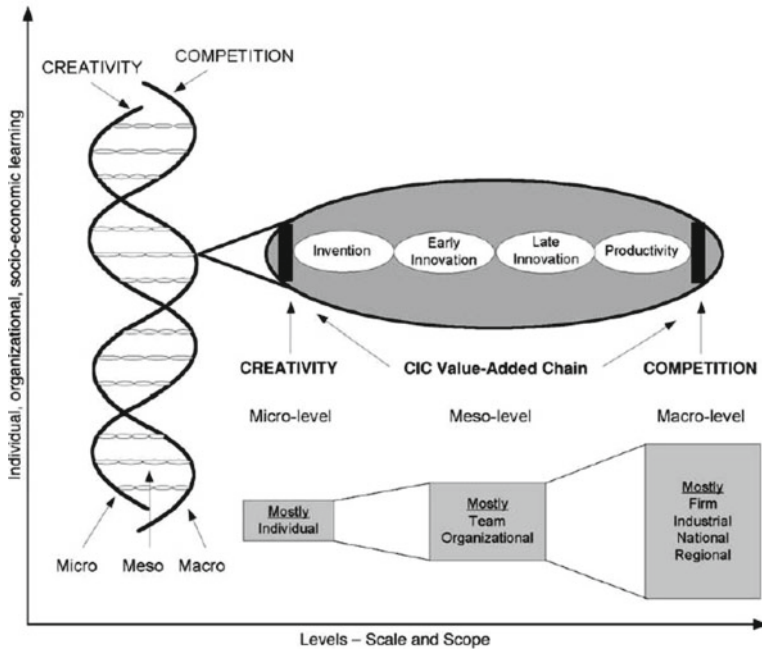


Fig. 2.1 Continuous and discontinuous innovation (Carayannis et al. 2003, p. 130)

comfortable changing the ingredients of a formula that works (Covin and Slevin 2002). Consequently, companies that perceive an unattended need or want out of that formula and can think of a way of responding to this demand or need in a way that implies a change in business model are usually not from the industry or not the market leaders (Christensen et al. 2002).

### 3.2 Creativity and Innovation

Koestler (1964) suggested that creativity, which subsequently leads to innovation, starts with a bisociation process. Bisociation is defined as “the simultaneous mental association of an idea or object with two fields ordinarily not regarded as related” (Merriam-Webster 2009). The greater the breadth of an individual’s knowledge, the more likely the bisociation process (Ireland et al. 2003), but one can assume that a team whose members have diverse backgrounds would also be more likely to experience a bisociation process. This would explain why innovation is more typically the results of a team effort, while invention is more typically the result of an individual effort (or serendipity) (E. G. Carayannis 2000–2009). Bisociation is also the concept Smith and Di Gregorio (2002) built upon when they posited that creativity skills include the ability “to manage and manipulate diverse matrices of information, to suspend judgment as complexity increases, to consider broad categories of domain



**Fig. 2.2** The creativity-innovation-competition double helix (Carayannis and Gonzalez (2003), p. 594)

information, to remember accurately, and to recognize patterns or opportunities from alternative matrices of information.” Bisociation and the type of knowledge one beholds can also be linked to different types of innovation. Should someone have deep knowledge of a subject, he would be more likely to develop incremental innovations, while someone with a broad knowledge across various fields is more likely to develop disruptive innovations (Ireland et al. 2003):

*Excellence is an art won by training and habituation. We do not act rightly because we have virtue or excellence, but we rather have those because we have acted rightly. We are what we repeatedly do. Excellence, then, is not an act but a habit. (Aristotle)*

Taking Aristotle’s quote in the context of bisociation, creativity is then not the result of serendipity but a process and a practice, so as to derive consistently innovation.

Carayannis and Gonzalez (2003) were inspired by the discovery of the double helix structure of the DNA and applied a similar structure to creativity, innovation, and competitiveness, in which creativity and innovation are part of a value-adding chain, starting with creativity, moving along early and late stages of innovation and improving productivity, to eventually result in increased competition (see Fig. 2.2). As we move up the value chain, we also move from a microlevel (individual) up to a macro-level environment for competition (firm, industry, or country). Carayannis and Gonzalez’s empirical research showed that creativity and innovation are critical

topics both for the private and the public sector. However, they went further and assigned a specific role to each actor of the GUI (government-university-industry). They posited that governments are responsible for ensuring a stable environment in which creativity and innovation can happen but also enforcing policies and rules that pertain to intellectual property protection, so as to provide not only a stable context but also one that fosters creativity and innovation. They encouraged universities to develop curricula that promote innovations, not just inventions, that is, inventions should be directed to answering business needs. Businesses should be responsible for developing and leveraging the resources necessary, that is, intellectual capital, social capital, and investments in research and development.

### ***3.3 Heterogeneity, Diversity, and Innovation***

Heterogeneity is defined as “the quality or state of being diverse and not comparable in kind” (Webster’s Dictionary). Adam Smith (1776) understood that an increasingly sophisticated division of labor was the main source of productivity growth. He also knew that, when looking across tasks, it implied an increasing fragmentation of knowledge and corresponding heterogeneity. Carayannis (2009) proposed that heterogeneity be viewed as a cause and effect of innovation. As just mentioned, Smith (1776) showed that division of labor leads to knowledge heterogeneity. This heterogeneity, based on the principle of bisociation (Koestler 1964), will lead to innovation. Innovation itself, through the output generated by the innovation process, contributes to increased heterogeneity.

When analyzing dynamic organizations, McGrath and Boisot (2003) concluded that effective dynamic organizations had to be able to act in the absence of planned change. They deduced that this was shifting the job of strategists from focusing on a “variety-reducing planning process” to “promoters of conceptual diversity.” Furthermore, March (1991) associated exploration in uncertain new areas with heterogeneity in resources accumulation, thus creating a potential for preferential access. The exploration of uncertain areas and flexibility about potential future choices lay at the heart of real options. This is why McGrath, Ferrier and Mendelow (2004) defined real options as “engines” of heterogeneity.

### ***3.4 Conclusion***

After a brief review of the basic forms of innovation, we focused on the role of creativity, diversity, and heterogeneity in innovation. The literature shows that diversity and heterogeneity contribute to innovation, which in turn contributes to diversity and heterogeneity, in a virtuous circle. A key point to take away from the perspective of this research is that real options are considered engines of heterogeneity and therefore fuel innovation as well.

## 4 A Review of Options Theory

The following sections review the main literature about options. After a brief introduction on financial options, the book summarizes the literature on real options, applied to discrete investment decisions, as well as corporate strategy.

### 4.1 Financial Options

Financial options are contracts between buyers and sellers that give buyers the right, but not the obligation, to buy (call option) or sell (put option) the underlying asset at a later date for a predetermined price. Should the market not be favorable to the buyers' "bets," buyers may decide to let the option expire, that is, not to exercise it. In 1973, Black and Scholes derived a differential equation that must be satisfied by the price of any derivative dependent on a nondividend paying stock. The Black-Scholes model is a rapid way of calculating the value of a European option.

For a call option,

$$C(S, t) = SN(d_1) - Ke^{-r(T-t)}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

where:

- $N(\bullet)$  is the standard normal cumulative distribution function.
- $T - t$  is time to maturity.
- $S$  is the [spot price](#) of the underlying asset.
- $K$  is the [strike price](#).
- $r$  is the [risk-free rate](#) (annual rate, expressed in terms of [continuous compounding](#)).
- $\sigma$  is the [volatility](#) in the log – returns of the underlying.

As simple as it is in this form, the model depends on very strict assumptions (Hull 2008):

- The stock price follows a geometric Brownian motion with  $\mu$  and  $\sigma$  constant.
- The short selling of securities with full use of proceeds is permitted.
- There are no transaction costs or taxes.
- All securities are perfectly divisible.
- There are no dividends during the life of the derivative.
- There are no riskless arbitrage opportunities.
- Security trading is continuous.
- The risk-free rate of interest,  $r$ , is constant and the same for all maturities.

In 1979, Cox, Ross, and Rubinstein proposed the binomial tree pricing model in their article titled “Options pricing: a simplified approach.” The greater the number of time steps in the tree, the closer the convergence toward the valuation of the Black-Scholes model. However, the more cumbersome the tree may be, it can be deemed more accurate than the Black-Scholes model in that it accommodates dividend-paying underlying assets as well as American-style options. Furthermore, the tree can be adjusted for more numerous outcomes at each step. Assumptions underpinning the binomial tree pricing model are otherwise similar to the ones of the Black-Scholes model.

For the purpose of this research, it is important to focus on two specific variables of option pricing: time to expiration and volatility. When either of these two variables increases, the value of the option (call or put) increases as well<sup>1</sup> (Hull 2008). Both variables are key elements defining uncertainty, which is typically considered as a negative element in investment decision making. This is precisely where real options attempt to bridge the gap between the finance theory and strategic planning.

## 4.2 Overview of Real Options

Keeping in mind the definition previously provided for financial options, a real option is similar but applied to a real, tangible, or intangible asset, rather than a financial underlying asset. A real option is the right, but not the obligation to undertake a business decision. Benaroch (2002) provided an extensive typology of real options: defer, stage (stop-resume), explore (pilot/prototype), alter scale (scale-up, i.e., expand, or scale-down, i.e., contract), abandon (switch use), outsource, lease, compound (two or more of the previously listed types), and growth (strategic).

Given the faster pace of change, tougher local and international competition, and more radical innovations and paradigm changes, business decisions face greater uncertainty. Thus, real-options analysis has become a more appealing approach for strategic decision making. The concept was first presented by Myers (1977) when he posited that some corporate assets, especially growth opportunities, could be viewed as call options: some investment opportunities grant the right, but not the obligation, to take specific operating action in the future or as Bowman and Hurry (1993, p. 761) explained it: “despite the absence of formal option contracts, they allow a similar pattern of investment behavior to occur.”

Real-options analysis developed partly as an alternative that would overcome some shortcomings of the NPV analysis, in particular how inadequately it captures two significant sources of value for a company (Schwartz and Trigeorgis 2001 p. 47):

- “Operating flexibility, which enables management to make or revise decisions at a future time (e.g. options to defer, grow, or abandon the project) within a single project”

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<sup>1</sup> Assuming early exercise is possible when considering time to expiration.

- “Strategic option value of a project with regard to future and follow-up investments”

Real-options identification is an important step. Not all managerial decisions are real options. In order to differentiate them, the existing literature has identified some key attributes (Kogut and Kulatilaka 1994; Dixit, Pindyck and Davis 1994; Copeland and Antikarov 2001; Durand et al. 2001):

- There needs to be a time frame associated with the option, so as to be able to compare on option with another.
- The decision has to be irreversible:
  - There should be a series of distinguishable and temporarily interdependent decisions (even if it's only two).
  - The irreversibility should be the same for all actors.
- Informational uncertainty is shared among all actors and that uncertainty diminishes as different sequences are realized (there has to be uncertainty about the underlying returns):
  - There is a series of probability events.
  - The decisions taken by the actors do not change the nature of the environment as it was defined at time  $t_0$ .
- An alternative strategic choice exists (management has to have flexibility to decide on the exercising of the option).

For Bowman and Hurry (1993, p. 762), “an option confers preferential access to an opportunity for investment choice – in the sense of gaining advantage over competitors, or in the sense of being better suited for one among several possible courses of action.” “Real options represent choices (strategic or tactical) under conditions of risk and uncertainty about tangible and intangible (knowledge-based) assets (as compared and contrasted to financial assets) that encompass timing, selection and sequencing attributes of significance for the entity that may choose to exercise those options or not (individual, society or company)” (E. G. Carayannis 2009).

Option valuation differs from the valuation of other assets in that risk and uncertainty are key factors. Both volatility and time to expiration greatly impact the value of an option. It is how uncertainty is captured and included in the valuation model that has since then interested managers, since only some projects with very specific characteristics (e.g., asset-in-place investments) fit traditional and mainly linear valuation methodologies. Translating options into the physical world lead to the development of real options.

Contrary to standard valuation methodologies (e.g., discounted cash flows), and as supported by Day and Schoemaker (2000), real options are not static, they're dynamic. Real-options valuation is not a snapshot in time; rather the process needs to be managed. Day and Shoemaker showed that the process can be decomposed in four phases:

#### 1. Adopting a real-options perspective

Real options are not yet part of mainstream thinking. It therefore needs some adaptation to systematically look at business and recognize opportunities through

an option perspective. To some extent, this justifies current practice – all decisions can be seen as option decisions since all projects inherently leave room for managerial discretion in their implementation. To help adopting a real-options perspective, Bowman and Hurry (1993) argue that firms make use of what they call “sensemaking,” that is, managers look at organizational actions taken and how resources were allocated in retrospect, trying to make sense out of them and retroactively identify what options were triggered. By this mean, managers can identify what Bowman and Hurry (1987) call “shadow options.” To be able to strike strategic choices, managers must first be able to recognize them.

## 2. Creating and structuring real options

Although project managers should be able to make the necessary decisions to ensure the success of their projects, it is important to think about this aspect beforehand and formally structure decisions to create future managerial flexibility. Moreover, most projects involve multiple or a sequence of decisions. Thus, one should look for opportunities to unbundle these decisions, so each represents one option. For the option to be most useful, all possible alternatives should be taken into account. One should therefore expand his consideration of additional possibilities for future action.

## 3. Valuing real options

The valuation of real options integrates various aspects: financial returns but also strategic positioning and knowledge gained. The financial aspect probably receives the most attention. It can be assessed in various forms: using financial models (essentially Black-Scholes using a replicating portfolio), decision analysis (decision trees), or threshold assessment (combination of quantitative analysis and managerial judgment). It is in the valuation of real options that one probably best notices that real options are a systematic way of making explicit what could be considered a “gut feeling” on part of managers when they decide to go ahead with a project that has a negative net present value because additional value could be derived in form of knowledge or strategic positioning.

## 4. Implementing a real-options approach

Because real options (and therefore their value) are dynamic, their implementation must be systematic. Assessing the value of the project only at one point in time defeats the superiority of the real-options approach; one needs to carefully monitor the progress of the projects, regularly test, and update his assumptions and based on this knowledge decide whether to exercise the option.

# 4.3 Overview Real Options and Strategic Investments

Since my main proposition is closely related to the fourth hypothesis stated by Bowman and Hurry (1993), we conducted a review of peer-reviewed articles and books that cited their 1993 article. During the second quarter of 2009, EBSCOHost database and Google Scholar yielded about 500 results in English, French, German, Spanish, and Portuguese that we reviewed to explore whether an empirical work as

the one we are proposing had already been conducted (see [Annex 1](#) for the bibliography reviewed). The result of this review was rather enlightening. A vast majority of articles research real-options theory or application at a disaggregated level, that is, applied to individual strategic decisions to be made. Of all the articles reviewed, only six contemplated strategy as a set of real options.

Tong, Reuer and Building (2004) provide evidence in support of looking at strategy as a portfolio of real options as their findings provide strong evidence that “certain corporate investments can provide future growth opportunities that are of value to the firm.” But they also caution that this finding does not apply universally across investment type. They find a positive correlation between R&D investments and firm value attributable to growth options, but find that this does not hold true for investments in tangible capital.

Barnett (2003) argues that using real options may generate too much flexibility opportunities for the organization to handle, which may be detrimental. Barnett (2005) furthermore argues that applying real-options analysis requires undivided managers’ attention, which is a scarce resource. Both of Barnett’s articles warn against the overuse of real options to generate more opportunities that the organization and its management can handle and argue in favor of a correspondingly reasonably sized portfolio of real options.

Smit and Trigeorgis (2006) propose a framework for valuing and managing portfolios of real options, which if it is to be applied to the corporate strategy would assume that managers do indeed design and implement their corporate strategy as a portfolio of real options.

Finally, Kogut and Kulatilaka (2001) and Grewal and Tansuhaj (2001) analyze real options in the context of organizations defined as a set of capabilities, which relates directly to knowledge: capabilities can either be considered a particular kind of knowledge (Loasby 1998) or they can be viewed as collectively held knowledge (Spender 1996). My proposition analyzes strategy as a series of strategic investments that represent a portfolio of real options, and knowledge and learning, which are key firm capabilities, as drivers of the real options.

The following sections summarize current research on strategic decision making and real options, first for disaggregated investment decisions, followed by a section on corporate strategy as a portfolio of real options.

#### ***4.4 Real Options in Entrepreneurship***

O’Brien et al. (2003) proposed an empirical test of the real-options logic to entrepreneurship. They argue that hardly any context would better fit the hypothesis for the definition of a real option than when an entrepreneur is considering launching a new venture. O’Brien et al. argued that at the very least, when faced with his entry decision, an entrepreneur would face the following choices: deferring, abandoning, switching inputs, altering scale, or staging the investment, all of which fit a real-options analysis framework. Their main findings reported that potential entrepreneurs

are less likely to found a new business as uncertainty about industry conditions increase. They also found strong support for their prediction that this holds truer in industries that require investments that are largely irreversible. Consequently, entrepreneurs generally recognize the option to defer their investment. Even if they have to abandon one extra period of profit, they value the knowledge that they will get during that period to make a wiser decision.

Although these empirical results were in line with existing theory (Pindyck 1991; Dixit 1992; Dixit and Pindyck 1994) and some existing empirical evidence (Episcopos 1995), it came as a contradiction to propositions set forth by McGrath (1999) who argued that the high variance of outcomes in entrepreneurial activities will encourage it because the higher the variance in returns, the higher the value of the resulting option. It is also important that McGrath concludes by underscoring the importance of entrepreneurial failure because it is “easier to pinpoint why a failure has occurred than to explain a success” (McGrath 1999, p. 28). Thus, there is considerable value for entrepreneurs in learning from their and others’ failures.

In addition to research from the entrepreneur’s perspective, researchers have also studied real options and entrepreneurship through the lens of venture capital firms. Hurry et al. (1992) studied the strategic logic of Japanese and US high-technology venture capital firms. Their main hypothesis was that the investment logic of Japanese venture capital firms would reveal a shadow call option and would therefore make smaller individual investments, make a larger number of investments, follow longer-term strategic goals, and culminate the venture by retaining an option on the new technology. Their hypotheses in terms of number and magnitude of investments found strong empirical support. In addition, they found that Japanese venture capital firms tended to report more often that their venturing objective was technology, while US firms would report ROI. Furthermore, Japanese firms considered the possibility of future relations with the venture when selecting where to invest and typically retained ties to the venture, while US firms sold their stock or went to an initial public offering. These elements provide additional support to the view that Japanese high-technology venture capital firms pursue an option-based investment strategy.

Furthermore, the concept of entrepreneurship and its real-options analysis framework has also been linked to strategic entrepreneurship (Ireland et al. 2003). According to Ireland et al., strategic entrepreneurship generates superior firm performance through the simultaneous pursuit of multiple small entrepreneurial ventures within an established firm that can leverage its already-existing competitive advantages, which a small venture may lack, to improve the probability of success. Ireland et al. used the real-options logic to propose staged investment in multiple entrepreneurial ventures within the firm. For each smaller-scale-staged investment, the firm gains further knowledge about the venture and is in a better position to more efficiently allocate its resources across the portfolio of small ventures. With a well-balanced and well-managed option portfolio of entrepreneurial ventures, the firm should be able to allocate its resources to its most valuable ventures.

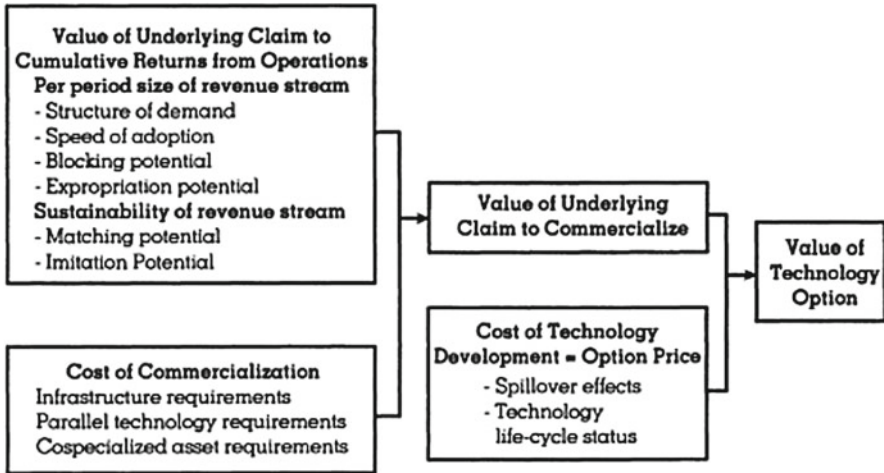


Fig. 2.3 Factors influencing the value of a technology positioning option (McGrath 1997 p. 988)

#### 4.5 Real Options in Innovation and R&D

Technology investments typically require large investments and carry a large degree of uncertainty. As such, traditional valuation techniques may lead to substantial underinvestment. It is in this basis that McGrath (1997) proposed to further the real-options approach to technology positioning investments, integrating both technical and external uncertainties (see Fig. 2.3) and analyzing their impact on timing and option value. Technical uncertainty can be partially dealt with through-staged investments. Should investment not reduce that uncertainty, the firm could postpone its investment. When faced with external uncertainties, the firm can “take strategic actions to amplify the value of the option” (McGrath 1997). An important point that McGrath raises is that to be effective in raising the value of the option, existing resources endowment should reduce uncertainty for the firm while not reducing it for competitors.

Grenadier and Weiss (1997) proposed an option-pricing approach for investments in technological innovations that moves away from the discrete investment decision toward a sequence of interdependent investment decisions. In particular, they consider the innovation investment strategy as a sequence of embedded options. When deciding whether to invest in a new technology, a firm not only invests in the new technology but also holds an option on future updates (option on an option). When considering upgrading to a new technology, they hold an option to exchange the technology it currently has for the upgrade. Grenadier and Weiss identified four possible “migration strategies: (1) a *compulsive* strategy of purchasing every innovation, (2) a *leapfrog* strategy of skipping an early innovation, but adoption the next generation of innovation, (3) a *buy-and-hold* strategy of only purchasing an early innovation, and (4) a *laggard* strategy of waiting until a new generation of innovation

arrives before purchasing the previous innovation.” Their model contemplated the effect of speed of innovation and expected technological growth. They concluded that in environments that sustain a rapid pace of innovation, leapfrog and laggard strategies are the most likely, while compulsive and buy-and-hold are more likely to take place in a slow-paced environment. Leapfrog and compulsive strategies are more likely to take place when the expected innovation growth increases, while the likelihood of laggard strategy decreases, and the one of the buy-and-hold remains somewhat constant.

As mentioned earlier, Hurry et al. (1992) researched the strategic investment logic of Japanese high-technology venture capital firms. Not only did their research show that these firms approached the venture capital process as a real option, but their findings regarding the culmination of the venture investments were also very telling regarding how Japanese firms view the acquisition of innovations and technology. While the venture capital process is managed as a real option, it is also part of another real option to acquire technology. This became apparent in the Hurry, Miller, and Bowman study when the fact that US venture capital firms exited their projects by profit taking was contrasted to the exit of the Japanese companies, which listed retaining stock in the venture or transferring it to a sister firm in their keiretsu or joint ventures. This was consistent with the objectives of the venture financing the firms disclosed, such as “new technology and business development,” “strategic move to new areas,” “proprietary technology,” or “diversification.” In addition, the Japanese firms invested smaller amounts in the new ventures than comparable US firms, even though the full development and deployment of the technology would require much larger investments, which suggests that their involvement in the venture capital process was part of a staging option strategy to learn more about the technology and maybe pilot it before fully engaging.

#### ***4.6 Real Options in the International Development of Firms***

Kogut (1991) proposed to analyze joint ventures in a real-options framework. He hypothesized that “the timing of the acquisition should be triggered by a product market signal indicating an increase in the venture’s valuation.” Using a sample of 92 manufacturing companies, he developed empirical results that support his hypothesis, showing that “unexpected growth in the product market increases the likelihood of acquisition.” One of Kogut’s main contributions is to propose something that goes against the mainstream literature in organizational behavior. Most of the literature has been focusing on minimizing risks, while Kogut is suggesting that uncertainty can also benefit firms if they use a more flexible production process or organizational design.

Entering a new market is always perceived as high risk, and such an investment requires a lot of attention, especially concerns about having to control the operations over a great geographic distance and operating in a foreign culture (Hymer 1960). Kogut and Kulatilaka (1994) proposed to look at a firm’s multinational network

through a real-options lens and highlight the operational flexibility that such a network provides as a valuable option. They used dynamic programming to compute a numerical example, which by far supports their theoretical model. Their results display an incremental profitability rarely short of 10 % and up to 35 %, which is far from negligible. Although the real options framework can be applied to many strategic investment decisions, they believe that it is particularly suited to the internationalization of a firm. They conclude that “despite the popular notion of the riskiness of international markets, it is [this] *uncertainty* that drives the opportunities available to the firm that is multinational, as opposed to only domestic, in its investments and operations,” (emphasis added) which lays at the heart of real-options theory.

#### ***4.7 Real Options in Merger and Acquisitions and Restructuration of Firms***

Hurry (1993, p. 70) defines global restructuring as “the strategic process of striking options to capture complementary opportunities, across global firms, for changes on portfolio scope and financing.” Hurry based his approach on Bowman and Hurry’s (1987) view of the value of a firm, in that it can be analyzed as the value of the business assets, but in addition, also the value of opportunities created by these assets, which represent a portfolio of options (of calls to expand the firm and of puts to contract the firm). Striking some of these options leads to the reconfiguration of the company’s portfolio. One of the main contributions of Hurry related to strategic management is that his theory advocates the conceptualization of strategy as a dynamic process. He posits that this would be particularly useful in some areas of research where results are debatable: citing Trautwein (1990), “areas such as merger and acquisitions, where cross-sectional approaches have not produced unequivocal results.”

Mergers and acquisitions (M&A) have faced serious critique in the literature, most scholars arguing that the acquiring firm reaps no or little benefits (Jensen, Ruback, Field and Park 1983; Loughran and Vijn 1997). Smith and Triantis (1995) posited that more gains are possible when analyzing such investment decisions as part of a framework that includes growth options, flexibility options (strategic diversification rather than purely financial), and divestiture options. Growth can be achieved through strategic acquisition, but Smith and Triantis highlight that growth options exist both for the acquiring as well as the target firm. The target firm may need larger infrastructure and access to cheaper capital, which the acquiring firm can provide, and the acquiring firm may benefit from knowledge transfer or access to new markets and collaborators. As with any option framework, Smith and Triantis highlighted the necessity of adequately identifying the types of options that exist in a particular acquisition transaction but also carefully developing and exercising them, so as to reach the full benefits of the synergies between the target and the acquiring firm.

The careful development and exercise of real options also lies at the heart of Carayannis’ (2008) theory of strategic knowledge arbitrage and serendipity as real-options drivers. Carayannis (ibid) stated that “strategic knowledge serendipity

provides the terms of the option, while strategic knowledge arbitrage influences the decision making.” Mergers and acquisitions illustrate this point very well, since they involve recombining and reallocating assets, both tangible and intangible. M&A learning at the tactical, operational, and strategic levels (Carayannis 1994, 1998, 1999, 2000) comes together to form the base of the M&A strategic knowledge arbitrage and serendipity. This, in turn, will define the terms of the options created by the newly merged company and inform exercise timing (or not), which, if exercised carefully will contribute to improved post merger integration and merged firm performance.

## 4.8 Organizational Strategy and Real Options

Luehrman (1998) showed that business strategies can be seen as a portfolio of real options. As Luehrman explains it, “a strategy defines the path a company wants to take from where it currently stands to where it wants to be.” This involves choices, learning, and sequence of major decisions. Carayannis (E. G. Carayannis 2000–2009) defines strategy as “the competence to discern the non-obvious faster, better, cheaper, longer.” Analyzing projects from a real-options perspective not only forces managers to think several moves ahead (which is nothing new to them), but the option pricing quantifies the value of follow-on opportunities better than standard discounted cash flow.

Bowman and Hurry (1993) also supported the view of an organizational strategy as a bundle or portfolio of options. In addition, they prolonged their theory to impact organizational structure. They based their proposition on Merton’s Theorem 7 (1973, p. 148):

*Theorem 7.* If  $S_i = S_j = S, i, j = 1, 2, \dots, n$ ;

$$Z_{n+1}(\tau) \equiv \sum_1^n \lambda_i Z_i(\tau)$$

for  $\lambda_i \in [0, 1]$  and  $\sum_1^n \lambda_i = 1$ , then

$$F_{n+1}(S, \tau; E) \leq \sum_1^n \lambda_i F_i(S, \tau; E).$$

Merton’s Theorem 7 states that generally diversification hurts an option on a portfolio, as it is more valuable to hold a portfolio of options than to have an option on a portfolio. As such, an organization will be better off if its structure allows it the flexibility to strike the various options it holds when appropriate rather than having a single strike power at the top of the organization that would exercise this right by impacting a lower level of the organization that in its turn would contain a bundle of options (therefore, exercising an option on a portfolio of options rather than managing a portfolio of options).

This real-options-based approach to conceiving strategy is congruent with another perspective on strategy as “the competence to discern the non-obvious faster, more clearly and more accurately” (E. G. Carayannis 2000–2009), and it

further highlights the role and influence of SKARSE™ and learning (E. G. Carayannis 2008). Luehrman (1998) also recommends that for project valuation, option-pricing techniques should be used as complements to existing techniques, not as replacements. In doing so, he emphasizes the creative aspect of finance instead of the more traditional due diligence. If used early on and given adequate freedom, finance can be more creative and play a more important part in the strategy design, that is, it can “contribute insightful interpretive analyses of sequences of decisions that are purely hypothetical—that is, while they are still mere possibilities.” Gaining this knowledge and knowing how, why, and when to use it is akin to a knowledge-based real option. It requires a mind shift that allows managers to consistently identify real options in their business and proactively manage them. Knowledge serendipity provides them with the necessary knowledge to define the terms of the real options, and knowledge arbitrage allows them to decide if, when, and how best to execute them. The creation and growth of a new venture can be seen as a portfolio of real options, whether embedded, serial, or parallel. This portfolio of real options can be envisioned in a mode 3 context (multi-nodal, multimodal, multilayer), in which real options could be multi-nodal depending on where the entity is situated on the path of real options, multimodal depending on which kind of real options is considered (embedded, serial, parallel), and multilayer depending on the level of synthesis one is considering (firm, industry, national levels) (E. G. Carayannis 2009).

## 5 Innovation Networks and Knowledge Clusters

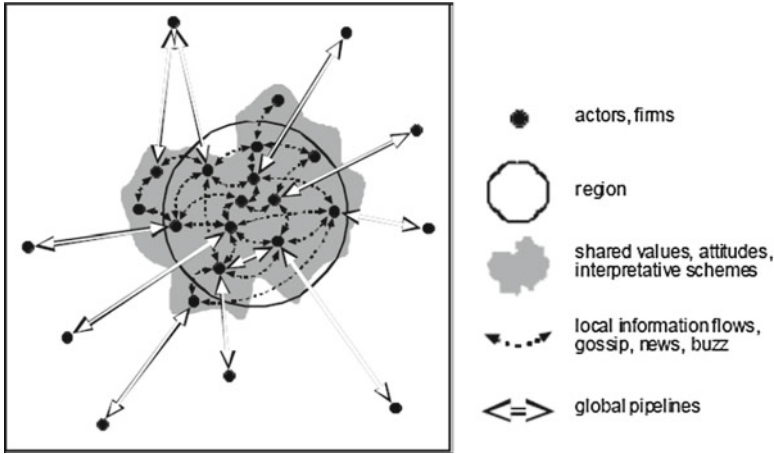
The following sections review the literature on innovation networks and knowledge clusters. We will consider the following definition of terms per Carayannis (2009):

*Innovation Networks* are real and virtual infra-structures and infra-technologies that serve to nurture creativity, trigger invention and catalyze innovation in a public and/or private domain context (for instance, Government-University-Industry Public-Private Research and Technology Development Co-operative Partnerships).

*Knowledge Clusters* are agglomerations of co-specialized, mutually complementary and reinforcing knowledge assets in the form of “knowledge stocks” and “knowledge flows” that exhibit self-organizing, learning-driven, dynamically adaptive competences and trends in the context of an open systems perspective.

### 5.1 Knowledge Creation Within the Firm

Learning within firms can take place many different ways (Simon 1991). Although the form can be very varied, Fuchs (2001) established that knowledge creation within firms is closely related to ongoing activities. Lawson and Lorenz (1999) expanded this idea and ascertained that what each employee learns is somewhat connected to what other employees may know or learn. However, each area of expertise develops its own body of knowledge, and when a firm develops too many



**Fig. 2.4** Local buzz and global pipelines

priorities, with their corresponding specialized knowledge, the common knowledge base of the firm significantly diminishes. Nonaka and Takeuchi (1995) showed that cross division knowledge creation therefore results in lower production costs. The result of intra-firm knowledge creation is mostly incremental learning.

## 5.2 Knowledge Creation Across Firms

Contrary to incremental intra-firm learning, the literature has contemplated for quite some time the fact that radical knowledge creation is usually an interactive process across several firms (Rosenberg 1982; Freeman 1985; Kline and Rosenberg 1986; Lundvall 1988). The division of labor and increased specialization have led to a growth of knowledge and of the economy (Adam Smith 1776; Young 1928). However, in a case similar to a firm too diversified, if the knowledge base across firms is too diverse, the interaction across firms and interfirm projects will be more difficult to manage (Storper and Venables 2004).

## 5.3 Knowledge Creation Across Clusters

The literature about clusters seems to be convinced of the theoretical superiority of geographically close clusters, but there is little empirical evidence to support this statement (Bathelt 2001). Owen-Smith and Powell (2002) showed that being local is not enough for knowledge transfer. Knowledge also travels through innovation and social networks, which are not defined geographically (see Fig. 2.4).

In support of this, Uzzi (1996, 1997) also demonstrated that “over-embeddedness” was not a positive factor: there is a decreasing return on proximity. Burt (1995) also emphasized the importance of having ties with remote networks to bridge structural holes. For a firm to enhance its “absorptive capacity,” it is important to have heterogeneous knowledge; otherwise it won’t be able to fully leverage the knowledge transmitted (W. M. Cohen and Levinthal 1990).

## ***5.4 Toward a Mode 3 Ecosystem***

Carayannis (2009) has built on the existing literature to develop a mode 3 of knowledge-generating system that is based on innovation networks and knowledge clusters. This mode 3 system possesses the following attributes:

- Multilayered (e.g., it happens a different levels: world/country/sector/firm)
- Multimodal (i.e., based on mode 1 and mode 2 system of knowledge production)
- Multi-nodal (i.e., there are multiple connection points within a layer: high connectivity)
- Multilateral (public, private, university, civil society – i.e., the four strands of the Quadruple Innovation Helix)

The four strands of the quadruple helix are government, universities, industry, and civil society. Adding civil society to the triple helix (GUI) combines bottom-up initiatives and practices with top-down policies. In essence, civil society is not only a fourth strand but the bridge and connector between the three remaining strands.

The quadruple helix is an architectural blueprint of the innovation ecosystem, how different sectors are intertwined. The triple helix was meant to work with modes 1 and/or 2. Now, the Quadruple Innovation Helix adds a fourth strand (civil society) and increases connectivity within and across strands. The Quadruple Innovation Helix is meant to work in mode 3 and will not work in modes 1 and 2 because of the diversity and heterogeneity of the participants (e.g., big companies and government interacting with individuals: this interaction is only possible through the higher interconnectivity of mode 3) (E. G. Carayannis 2009).

## ***5.5 Conclusion***

In essence, innovation networks and knowledge clusters are meta-options. A firm has the option to network or not, to cluster or not. When looking at a system that consists of innovation networks and knowledge clusters, one can see a bundle of embedded options.

## 6 Strategic Knowledge Arbitrage and Serendipity (SKARSE™)

The following sections review the literature on strategic knowledge arbitrage and serendipity and on how these concepts become real-options drivers. As the concepts are still fairly young (and there is little in the literature), we will start with a definition of terms.

### 6.1 Definition of Terms

As the literature on the role of knowledge in gaining and sustaining competitive advantage became more active, more studies were conducted about how to keep abreast of one's competitors' development and concluded that much of this knowledge was involuntarily diffused, mostly by third parties (e.g., investment bankers, board members, consultants) (Semadeni 2001). The early definition of knowledge arbitrage (both in academia, Kao 1996, and in the press, *McKinsey Quarterly* 1998) was related to multinational issues: "with individuals who span national and cultural boundaries capitalizing in the arbitrage of knowledge from one country or culture to another" (Semadeni). Semadeni focused his research on the role of management consultants, which he perceived as dual; the role of knowledge arbitrageur, in which the consultant transmits knowledge; and the role of knowledge arbiter, in which there is much room for discretion regarding what knowledge is subject to arbitrage or not.

Davis (2000) highlighted the importance of defining knowledge patterns, especially in the knowledge-based economy for which knowledge is a fundamental input, but also a factor that is fast changing and growing increasingly complex. He posited that pattern recognition "supports effective and rapid decision making." Davis identified 29 knowledge patterns, including knowledge arbitrage, which he defined as "the efficient sourcing and distribution of ideas and products drawing on the best ideas and lowest priced inputs from around the globe." However, Davis' study did not go into the details of how to leverage knowledge arbitrage.

Carayannis (2008) proposed a definition that specifically applies to strategic knowledge:

Strategic knowledge arbitrage. This refers to the ability to distribute and use specific knowledge for applications other than the intended topic area. More specifically, it refers to the capacity to create, identify, reallocate and recombine knowledge assets more effectively and efficiently to derive, develop and capture nonappropriable, defensible, sustainable and scalable pecuniary benefits.

As a complement to strategic knowledge arbitrage, Carayannis also defined strategic knowledge serendipity as follows, coining the concept of SKARSE™ (strategic knowledge serendipity and arbitrage):

Strategic knowledge serendipity. This term refers to the unintended benefits of enabling knowledge to 'spill over' between employees, groups and functional domains ('happy acci-

dents' in learning). More specifically, it describes the capacity to identify, recognize, access and integrate knowledge assets more effectively and efficiently to derive, develop and capture non-appropriable, defensible, sustainable and scalable pecuniary benefits.

## 6.2 *Leveraging SKARSE™ for Real Options*

As described by Carayannis (2008), firms move through the stages of co-opetition, coevolution, and co-specialization (C3) by developing and exercising series of real options. To achieve robust competitiveness and sustainable entrepreneurship, firms have to develop an “unfair” competitive advantage (even for a short period of time). They can develop that competitive advantage by exercising real options. But to increase the probability that this competitive would be “unfair” for at least a period of time, firms should leverage strategic serendipity and arbitrage and use them as drivers of the real options they define and manage. “Strategic knowledge serendipity provides the terms of the option, while strategic knowledge arbitrage influences the decision making” (Carayannis 2008, p. 349).

## 6.3 *Conclusion*

The literature on strategic knowledge and serendipity is still in its infancy, especially in terms of recommendations on how to leverage it to derive a sustainable competitive advantage. The most advanced one is the framework proposed by Carayannis (2008), building on C3 and leveraging SKARSE™ as real-options drivers.

## 7 *Conclusion*

This chapter covers the main elements of the conceptual framework proposed in Chap. 1, namely, real options, innovation, innovation networks and knowledge clusters, and strategic knowledge serendipity and arbitrage. It has also reviewed the literature for the concepts that provide the context for the conceptual framework: decision making and the growth of the firm.

The key take-away of this chapter appeared under the real-options literature review, the main conclusion being that even though real-options analysis has become increasingly popular, it still tends to focus on decision making for discrete investments. Bowman and Hurry (1993) and Luehrman (1998) are the key researchers that have written about real-options frameworks applied to corporate strategy. This provided the opportunity for the work presented here forth.

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