Contributions to Management Science

Valuation of Network Effects in Software Markets

A Complex Networks Approach

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Chapter 2
Investment and Company Valuation

"Res tantum valet quantum vendi potest - The value is determined in the market."
Granger and Morgenstern (1970)

The most relevant concepts of the valuation literature are reviewed in this first chapter of the theoretical framework. First, the background of the relevant conventional valuation approaches is depicted, before the more innovative Real Options Valuation approach and the underlying Option Pricing Theory are summarized. The insights in this chapter provide the financial background for the subsequent design of a framework for valuations in software markets.

2.1 Principles of Investment Valuation

The review of research on *investment valuation* reveals the vital importance of recent research contributions. Capital budgeting research emanated originally as an individual stream of research focusing on economic resource allocation with the goal to determine the value of investment projects or assets.[1] Since the 1960s valuation tools in corporate strategy have flourished, due to the large emphasis on rational planning. A predominant strategic paradigm stated that accurate valuation and decisions about financial commitments are crucial for shareholder value creation and the survival of companies (Trigeorgis 1996). During the 1970s and 1980s the focus of financial research was on decentralized static investment projects. At the same time,

[1] The value of an asset is frequently defined as the sum of the subjective utility provided to its owner (Moxter 1991). While the neoclassical theory assumes that the price and the value of an asset are identical, more recent research on behavioral finance indicates that the two can differ (Shleifer 2000). In this context it is also important to note that motivations to conduct valuations are diverse and influence the outcome (Kühnemann 1985; Born 1995; Koller et al. 2005). Analogous to assets, the value of a company is defined as the total utility of a portfolio of investment projects. The company is interpreted as a set of temporary production functions (Busse von Colbe and Coenenberg 1992). Please note that the primary focus of the subsequent investigations is on asset valuation of customer networks in the context of company valuation as defined in Sect. 1.3. Hence, the terms customer network-centric valuation of companies operating in software markets and valuation are used interchangeably.

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the focus of the research was on valuation of stand-alone projects assuming passive management and certainty (Bamberg and Coenenberg 2004; Laux 2005). The methods developed until the late 1970's were not capable to account for the strategic value of the flexibility to alter plans (Trigeorgis 1996; Copeland and Antikarov 2001; Koller et al. 2005). Later financial research extended the set of applications to valuations under uncertainty. However the prevalent techniques were not capable of capturing all important aspects. Hence, the extension incurred frequently biased results and management decisions were based on managerial charisma. Consequently, managers made intuitive decisions in favor of strategic investments, based on the claim that the investment analysis does not account for all inherent flexibilities of risky projects.[2] This development caused a crisis in the research on valuations, in which it was difficult to identify market values due to a large theory-practice gap (Arnold and Hantzopoulos 2000; Boer 2002). While some academics argue that this gap is an intrinsic problem of financial research, others insist that the future is unpredictable, but suggest this should not be a preventive obstacle for research on valuations.

The resolution of the crisis was an article on a closed-form equation for financial option pricing which was published in 1973 (Black and Scholes 1973). This concept derived a theoretical price for all financial options and initiated a boost in the trading of derivatives. But the increased option thinking also affected other research areas. In 1977, Myers recognized that many projects handled by companies can be interpreted as *real options*. In the following decades these real options became one of the most promising valuation approaches and a large research area. During the 1970s and 1980s the application of dynamic investment approaches considering the reaction potential to uncertainties was gradually promoted to other areas (Trigeorgis 1996, p. 2f). Today, Real Options Valuation is successfully applied in many areas, such as the valuation of natural resources, electricity generation, and research and development investments (Coy 1999). Some models are even designed specifically for valuations in software markets (Schwartz and Moon 2000). Promising aspects of this concept are the consideration of the flexibility and the link between capital budgeting and corporate strategy. In theory, real option valuation looks like the perfect tool for managers to use as it provides more accurate values and normative investment decisions, but a review of its reach reveals that in practice it is not very popular (Graham and Harvey 2001; Koller et al. 2005). In this book some of the underlying problems are investigated and resolved.

2.2 Traditional Investment Valuation

Traditional corporate financial literature provides a variety of methods for the valuation of a company, which vary with respect to the required input data and the resulting level of detail (Busse von Colbe 1957; Ballwieser 1987; Moxter 1991;

[2] Risk is the possibility of an either favorable or unfavorable deviation from an expected value that is quantified by probabilities (Mikus 2001).

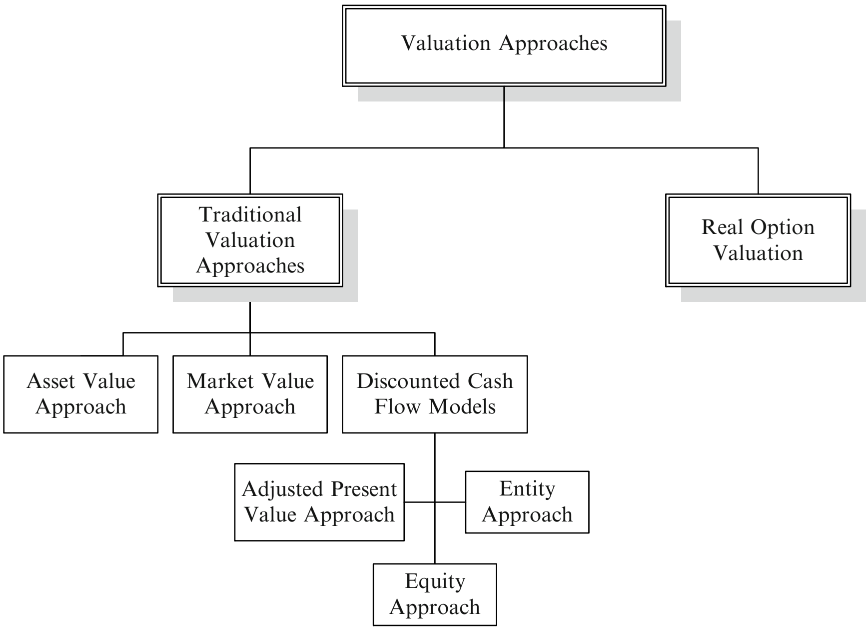

Fig. 2.1 Overview of relevant Valuation Approaches
Source: Author

Copeland et al. 1996; Ross et al. 1996; Brealey and Myers 1996; Koller et al. 2005). But due to the specific market characteristics only a few approaches are suitable for valuations in software markets. Figure 2.1 summarizes the most relevant models.

2.2.1 Asset Value Approach

The *asset value approach* states that the value of a company is equal to the sum of its assets valued from the perspective of either a going-concern or liquidation. If the going-concern of the company is assumed, the value of the company is equal to the sum of all operating assets plus the proceedings of all non-operating assets net of liabilities. In contrast, the liquidation value is the sum of all sales prices minus the liabilities and liquidation costs (Damodaran 1996). It is frequently used in a comparison with other valuations as it represents the minimum value of a company.

2.2.2 Market Value Approach

According to the *market value approach*, the values of assets and companies are derived based on proxies valued in financial markets (Born 1995). As there are a variety of proxies, the Similar Public Company Method (Gooch and Grabowski 1976), the Recent Acquisition Method, and the Initial Public Offering Method are each distinguished from one another (Bateman 1971). The respective multiples and ratios of traded companies are calculated based on accounting data, e.g. turnover or EBITDA margin, and allow a quick intra-industrial benchmarking analysis. All methods assume efficient capital markets and the Law of one Price which states that comparable assets are supposed to have the same prices as arbitrage would be otherwise possible (Fama 1970). Thereby, risk is implicitly treated as the risk premium is contained in the multiples of the proxy and frequently adjusted with an additional risk premium or an investment specific discount. In practice, market value approaches are very popular. Empirical studies comparing the popularity of valuation tools reveal that in nearly 73% of all international financial transactions marked based approaches are applied, second only to Discounted Cash Flow models which have a predominant role in valuation with a popularity of 95% (Peemöller and Kunowski 2002). Nevertheless, the approaches do not provide a true and fair view as the approach does not adequately incorporate the idiosyncratic risk profile of the valuation target.

2.2.3 Discounted Cash Flow Models

The *Discounted Cash Flow* (DCF) paradigm is the most popular instrument for estimating the value of both projects and of companies. It states that the respective value is the cumulated present value of expected predicted cash flows and a normalized terminal cash flow discounted by a respective risk-adjusted discount rate (Brealey and Myers 1996; Koller et al. 2005). In this concept the risk-adjusted discount factor represents the cost of capital which can be derived by capital market models such as the *Capital Asset Pricing Model* (CAPM) or the *Arbitrage Pricing Model* (APM).[3] Another critical aspect of the DCF is the calculation of the terminal value as it can account for more than 80% of the total corporate value and is even higher for software companies (Brealey and Myers 1996). Literature provides a variety of approaches for valuing the terminal value, such as the Gordon Growth model, the Multi-Stage Growth model or the convergence model (Ross et al. 1996). In essence, the approaches assume that the terminal value can be derived by a perpetuity growth rate, which is frequently approximated by an industry average (Gordon 1959; Koller et al. 2005). The various DCF approaches can be distinguished into Entity-, Equity-,

[3] The opportunity costs of capital are the sum of interest for equity and debt financing. The most influential cost of capital concepts are the CAPM and the APM (Sharpe 1964; Lintner 1965; Mossin 1966; Ross 1977). While the original model was published as Arbitrage Pricing Theory with a focus on securities, in the following the broader term Arbitrage Pricing Model is used which also comprises publications on the pricing of derivatives. Please consider (Ross et al. 1996) for further information.

and Adjusted Present Value approach based on varying assumptions with respect to the cash flows, the capital structure, and the underlying taxation system.[4]

2.2.3.1 Entity Value Approach

In the first step of the entity approach, the total enterprise value is computed based on an all equity financing fiction, before the value of debt is deducted in order to determine the residual value of the equity. The total enterprise value V is equal to the sum of all gross cash flows discounted by the *Weighted Average Cost of Capital* (WACC), such that

$$V = \sum_{t=1}^{T} \frac{E(CF_t)}{(1 + WACC)^t}, \tag{2.1}$$

with the investment time horizon T and the cash flows CF_t at time t (Copeland et al. 1996; Koller et al. 2005). In order to derive the equity value EV, the market value of interest bearing net debt DV is deducted

$$EV = \sum_{t=1}^{T} \frac{E(CF_t)}{(1 + WACC)^t} - DV. \tag{2.2}$$

The additional value of a tax shield is reflected by the term 1− corporate tax rate s in the calculation of the WACC, which is defined as

$$WACC = E(R_D)(1 - s)\frac{D}{E + D} + E(R_E)\frac{E}{E + D}, \tag{2.3}$$

where expected returns of the equity and debt market $E(R_D)$ and $E(R_E)$ have to be derived by the CAPM or the APM. The computation of the WACC implies a circular problem as the determination of the WACC requires the enterprise value ($V = E + D$) which, in turn, should be determined with the help of the WACC. This circular problem can be resolved by assuming a target capital structure or iterating the capital structure (Ross et al. 1996).

2.2.3.2 Equity Value Approach

The equity value approach directly determines the net value of the equity (Ross et al. 1996; Koller et al. 2005). Net cash flows are the financial flows to the shareholders that can be withdrawn from the company. Accordingly, the present value is calculated by discounting available cash flows to the holders of equity capital,

[4] Please consider (Brealey and Myers 1996) for further details on DCF models.

after allowing for cost of servicing debt capital. Formally, the equity value of the company is

$$V_E = \sum_{t=1}^{T} \frac{E(CF_t^E)}{(1+r)^t}, \tag{2.4}$$

with the company value V_E, the time horizon T, and the opportunity costs of capital r. The cash flows CF_t^E at time t are defined as

$$(E_t - A_t) - ((E_t - A_t - r_{FK} \cdot FK_{t-1}) \cdot s - r_{FK} \cdot FK_{t-1}) - (FK_{t-1} - FK_t) - C_t, \tag{2.5}$$

with E_t as inflows and A_t as outflows at time t, C_t as capital expenditures, FK_t as the market value of debt at time t, with r_{FK} as the cost of debt and s as the corporate tax rate. The cost of equity can be determined, e.g. with the help of the CAPM as $r_{EK} = r_f + [E(r_m) - r_f] \cdot \beta$, with $E[r_m]$ as the expected return of the market portfolio, the risk free rate r_f and the beta factor β.

2.2.3.3 Adjusted Present Value Approach

A third DCF approach is the *Adjusted Present Value* (APV) model, in which the value of the company is deconstructed into several elements driven by the purpose of isolating the value of the tax shield. First, it is determined which cash flows of the company can be withdrawn based on full equity financing and discounted at the equity financing costs in order to determine the operative value of an unlevered company. In the final step, the tax benefits resulting from the tax shield are added and the respective adjusted present value is derived (Ross et al. 1996).

2.3 Real Option Valuation

Software companies operate in a dynamic and competitive environment with a high exposure to uncertainty.[5] In such situations real options provide their owner in analogy to financial options with the right to exchange the cash flow of an underlying against the value of an exercise price (Koller et al. 2005). In other words, there exist additional operative or strategic flexibilities to pursue profitable opportunities which increase the value of an investment project or of a company. Such asymmetrical payoff structures, resulting from managerial flexibilities, can be interpreted as valuable real options. Further examples of real options derive from flexibilities to defer, to change or to terminate an investment (Trigeorgis 1996).[6]

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[5] Please confer Sect. 3.3.

[6] Please confer Sect. 2.3.3 for a typology of real options.

2.3.1 Option-Pricing Theory

Real option valuation (ROV) stands on the shoulders of the *Option Pricing Theory* (OPT).[7] Accordingly, an option is defined as a financial contract that provides its owner with the right but not the obligation to exchange an asset or a financial contract against another at a given price at the expiration date (Black and Scholes 1973; Margrabe 1978; Fischer 1978; Stulz 1982).[8] All options share three essential features, namely

1. flexibility,
2. uncertainty, and
3. irreversibility.[9]

If the prerequisites are fulfilled, the option pricing theory can be applied in order to value a spectrum of options, ranging from simple plain vanilla options to more complex options, such as compound options, options with a stochastic underlying, with a stochastic exercise price, with different exercise times, or with varying convenience yields (Hull 1989). All types of options have in common that the pricing is based on risk neutral valuation by assuming a perfect and arbitrage-free financial market in which a replicating portfolio of traded securities is constructed in order to mimic the payoffs of the option (Ross 1977). Cash flows are discounted by a certainty-equivalent growth rate representing a risk premium that would be appropriate in a market risk-neutral equilibrium in order to transform the expected cash flows with equivalent martingale measures into objective probabilities. The *Law of One Price* and *dynamic tracking* allow one to assume that the value of an option is equal to the value of the twin portfolio as there would otherwise be arbitrage opportunities (Merton 1976). Hence, the goal is to replicate the cash flows of the investment by a portfolio of twin-securities with returns perfectly correlated to the underlying.[10] In perfect capital markets a synthetic hedge can be designed by combining the twin securities and risk-free bonds such that the fixed final pay-offs of the correlated security and the cash flows discounted at the risk-free rate match the value of the option (Trigeorgis 1996; Koller et al. 2005). In other words, if investments have the same payoffs, they are supposed to have the same prices. Consequently, the value of the option can be determined by replicating the investment and value the replication, based on the assumption that in perfect capital markets any arbitrage opportunity would result in a revaluation of the asset or the derivative.

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[7] Please confer (Wilmott et al. 1995) for an extensive overview on option pricing theory.

[8] More generally, the option embeds the right to purchase or to sell an underlying at a predetermined exercise price on (European) or before (American) a predetermined date. Values of options can stem from two different sources, the *intrinsic value*, which is equal to the price differential between the underlying and the exercise price, and from the *time value* until expiration (Myers 1977).

[9] Please confer (Hull 1989; Trigeorgis 1996; Neftci 1996) for further information.

[10] The portfolio is also called tracking portfolio (Amram and Kulatilaka 2000).

2.3.2 Real Options Analogy

Software companies operate in a risky and competitive environment. They exhibit an asymmetric payoff structure due to managerial flexibilities, which can be interpreted in an analogy to financial options as real options (Myers 1977). Accordingly the equity holders are considered to own options on the total asset value less the current debt burden. Thereby, the real options quantify the additional operative or strategic flexibilities that increase the value of an investment project or a company, such as flexibilities to defer, to change or to terminate investments (Trigeorgis 1996; Koller et al. 2005).[11] While the approach was originally designed to value single real options corresponding with single investment projects, it can be extend to aggregated company valuation by interpreting the company as a portfolio of options.[12] With respect to valuation in software markets real options allow managers and financiers to capture the value of customer networks in software markets as growth options if the required option parameters are available. Accordingly, a call option on the cash flows of the company is purchased for a relatively small investment into the customer network of software companies, which can be obtained once the customer network reaches a critical mass. In other words, the overall value is decomposed in a risk-less and a risky component. While the passive component can frequently be determined with a static DCF calculation, the optional value of the growth option is determined by a real option valuation which can comprise one or multiple interacting options. In sum, the overall value is given by

$$V_U = V_S + V_D, \tag{2.6}$$

with a static value V_S and a dynamic value V_D. Although some simplifying assumptions may be required in order to derive the parameters for the valuation, the additional investigations of the managerial flexibilities based on ROV can significantly increase the quality of the valuation. This is particularly relevant if the investment is subject to high managerial flexibilities and a high degree of uncertainty. Both conditions are frequently met in software markets.

2.3.3 Typology of Real Options

Within the field of research there are a variety of classifications for real options (Trigeorgis 1996, p. 2f) (Lander and Pinches 1998, p. 540). The most suitable typology for valuation in software markets is based on the varying flexibilities of the respective underlying (Hommel and Pritsch 1999, p. 125).

[11] Please note that the value of a real option is zero once it is exercised, but it can not have a negative value as it is a right and not a binding obligation (Hommel and Müller 1999).

[12] Please note the interdependency of multiple real options.

1. *Deferral Options*. *Deferral options* are options on cash flows in exchange for the initial investment providing a flexibility to extend the deadline. Therefore, they are also coined *options to wait*. As far as the modeling is concerned, the option to wait can be interpreted as a call option on future cash flows in exchange for an adequate option premium.
2. *Liquidation Options*. *Liquidation Options* are put options that allow one to terminate an investment earlier than initially expected. It is also termed *option to abandon* or *exit option*.
3. *Shut-Down Options*. *Shut-down options* allow one to interrupt the production for a certain time. They are also called *options to shut down and restart*.
4. *Continuation Options*. *Continuation options* results from the multiple stages of an investment financing. This class of options is also labeled *options to stage investments*, which can be modeled as a compound option.
5. *Scale-Up and Scale-Down Options*. *Scale-up and scale-down options* provide the owner with the right to extend or contract the production if market conditions require an adjustment of the production volume. They are also termed *options to expand or to contract* business.
6. *Switching Options*. *Switching options* contain the flexibility to choose between various input factors and are also termed *exchange options*.
7. *Innovation Options*. *Innovation options* provide the flexibility to choose between various production processes. They enable owners to benefit from follow-up projects and have the payoff profile of a *compound option*.

The outlined options can be grouped into the following three clusters (Fig. 2.2).

(a) *Learning Options*. These options provide their owner with the flexibility to delay an investment until more information is accessible. The delay is particularly valuable if large irreversible investments are investigated. Examples are the option to wait and the option to stage the investment.
(b) *Growth Options*. Growth options are the second class of options that allow their owner to benefit the scale of operations under positive environmental conditions. Examples are the options to innovate and the options to expand as they allow the exploitation of further growth potentials. This class of options is frequently the most valuable type of real option in the valuation of turnarounds.
(c) *Insurance Options*. Insurance options comprise options to alter scale, switching options, options to abandon investment and the option to stage an investment. These options allow a reaction to unfavorable market developments. They allow one to reduce the downside risk and the overall volatility of the project.

Besides the functional distinction, other characteristics to classify options are their interdependencies and their time horizon. Independent options are valued on a stand-alone basis, while *compound options* are interdependent (Geske 1978).

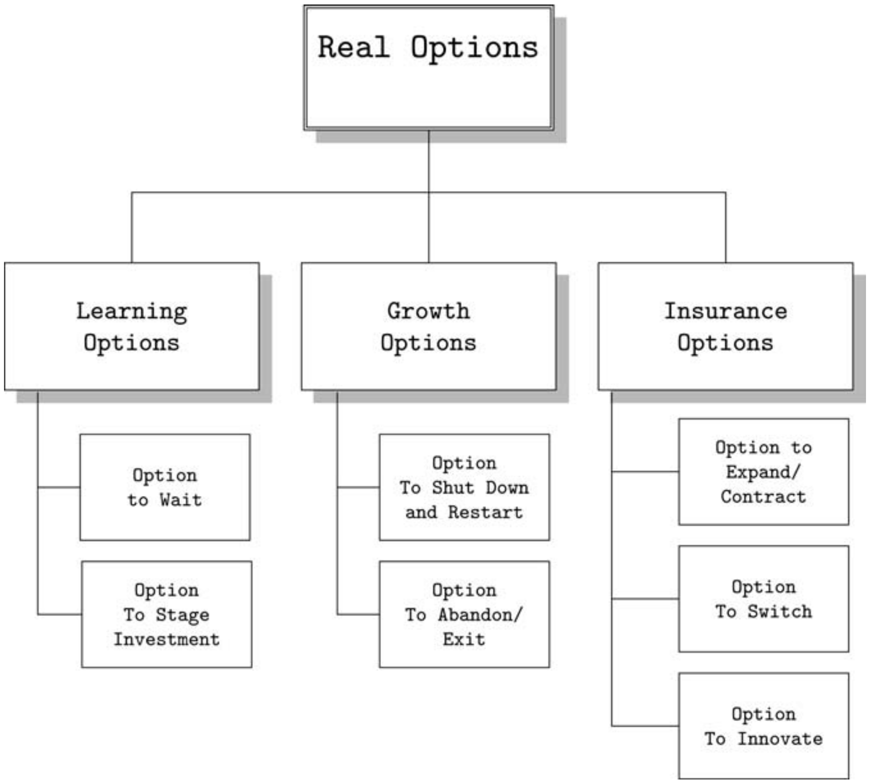

Fig. 2.2 Real Option Typology
Source: (Hommel 1999)

2.3.4 Real Options Management Process

While there are various frameworks for structuring Real Option valuation, the integrated Real Options Management Process of (Hommel 1999) consists of three interdependent steps which are depicted in Fig. 2.3 (Hommel 1999).

1. *Identify Real Options*. In the first step, the relevant sources of uncertainty and respective flexibilities have to be identified. At the same time it is important to consider the limitations of the option analogy in order to determine the scale and scope of the valuation model.
2. *Valuation of Real Options*. After the identification it is necessary to quantify and to value options and their interactions. Therefore, a suitable option valuation approach has to be identified before the respective parameters of the approach are derived. If multiple real options are involved, the interaction of real options has to be considered. Later it is necessary to assure the rationality of the valuation, which can be achieved by stress testing the underlying assumptions.

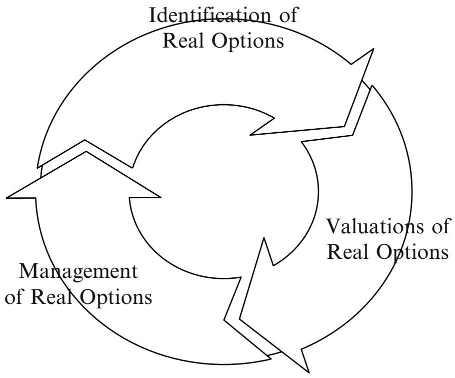

Fig. 2.3 Real Options Management Process
Source: (Hommel 1999)

The resulting alternatives have to be compared in order to determine the most promising strategy.

3. *Management of Real Options*. Once the options are valued, management should implement strategies that increase the overall value of the company. This can be achieved by integrating option pricing strategies into strategic management. Identified real options have to be tracked. But at the same time it is important to continue the identification process of new Real Options. Proactive management of Real Options should be pursued by influencing the value drivers of real options in order to gradually increase the value of the identified options.

Alternatively, Cropland suggests a four-step process model that could be adjusted to valuation in software markets (Copeland et al. 1996, p. 417). While the first two phases have a preparatory character, the last two comprise the quantification. On a finer level of detail, the interdependent phases can be described as follows.

1. *Design of a DCF Model*. In the first phase of the model the competition, the price and other market parameters are investigated in order to assess the overall importance of relevant real options.
2. *Risk Assessment*. The base case of the DCF valuation is evaluated with respect to the main sources of uncertainty such as inside technological or outside economic risks and the respective managerial flexibilities. In this context major decisions and milestones have to be identified, which can be supported by the outlined classification scheme of relevant Real Options.[13] Once the options are identified, their development of multiple options can be modeled based on event-based decision trees, while single options can be represented by simple time-line graphs (Copeland and Antikarov 2001, p. 418).

[13] Please confer Sect. 2.3.3.

3. *Simulation Phase*. After a determination of the options, they have to be quantified, which can be achieved by either analytical or numerical approaches.[14] Therefore, the gross value of the company is determined for various points in time with respect to the identified uncertainties and decisions, while interactions of options are ignored. At the same time, competition can be incorporated into the model by adjusting the dividends.
4. *Interactions among Real Options*. In the final phase, the interactions among real options are considered. The can have nonlinear sequential or simultaneous impacts on each other that have to be taken into consideration.[15]

Although this process model contains important issues that are relevant to valuations in software markets, some adjustments are required in order to account for the industry specific characteristics, which will be investigated in the subsequent chapter on modern software markets.[16]

2.3.5 Real Options in Practice

Empirical studies investigating the preference of practitioners with respect to investment valuation tools revealed that both the acceptance of financial instruments is different in various countries, and that for a variety of reasons it always requires some time (Peemoeller et al. 1994; Trigeorgis 1996; Copeland et al. 1996; Leslie and Michaels 1997; Koch 2000). While the Internal Rate of Return was the predominant valuation tool in Germany during the 1970s, in the 1980s, the DCF approaches reached a similar popularity. Research indicates that real options have become increasingly important, but remain a complementary tool to the traditional valuation tool kit. Driven by the interest to explain high valuations despite negative cash flows, research on Real Options experienced a boost during the years of the Internet-hype. But this interest diminished after the stock market crash. Nevertheless, real options analysis is applied nowadays in several industries, such as construction, resource intensive industries, biotechnology companies, media companies and strategic consultancies. Empirical research on the popularity of valuation approaches illustrates that the importance of valuation instruments increased over time, and most studies find a low but increasing percentage of advanced valuation techniques (Ho and Pike 1991).

Investigations concerning the quality of the Market Value and the DCF approaches come to contradictory findings, as a comparison of the valuation results with the respective stock price reveals that frequently very rigid assumptions diminish the explanatory potential of valuation models (Copeland et al. 1996; Damodaran 2001).

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[14] Please confer Chap. 4 for further reference.

[15] Please confer the sensitivity analysis in Sect. 8.5 for details on possibilities to account for such interdependencies.

[16] Please confer Chap. 3.

The oversight of real options is a reasonable explanation for this low performance. An analysis of German NEMAX 50 companies compared a passive DCF value with the stock price and found that only 16% of the value was explained by the DCF values, while the residual 84% were attributed to options (Rohjahn and Berner 2002). In a similar study, a passive DCF value accounts for only 6% of the overall value while the residual optional value is 94% (Stemmann and Treptow 2001). Despite the great importance of optional values, a survey reveals that 84% of the interviewed companies do not apply real options, while 8% do not even see a necessity for a real option valuation as they are convinced that intuitive risk adjustments, decision-tree analyses, etc. are sufficient tools. (Vollrath 2001) The low popularity is confirmed by an additional study, stating that at that time only 22% of the German DAX, NEMAX and consulting companies explored real option valuation (Peemöller et al. 2002). The main reasons for this low popularity are the complexity of the approach, lack of experience with more complex approaches, and nearly a third of the interviewed managers are convinced that other valuation tools lead to similar results. Therefore, despite the aforementioned contributions, it is very unlikely that the real options approach will replace the predominant DCF approach in the near future. It will allow rather a complementary quantification of managerial flexibilities, as the subsequent discussion illustrates.

2.3.6 Reconsideration of Real Options

Real option approaches relax some of the limitations of traditional approaches, as they allow one to analyze investment decisions under uncertainty, and account for managerial flexibilities (Trigeorgis 1996). A central advantage is that neither subjective biased probabilities nor subjective risk preferences are required. Instead, values are derived from the quasi-objective capital market based on the risk-neutral valuation principle. Therefore, some researchers consider real options to be the new standard valuation tool in corporate finance, while other financial researchers are not convinced that real options are suitable to value real world flexibilities as they are constrained by the following six most relevant limitations (Kester 1984; Schluechtermann 1996; Kruschwitz 2005).

1. *Intuition*. The Real Option Approach is not very intuitive as it requires knowledge of option theory. But as derivatives are part of many courses in modern management education, the popularity of the option pricing theory is likely to increase over time.
2. *Competition and Competitive Interactions*. Competition can dilute the value of real options. While all financial options are proprietary to their owners, as they guarantee an exclusive right, not all real options are proprietary. Some real options can contain legal rights, such as patents etc., while other types of real options are collective property, such as first mover advantage growth options. Such options are shared by all competitors and are difficult to protect, which can imply a dilution of their values.

3. *Illiquidity and Transaction Costs*. Financial options are fungible. They are traded in efficient financial market at minimal transaction costs, whereas real options are rather illiquid. Particularly real world capital budgeting projects are not traded continuously. Therefore, is doubtedful if a replicating portfolio can be constructed. Alternative proxies have to be used which are effected by tracking errors. In addition, real options depend frequently on other options or assets. Such a collective portfolio is even less fungible as it requires to align the interest of multiple owners.
4. *Strategic Interactions*. The value of financial options vitally depends on the value of the underlying. Similarly, the value of simple real options depends on the development of their underlying, while the value of more complex real options can interact with other flexibilities, such as further discretionary investment opportunities. Such options provide options on options, which are also termed *compound options*. They are more complex to evaluate as multiple options are non-additive, the complexity of the approach increases with an increasing number of relevant options, whereas the marginal contributions of additional options are still positive but decreasing (Schwartz and Moon 2000). Since six real options frequently cover over 90% of the total optional value, the focus should be on the six most important sources of flexibility and uncertainty (Trigeorgis 1996).
5. *Computational Complexity and Information Requirements*. Depending on the implemented Option Pricing Model, the computational requirements of the real options approach are more challenging than those of other approaches. It is possible to observe that over time the computational capacities of standard computers steadily increase. Therefore, it is becoming increasingly easier to implement even challenging option pricing models with home computers. But the implementation of a real options approach always requires a variety of detailed data which is frequently unavailable.
6. *Standard Stochastic Processes*. Empirical studies testing the Moon and Schwartz model come to opposing conclusions with respect to the precision of the utilized standard stochastic processes. While Schwartz and Moon test the model in a clinical study and reach a positive conclusion, other researchers come to different conclusions. Accordingly, empirical results reveal that the Schwartz and Moon model is an important research contribution but should be improved in order to reach a higher reliability (Keiber et al. 2002).

Some of the outlined restrictions can be resolved by advanced valuation models. But such advanced models cause a dilemma between their accuracy and the respective costs (Meise 1998; Hommel and Müller 1999; Kühn et al. 2000). As the quality of input parameters determines the quality of the analysis, prohibitive information costs can prevent the application of the real options approach. In turn, it is possible that the incremental gain of information outweighs the required additional effort. Based on the insight that the Real Options approach has the potential to contribute to valuations in software markets, the following research is dedicated to identifying implementation barriers and room for improvement for valuation in software markets. For this reason, the background of software markets is studied on a finer level of detail in the subsequent chapter.

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