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New Perspectives of Real Options Theory for Policy Analysis

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Executive summary

Should a municipality invest now (or should it wait) with investing in broadband networks at a time when demand is highly uncertain? Should public subsidies further support wind energy even if these technologies might generate real benefits only in a few years when energy prices go up? How can policy makers include possible (higher valued) expansion options in the evaluation of project proposals? Real options analysis provides answers to this kind of questions as it tries to conceptualize uncertainty in particular volatile market, technological or industry environment. In these environments, static Net Present Value (NPV) calculations are limited as they do not include the option to wait with investment decisions and learn until changes in the environment are more (or less) favourable.

Based on the dynamic view provided by real options theory, policy makers can include the option to wait with an investment (until the NPV is higher than the option to wait). In using the tools and methods provided by stock option models, real options theory proposes that decision makers can "buy" an option to invest in the future and, at the same time, are able to observe and to learn about the dynamics in dynamic markets and industries. In contrast to managers, however, policy makers should combine the real options analysis with an examination of the particular form of market failure that coexist together with uncertainty and irreversibility in these markets and industries. In a public policy context, real options analysis commences with an in-depth qualitative examination of the policy problem (studying the particular form of market failure) followed by static NPV calculations. Afterwards, the framing of the real options problem should pave the way for real options modeling and analysis.

The focus in this report has been on applying the heuristics of real options theory to some 'real life' situations. In the case of municipal telecommunication networks, we were looking an application of the "option to wait" and concluded that this option will enable local municipalities to avoid the drawbacks of a negative NPV. The option to wait in the case of municipal networks allows to re-evaluate new investment decisions at each stage of expansion of the network depending on the demand for new telecommunication services. In the case of wind energy technologies, we further discussed the utilization of a "compound option", which enables decision makers to postpone the important (future) investment decision and start on a smaller scale with an initial investment than can be extended at a later stage (when technical and market uncertainty has been resolved). In the case of FES subsidies, we applied the "option to expand" which allows to select between a number of different competing projects on the basis of the future growth potential and initial investment at an early (test) stage. Given that the concept is working, additional investment can be allocated. Building on this heuristics more advanced real options models can be developed that are multi-stage (not just single period investment) and therefore have to include option valuation lattices.

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1. Introduction

1.1 Background and Current Discussion

In the current volatile and highly uncertain environment characterized by rapid technological change, continuously shifting demand and market conditions, public policy makers feel increasingly the need to reconsider traditional instruments to evaluate investment decisions. In the European context, the discussion over these instruments has been embedded in a European-wide drive towards realizing the objectives of the Lisbon Agenda, on the one hand, and, a stronger need for the policy makers to operate close to market conditions. As the Lisbon Agenda has been aimed at stimulating investment decisions that foster the growth of new innovative technologies and services and facilitate structural change in the European economy, these decisions have frequently been investigated as to whether or not they are in line with Treaty Provisions on State Aid (Articles 87 to 89). Another parallel drive on the European level has been the move to open up different (formerly closed) markets to competition (in particular Article 86). As these movements on the EU level carry the promise of more competition, more consumer choice, lower prices as well as new products and services, the role of government intervention has to be reconsidered. Policy analysis based on the utilization of the right instruments to evaluate investment decisions have been central in this context.

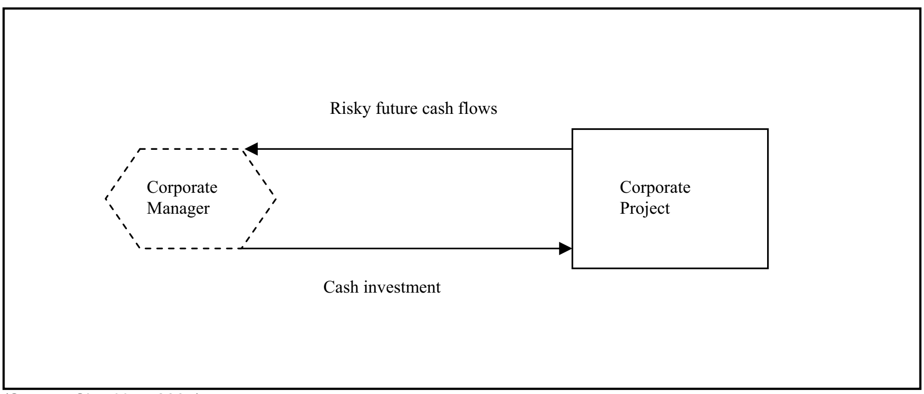
Policy analysis is about detecting some sort of market failure and finding solutions to correct for them. As markets fail, firms do not maximize social welfare but generate (only) private gains for themselves. In other words, these situations are not beneficial for the society as a whole and public intervention seems warranted. As the case for government intervention due to market failure has been well established in a static context, examining different forms of market failure in a dynamic context and establishing solutions for them has just recently been started (Link & Scott, 2001). As there are a variety of forms to correct for insufficient private investment incentives ranging from governmental subsidies to regulation, providing incentives for investment in new technologies and services has shown to require a dynamic and evolutionary approach towards market failure and market inefficiencies (Metcalfe, 1995). To examine market failures, the common denominator in conventional economic approaches has been to use some form of discounted cash flow (DCF) analysis to calculate the net present value (NPV) of investment projects. However, under conditions of high uncertainty with respect to demand, market and technological conditions, NPV calculations might provide the wrong results to decision makers.

What net present value calculations actually do (if estimated correctly), they provide decision makers with a comparison between the investment opportunity, on the one hand, and the investor's similar-risk opportunity in the financial markets, on the other hand. If the NPV is positive, a higher rate of return than a similar-risk financial market portfolio is expected. The present value of the project is actually the financial market value of the project. In order to approximate the financial market value of a project, discounted cash flow analysis is usually applied. However, there is a difference between NPV calculations and using DCF (as one of many valuation tools). DCF methods work fine in environments that require to calculate a static NPV that means no flexibility and a all-or-nothing decision. However, if flexibility should be built into the model, DCF provides a poor estimation of the project's financial market value and the static NPV may provide the wrong recommendation.

1.2 Difference between Real Options and Cost Benefit Analysis

Standard books on policy analysis are drawing on classical cost-benefit analysis to evaluate investment decisions of policy makers (Brent, 1997, Cullis & Jones, 1998, Stockey & Zeckhauser, 1978). Prior to making these decisions, these approaches often use traditional discounted cash flow (DCF) analysis and the related internal rate of return (IRR) to define the return of investment (ROI) of an investment project, they make implicit assumptions that might not hold in reality. DCF analysis assumes, for example, that decision makers pursue a proposed investment strategy to completion and that they will passively allow the project to unfold in time. In traditional DCF analysis, the manager has to give up cash today in exchange for a risky stream of cash in the future (see Figure 1).

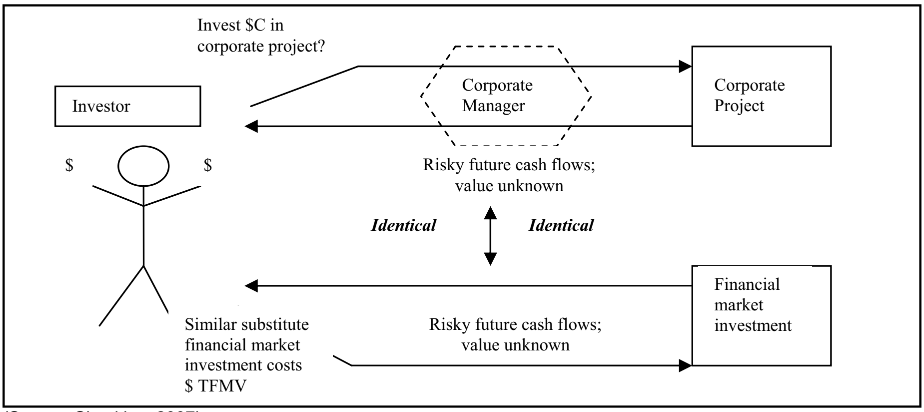
Figure 1: A traditional view on net present value (NPV) valuation



(Source: Shockley, 2007)

Real options theory uses the tools and methods provided by (financial) options theory to evaluate physical or real assets (in the "real" world) as opposed to examining financial assets or stocks and bonds (in the financial world only). With real options the decision maker has to be aware that its role is not only one as an intermediary between the investor and the total financial market value of the possible project but that he has to compete with a similar substitute portfolio provided by financial markets (*$ TFMV*). To calculate the this substitute financial market portfolio, decision maker can add up the total value of market prices of securities (like government bonds) by using different linear pricing models. Therefore risk-adjusted discounting becomes part of the analysis (Shockley, 2007)(see Figure 2).

Figure 2: NPV Valuation in Financial Markets as an Alternative



(Source: Shockley, 2007)

In contrast to the static NPV, the *true* project NPV differs as it includes the true financial market value of project's incremental cash flows (Shockley, 2007). In other words, the definition of a true project NPV is:

$$\text{True Project NPV} = \frac{\text{True market value of project's}}{\text{incremental future cash flows}} - \text{Capital investment required for the project}$$

Or in referring to Figure 2:

$$\text{True project NPV} = \$\text{TFMV} - \$\text{C}$$

For the investor the key question is whether the investment in the corporate project would be at lower costs (given that cash flows are identical) compared to the costs of the financial market substitute (Shockley, 2007). For the (policy) decision maker the key question is to intervene in the market at a time when the value of the real NPV is higher than that of a comparable financial market substitute. Therefore it is a not a once-and-for-all question with respect to an investment but it is more about the right timing of investment. Real options theory allows for the right timing in adding managerial flexibility to investment decisions.

1.3 Including Dynamics and the Right Timing of Investment

Based on a dynamic approach towards the calculation of NPV, the research question for the analysis has to be changed. As for traditional static NPV, such question could have been: How do DCF techniques enable us to determine whether or not to recommend investment in a project under conditions of future uncertain cash returns and substantial up front capital investment. In order to calculate a real NPV based on a dynamic approach, a different question needs to be asked like how does the option to wait (and to learn about future market, technology and demand uncertainty) influences our calculations about the NPV in a dynamic context. In asking this question, it becomes also clear that real options theory has to be considered as a complement to static NPV calculations. Furthermore, static NPV based on DCF techniques still works fine in a static context. However, in order to examine the potential of real options analysis, let's have a look at the different theoretical arguments and the general approach towards real options (see section 2); an application of the "option to wait" in the case of municipal investments in telecommunication networks (see section 3); the utilization of a "compound option" in the case of wind energy technologies (see section 4) and application of an "option to expand" in the case of regional development programs (based on FES subsidies) (see section 5). A short summary and an elaboration about the limitations of the study concludes the analysis (section 6).

2. Policy Analysis and Real Options Theory: Including Risks

2.1 Introduction

Simply the notion of uncertainty does not indicate the need for government policy intervention, i.e. if uncertainty makes firms less eager to invest government investment incentives are not *per se* necessary. There can be instances under which the social planner will receive information by just waiting and has to consider the opportunity cost of sinking resources into a project. Based on real options reasoning, a case for government invention arises only if firms face a different *value of waiting* than does society as a whole. In other words, policy intervention is justified only if some kind of market failure coexist in conjunction with uncertainty and irreversibility (Dixit & Pindyck, 1994). However, let's run through the different arguments in turn.

2.2 The Under-investment Problem and Risks

A general starting point for analyzing government incentives to invest in technological change has been Arrow's under-investment problem. In examining fundamental issues surrounding R&D decisions, Arrow (1962) proposes that a firm will be less likely to undertake an investment, if it is considered as risky, and the firm is unable to shift the risk (compared to a project that is considered as safe). Even if some of the risks can be spread given well-functioning capital markets and the underinvestment problem can be mitigated, short-termism might emerge as equity markets are more concerned with the short term performance of a company in terms of current dividends and earnings per share. This can hinder the long-term development of a company with respect to its investment policies (Arrow, 1962). Therefore a more principle concern for policy analysis is when do firms undervalue R&D investments, resulting in less R&D than the social optimum and in what kind of situations can real options theory provide solutions for this under-investment problem?

To calculate the net present value of a potential R&D project (Hirshleifer, 1958), managers compare the initial commitment of funds I_0 to R&D with the expected subsequent cash flows in each period X_t, starting in period k and continuing until T, discounted back to the present at an appropriate discount rate in each period r_t demonstrated in equation 1:

$$NPV = -I_0 + \sum_{t=k}^{T} \frac{E[X_t]}{(1+r_t)^t} \tag{1}$$

Government-backed incentive schemes can take different forms with subsidies and favorable tax treatments as the most obvious. The government can offer subsidies by choosing the allowable depreciation δ on the investment (for corporate taxes being t_c):

$$NPV = -I_0 + \sum_{t=k}^{T} \frac{E[X_t](1-t_c) + t_c \delta I_0}{(1+r_t)^t} \tag{2}$$

As can be seen from (1) and (2) the investment criterion is sensitive to the calculation of the discount rate. The correct discount rate is the opportunity costs of capital which is appropriate to the class of investment. Conventionally, the opportunity cost of capital is obtained from a model of asset pricing such as the capital asset pricing model (CAPM). For example, the discount rate relevant to a project i can be derived from CAPM is the risk free rate r_f plus a risk premium

$$r_i = r_f + \beta(r_m - r_f) \tag{3}$$

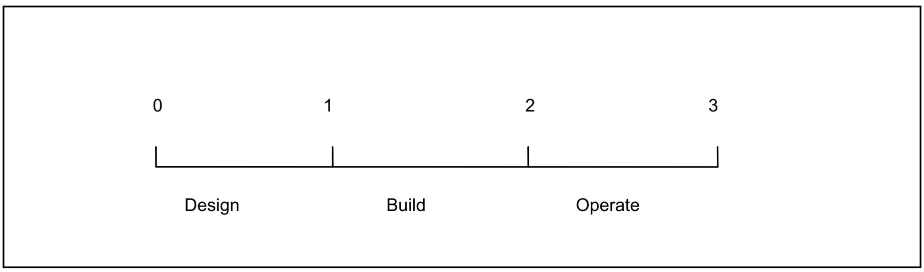
The risk premium is equal to the systematic risk of the asset β_i and the excess return over the market return r_m. The systematic risk are then mostly observed in other firms (Goodacre & Tonks, 1995).

In addition to conventional ways in which governments can provide subsidies (like a favorable tax treatment or financing parts of a project) (Metcalfe, 1995), there are also ways in which public institutions can share the risk of projects including public-private partnerships (PPP).

2.3 Public Private Partnerships (PPP) As Risk-Sharing Institutions

In order to share the risks of (mostly) large scale projects, public private partnerships (PPP) have been developed as a way to find a variety of private investors (e.g. banks and private companies) as well as involve public and semi-public institutions (e.g. local municipalities or woningbouwcorporaties) in these projects. The problem in these partnerships has been that the partners involved have different interests which will become apparent during the different phases of a project. The legal framework for PPP has been provided by the EU Directives in the area of Public Procurement 2004/18/EC and 2004/17/EC as well as different national case law in the area. An economic framework for evaluating the social costs and benefits during the different phases of a PPP has just recently been developed based on the idea that the contracts (for all parties involved) will be incomplete. That means due to uncertainty involved in PPP there is room for opportunism (and cheating) of different parties in the PPP (Hart, 2003). Conventionally two distinct phases of PPP development are distinguished: A phase to build and a phase to operate the project. For both phases the parties in the PPP have to set up different forms of (incomplete) contracts which might lead to overinvestment and loss of quality of service provision in the project (Hart, 2003). However, there is a third phase which precedes these two phases which is the design phase. Sometimes this phase is included in the building phase, but for public policy makers the design phase is de facto the initial planning phase for such project as the initial NPV of the project has to be calculated that can be used to justify such project in the first place. At a later stage, a NPV calculation can even include the benefits accruing from selling certain parts of the networks at the transition from building to the operating phase (see Figure 3).

Figure 3: Timeline and Phases in Public-Private Partnerships



To account for the market dynamics, an extension to these conventional (static) models has to made with respect to changing (e.g. market, technology or demand) conditions that can include flexibility of decision makers to go ahead or to stop projects depending on the expected returns during the different phases of a project.

2.4 The Advantages of Real Options Theory

Under traditional NPV analysis, including capital asset pricing models[1], the impact of risk is one-directional: risk is assumed to depress the value of the investment. By contrast, real options show that risk can be influenced through managerial flexibility, which becomes a central instrument for value creation.

1 There are also other methods of finding the relevant discount rate including the weighted average costs of capital (WACC), multifactor asset-pricing model (MAPT) or the arbitrage pricing theory (APT) which might be appropriate in a different context. However, they share disadvantages of underestimating the flexible value of a project, of considering outcomes of the analysis as being static and decisions taken as irreversible (for an extended discussion on these different approaches see (Mun, 2002)).

Under such circumstances, uncertainty may amplify the value of an investment opportunity (Micalizzi & Trigeorgis, 1999). Decision makers have the flexibility to respond to unexpected market and/or technological developments and constraints. Real options theory allows for flexibility in decision-making as decision makers have the right to invest, but not the (legal) obligation to exercise this option.

The role of real options analysis is to quantify how much future opportunities are worth today. It starts by recognizing that most project opportunities are composed of a series of managerial options: decisions to invest can be deferred, activities can be stopped temporarily or definitively, and inputs can be switched, and so on. By using option-pricing models, it becomes possible to quantify these opportunities and indicate when these options should be optimally exercised.

The assumption is that there are investment opportunities which represent an option as decisions about these opportunities can be deferred. A decision maker has therefore the choice between investing immediately or deferring the investment decision, i.e. there is time flexibility which has a value. In general, the decision maker has an option to invest, which can be exercised now or later, much like a financial option (see Box 1).

Box 1 Option Pricing Variables: Linking Stock Options to Investment Decisions

Call option on stock	=	Future investment decision as a real option
Current value of stock	=	Expected present value of future cash flow
Strike price	=	Expected investment cost
Time maturity	=	Life-time of the investment opportunity
Volatility	=	Project value returns' volatility
Dividend on stock	=	Cost of keeping the investment opportunity alive
Risk-free interest rate	=	Risk-adjusted interest rate

Source: (Botteron, 2001).

In financial terms, an American financial call option provides the investor with the right, but not the obligation, to buy an asset at a predetermined price at or before a specified date. This is the same for an investment if considered as a real asset, where decision makers have the right, but not the obligation, to exercise this investment option. Different real options that influence these decisions are shown in Table 1.

Table 1: Different Real options and their Description

Option	Description
Defer	To wait to determine if a "good" state-of-nature obtains
Abandon	To obtain salvage value or opportunity costs of the asset
Shutdown & restart	To wait for a "good" state-of-nature and re-enter
Time-to-build	To delay or default on project – a compound option
Contract	To reduce operations if state-of-nature is worse than expected
Switch	To use alternative technologies depending on input prices
Expand	To expand if state-of-nature is better than expected
Growth	To take advantage of future, interrelated opportunities

What difference does the real options approach make with respect to asking the "right" question about a particular investment project? Let's have a look at some examples for different research questions that can be asked compared to more traditional (static) NPV analysis (see Table 2).

Table 2: The "Right" Questions asked by Real Options Theory

Frequently Asked Questions Solved by Using Real Options	Flexibility Management	Strategy Valuation	Examples of Application
Have you considered the opportunity of deferring your investment decision? Is the Net Present Value (NPV) of your investment project higher than value of the option to defer it?	Time	Option to Wait	Any strategic investment, delocalization, land development, ENR project valuation, oil extraction
Have you considered the opportunity of switching the inputs or the outputs in your production system? Have you also considered that you could share your production between two sites so that yare arable to switch production as needed?	Switch output/input/location	Option to Switch	Products subject to changes in consumer taste, fashion effects, power plant valuation
Have you considered taking advantage of new opportunities afforded by a new technology, a new R&D project, a new location, or an acquisition?	Further developments	Option to Grow	Early investments in R&D projects, ENR, strategic acquisitions, multiple-generation product development, M&A
Have you chosen the right size for your new factory? Have you accounted for the opportunity of upgrading it? When should you upgrade it?	Upgrade	Option to Expand	Factory upgrade, extension of activities
Have you accounted for the fact that intangible assets have an option value? Have you considered their future opportunities?	Time combined with legal protection	Option to Develop	All R&D projects, start-ups, Internet applications, patents, licenses, brands, learning processes, etc.
Have you accounted for the value of reselling equipment or expertise, even if the project itself is abandoned? By incorporating staged-abandonment options to evaluate a multistage research program that could be abandoned at various points in its development, you can better assess and understand the value of your R&D projects at each stage of their development	Resell equipment / Knowledge	Option to Abandon	All R&D projects (particularly in capital-intensive industries)
Have you accounted for the fact that shutting your mine done temporarily when the mineral price falls adds value to your mining project?	Shut down temporarily	Option to Stop temporarily	Industries subject to fluctuations in input / output prices (particular ENR industries)
Have you accounted for the fact that exercising a real option can give birth to other real options?	Strategy process setting	Combinations of Options	Start-up ventures, deferring / accelerating / combining project stages in R&D projects

Source (Botteron, 2001).

2.5 Assumptions of Real Options Theory

Real options characterizes investment decisions as influenced by uncertainty, the provision of future managerial discretion to exercise this decision at the appropriate time, and irreversibility (Dixit & Pindyck, 1994, Kogut & Kulatilaka, 2001). With respect to understand the real options heuristics, as Kogut and Kulatilaka (2001) put it:

"An option has value only if there is uncertainty, though defining the relevant source of the uncertainty is not trivial. An operationally important element of design is the provision of discretion, such as the staging of an R&D project to correspond to discrete points of go-no go decisions."

Irreversibility, as a central assumption in real options thinking, refers to the inability to revisit an investment of decision without incurring costs as these costs are sunk (as they are industry and firm specific) (Dixit & Pindyck, 1994).

In traditional organizational theory, uncertainty has been considered as imposing a threat on the stability of the technical core of a particular organization. From a real options point of view, uncertainty provides organizations with opportunities to explore new capabilities and to successfully adapt to the evolution of the market environment (Kogut & Kulatilaka, 2001).

2.6 Current Discussion on Real Options Theory

As the theoretical literature on real options and industrial organization theory has been thoroughly been surveyed elsewhere (Boyer, Gravel, & Lasserre, 2004, Smit & Trigeorgis, 2004), here we will just present a short overview of main authors (see Table 3).

Table 3: Real Options Categories and Major Authors

Real option	Description	Specific application	References
Deferment or temporary suspension	Option to postpone the investment outlay or to temporarily suspend production while preserving the technical feasibility of the project	Natural resources and oil, real estate and vacant land, launch of a new product	(Ingersoll & Ross, 1992, McDonald & Siegel, 1986, Paddock, Siegel, & Smith, 1988, Trigeorgis, 1990)
Expansion	Option to expand the scale of the project by investing an additional amount of capital as exercise price	Launch of new products or new versions of the base product, targeting new market niches, entering new geographical markets, strategic alliances	(Kester, 1984, McDonald & Siegel, 1986, Trigeorgis, 1988)
Switching	Option to switch among alternative operating modes according to the relative fluctuation of some reference variables	Research and development. geographical diversification, global cost reduction strategies	(Kensinger & Martin, 1988, Kulatilaka & Marks, 1988, Kulatilaka & Trigeorgis, 1994, Margrabe, 1978)
Contraction and/or abandonment	Option to reduce the scale of the project, or to abandon it to realize its scrap value	Altering R&D process, withdrawing from a market niche, reducing the capital invested in a business unit	(Myers & Majd, 1990)

Source (Micalizzi & Trigeorgis, 1999)

As discussed earlier, with a static NPV analysis value is characterized as a single time-value discounted number which represents all future net profitability (Mun, 2002). However, there are a number of risks that influence the valuation of projects were decision makers do not have any influence but that effect on the profitability of NPV. There are principal areas of flexibility for decision makers that can be found by identifying and specifying real options. There are two main categories: First, real options that are determined by the characteristics of specific industrial sectors; and second, real options emerging at each development phase of a project, i.e. process-specific real options (Micalizzi & Trigeorgis, 1999).

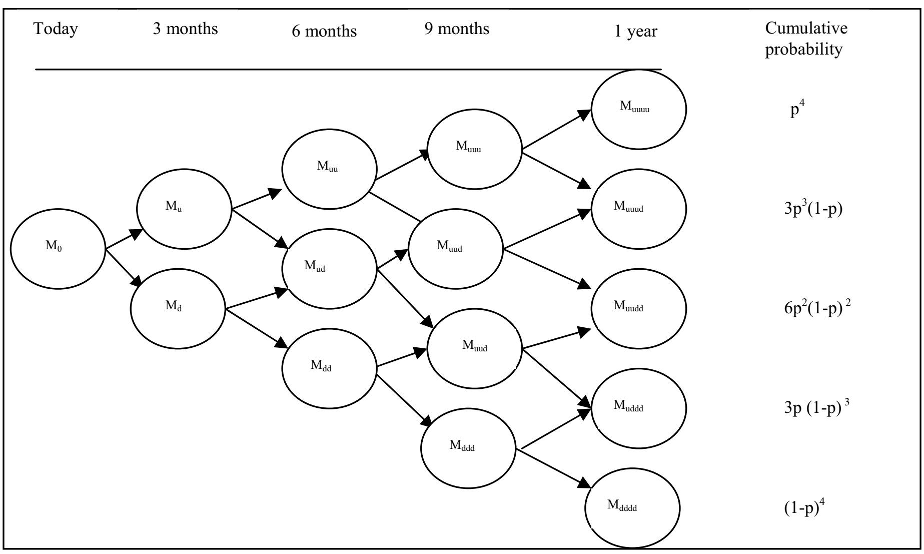
The first category of real options stems from the specific structural characteristics of a given industry. Examples of such options are the option to develop, which is crucial for the pharmaceutical industry, or the option to temporarily suspend, which may be relevant in certain mineral extraction industries. The second type of options arises from the particular product phase, which of course also depends on the industry sector. The option to abandon is usually present in the research and development phase of new products. Likewise, the option to expand commercially arises from the product launch phase of a new product or the penetration of a new market (Micalizzi & Trigeorgis, 1999).

2.7 Dynamics and Uncertainty: Stochastic Processes

In order to combine dynamics with uncertainty, real options models are based on stochastic processes, i.e. they include a variable that evolves over time in a way that is at least in part random. The nature and properties of these stochastic processes have to reflect the underlying dynamics of future cash flows. Commonly used approaches include closed-form equations like the Black-Scholes model and its modifications, Monte-Carlo path-dependent simulation methods, lattices (for example, binominal trees) and other methods (Mun, 2002).

Such binominal tree is drawn in Figure 4, it can be seen that the number of possible outcomes at the end of the game grows as steps (e.g. evaluation moments for projects) are added. Furthermore, and more importantly, with variations in the probability distribution the value of the asset from M_0 changes.

Figure 4: A Four-Period Binominal Model with Cumulative Probabilities



Source: (Shockley, 2007)

2.8 Real Options Criteria for Optimal Investment

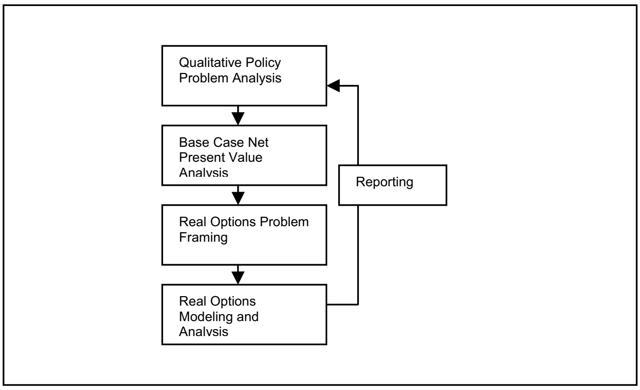
Real options theory proposes that the option value of waiting with investment increases with revenue uncertainty. Furthermore it is known that it is optimal to invest when the net present value exceeds the option value of waiting. However, there are a number of additional criteria for decision makers to consider in order to pursue investment in a competitive market context. For example, the strategic interactions between market parties are decisive in order to identify their investment strategies in case of demand uncertainty (Huisman & Kort, 1999) or technological uncertainty (Huisman & Kort, 2004). This has been the focus of a stream of literature aimed at combining real options theory with game theoretic approaches (Boyer, Gravel, & Lasserre, 2004, Smit & Trigeorgis, 2004). In their search for additional criteria for policy makers, Dixit and Pindyck (1994) propose that the dynamics and uncertainty are not by themselves sufficient conditions but that they in conjunction with market distortions or market failure call for government intervention. Until now, this literature has not been connected with discussions on cases for government investment in technological change related to market failure and market imperfections like knowledge diffusion, buyer surpluses, duplication of research, inefficient standardization, asymmetric information or economies of scale (van der Horst, Lejour, & Straathof, 2006). However, there are also other forms of market failure which emerge in dynamic markets (Link & Scott, 2001).

2.9 Summary: Steps in Performing Real Options Analysis

From the above it can be concluded that in contrast to existing approaches to the calculation of NPV within policy analysis, real options theory takes a dynamic perspective on the firm and the industry environment. With real option theory, policy makers can include the option to wait with an investment (until NPV is higher than the option to wait). Therefore they can “buy” an option to invest in the future and, at the same time, are able to observe and to learn about the dynamics in particular markets and industries. Furthermore, in cases in which firms are hesitant to invest in the face of ongoing uncertainty, the government should not necessarily act as a party to provide additional investment incentives. Policy intervention is justified only if some kind of market failure coexist in conjunction with uncertainty and irreversibility. From the real options lens, the timing of public investment becomes crucial. In a positive situation, the call option can be utilized and investment can be provided, in a negative situation, investment can be postponed. Public private partnerships can provide a solution to market failure emerging in dynamic markets.

Figure 5 shows a brief summary of the steps involved in a real options process: The cycle starts with a qualitative policy problem analysis, in which decisions have to be taken with respect to projects, initiatives or strategies that should be included in the analysis depending on particular political priorities, visions, missions, etc. An investigation into the particular form of market failure is part of the analysis. The second step involves a calculation of the (static) net present value for each project including sensitivity analysis. The third step is critical as it aimed at formulating the policy problem in the context of the real options paradigm. Here different strategic optionalities like the option to expand, contract, abandon or growth should have become apparent. At this point the analyst should choose from the list of options to analyze the problem in more detail.

Figure 5: Steps in the Real Options Process



The fourth step is to introduce uncertainty and value flexibility in the model based on assumptions about the probability distribution of the underlying values. Based on mapping a binominal tree in which the valuation of a risky assets includes two states (an “up” state and a “down” state), these probabilities can be visualized and with different stochastic methods forms (like Monte-Carlo simulation) calculated. The final step includes reporting the results of the analysis which feeds back into (another) cycle of real options analysis. However, let’s have a look at some practical applications in turn.

3 Case Study: Infrastructure Competition and FTTH Networks

3.1 Introduction

The implementation of municipal FTTH (Fibre-to-the-Home) network initiatives has been accompanied by a fierce public debate about whether (or not) local authorities should intervene in markets for broadband access. Despite high regulatory uncertainty, resistance by incumbent (cable and telecom) companies and market uncertainty, the development of FTTH networks has been fostered by different forms of municipal involvement. Regulatory uncertainty for these networks has been created as the European Commission still conditionally approves municipal FTTH networks on a case-by-case basis if they are in line with Treaty Provisions on State Aid (Articles 87 to 89). In the Netherlands, market parties accounting for the lion's share of broadband access have been incumbent operator KPN and the different regional cable operators. Other new access technologies such as glass fiber networks or wireless technologies currently contribute just a mere 0.1 percent to this market (EC, 2005). In contrast to these technologies, municipal FTTH networks belong to the next generation infrastructure. The distinction between "next generation" infrastructure and current generation of services provided by local cable television or telephone companies is crucial as these companies (still) offer broadband access at data rates that are typically significantly below 10Mbps and do not (generally) support triple play services. Market uncertainty is generated as these networks are able to provide triple-play services for which demand is highly uncertain and volatile.

Recently a number of initiatives of municipalities have emerged aimed at the implementation of new FTTH networks in different regions in the Netherlands. At a first glance, this seems surprising as the Netherlands is one of the leading countries with respect to internet penetration in the world (OECD, 2006). However, municipalities have argued that there is a role for municipalities in the implementation of these networks if incumbent market parties are not willing or not able to provide sufficient broadband capacity within their local communities. In the Netherlands as in other parts of Europe, a number of municipal initiatives have recently emerging which have partly been approved, partly been terminated due to European legislations.

In the Netherlands, a number of municipalities (e.g. Eindhoven, Den Haag Amsterdam) have taken the lead in implementing these networks. Compared to traditional cost-benefit analysis (CBA), real options theory provides guidelines in situations characterized by high uncertainty and volatility. It has been proposed that the option to postpone provides municipalities with a possibility not only to provide new emerging (triple-play) services but to pursue public policy objectives in the framework of wider (social) benefits to local communities (Sadowski, 2006). The question emerging is the extent to which a real options approach will provide a better approximation for the NPV valuation in contrast to a static NPV. Research has shown that municipalities value the cost and benefits of FTTH networks differently compared to private incumbent companies. In applying real options theory, the option to postpone changes the valuation of municipalities to invest in FTTH networks.

3.2 The Regulatory Framework and the Need to Act as a Market Party

On the level of the European Union, the legal and regulatory discussion has been focused on three different strands related to a) the diffusion of broadband infrastructure throughout Europe as part of the realizing the Lisbon Agenda of the EU, b) the overhaul of the current regulatory framework of the EU in the area of telecommunications and c) the application (and discussion) of current European competition law. Let's turn to some of the arguments within the discussion.

The European Commission uses as a justification for further investment in broadband infrastructure the lagging position of Europe in comparison with the United States and South Asian countries. Even if broadband has grown rapidly and the penetration rate reached in 2005 11.5 percent of the EU population (almost 53 million lines), up from 7.3 percent in 2004 within the European Union (EC, 2005), Europe is still lagging in the diffusion of broadband. Therefore broadband diffusion has been considered as a priority and within the objectives of the Lisbon Agenda. A justification for investing in municipal networks has been developed in particular in supporting less favored regions with new telecommunication infrastructure, but also in providing incentives for regions to develop and experiment with new services. However, these objective can conflict with other regulations within the European Union.

The New Regulatory Framework of 2003 does not directly address municipal networks of local communities, but refers to them in the context of markets that have transitional problems. With the overhaul of the EU regulatory framework starting in 1999 with the publication of the Communications Review by the European Commission, a discussion started aimed at redefining the balance between incentives to build new networks and to access existing ones. As a result, a package of directives was introduced that represent the New Regulatory Framework of the EU. Within this framework, the Directive (2002/19/EC) on Access and Interconnection was aimed at discussing the conditions under which regulatory intervention should occur in the presence of some form of market dominance. It also provided room for ex-ante regulation in markets (like for broadband access) that have "transitional problems" as a result of technological developments. These markets that were (expected to be) unable to generate effective competition and therefore subject to some sort of sector-specific regulation were further specified in European Commission's Recommendation on relevant product and service markets.[2]

Within competition law of the European Union, Article 87 of the EC Treaty characterizes relevant legislation for the municipal networks with respect to State Aid. Article 87 focuses on state subsidies that distort competition in the common market. As Article 87 is under discussion to provide 'less and better

2 (C(2003) 497)

aid' (Kroes), there are important repercussions for public intervention in broadband markets. Currently there are three options for public involvement in these markets: a) as an investor that invests similar to a private party ("market investor principle"); b) if the (local) government invests in the passive infrastructure and opens access up to all interested private parties on non-discriminatory terms and c) as the (local) government intends to deliver services as part of general economic interest (Hencsey, Reymond, Riedl, Sanatmato, & Westerhof, 2005). The Green Paper on Services of General Economic Interest (SGEI)[3] has been central in defining the balance between common service obligations and economic efficiency arguments with respect to investment in new telecommunication infrastructure. A number of local broadband initiatives by municipalities have recently been approved by the European Commission, however, only a few have been implemented as a compensation for a service of general economic interest. The different options provide new opportunities for public involvement in so-called "black areas", areas characterized by high demand that supports a competitive supply.[4]

3.3 Imperfect Access Markets and Demand for Triple Play Services

Demand for triple play services (voice, internet and television) has been uncertain and highly volatile even if has been touted as the next logical step in the development of the telecommunication network. However, there are currently a just a limited number of competing network technologies in local access markets that are able to provide triple play services (such as ADSL-2) offered by a limited number of market parties. Due to its characteristics, competition in this market can be described as imperfect (de Bijl & Peitz, 2002). Even if the growth in traditional network technologies (cable modems and xDSL) in the Netherlands has been rather high (OECD, 2006), investment in next generation networks (capable of providing triple play services) has been delayed due to the behavior of existing market parties (Sadowski, 2006).

Fiber optic cables (as part of Fiber-to-the-Home (FTTH) networks) are considered as a critical component in next generation infrastructure. Even if fiber optic cables are difficult and costly to install (compared to traditional network technologies), after installation they are long-lived. Local fiber facilities can provide very high transmission rates, even if they require high and largely fixed/sunk costs (Lehr, Sirbu, & Gillett, 2004). Due to these costs characteristics, existing market parties have been rather reluctant to invest in these new technologies, but instead gradually improved the offerings of their existing networks. However, there are not only insufficient incentives for market parties to invest in next generation networks, but these markets are also characterized by market failure. The form of market failure is that the

3 (COM(2003)270 final)

4 The Commission of the EU makes a distinction between 'black areas' with high demand supporting competitive supply, 'grey areas' in which the network is controlled by a single operator refusing access to its basic infrastructure and 'white areas' with no broadband provision at all.

investment behavior of existing market parties in particular technologies and the behavior of users of this technologies insufficiently match from the social welfare point of view (Link & Scott, 2001). In contrast to the CBP document *Do market failure hamper the perspective of broadband* (CPB, 2005), this form of market might appear in dynamic markets characterized by rapid changing demand and technological conditions.

3.4 Public-Private Partnerships (PPP) and Market Failure

In order to comply with European legislation and to act like a market party, municipalities have increasingly become involved in private-public partnerships (PPP) with the objective to develop municipal FTTH networks. There have been a variety of forms of PPP ranging from the bundling of demand for triple play services by private companies as well as semi-public and public organizations at particular locations (e.g. business parks) over separate infrastructure projects for private (e.g. city rings) to whole city-wide infrastructure projects for the public at large (Tapia, Stone, & Maitland, 2006). The common denominator in these projects has been that established private market parties would be hesitant to invest (i.e. would wait longer than socially desirable). In other words, there is a market failure of some form which can be corrected by setting up a PPP that even can stimulate competition in the market (Link & Scott, 2001).

An early example of such PPP has been the “Netwerk Exploitatie Maatschappij” (NEM) B.V. in Nuenen (which is part of the city of Eindhoven) which was set up in order to invest and operate an FTTH network in the municipality of Nuenen. Based on a subsidy of the Ministry of Economic Affairs (“Kenniswijk” subsidy) which amounted to € 800,= per connection per user, the residents of Nuenen (7445) put these subsidies together in a cooperative initiative (“Ons Net”). “Ons Net” became than part of the “Netwerk Exploitatie Maatschappij” (NEM) B.V. which initially also included “Helpt Elkander” (a residential housing corporation in Nuenen). NEM should not only be responsible for the design and building of the FTTH network (phase 1 and 2) but also for the operation of the network in phase 3. The order to implement the FTTH network was given to Volker Wessels Telecom, a telecommunication infrastructure construction firm. The interesting phenomenon happening in the case of the Nuenen FTTH network was that after the design and building phase, financial problems let to a situation in which Volker Wessels became part of the NEM through an investment company called Reggefiber (for an extended discussion of this case see (van Rijssel, 2006). Therefore it can be decisive for public policy makers involved in PPP to anticipate the different stages of a PPP and develop certain outcomes in cases the project does (not) achieve expected results.

In order to provide a dynamic view, the different phases of a PPP for municipal FTTH initiatives have to considered in conjunction and factors determining change in PPP. For municipal FTTH initiatives, an important factor has been how the demand for triple-play services might develop which further reduces market uncertainty for private parties. In the first phase of the

PPP, demand uncertainty is very high. In this phase, municipalities have to find private investors that would be able and interested in co-financing the project. At this phase the market would not provide by itself sufficient private finance to start up these projects as they were considered as being too risky. In this situation, municipalities were able to share the risks with private investors and could, in addition, bring together different semi-public and public organizations as members of a consortia that function as first users for these networks. As a result of this phase, the consortium would reduce the risk for private investors which is the pre-condition for phase two. During phase two, demand uncertainty will be further reduced as users increasingly opt for new triple play services. At this phase, market parties would consider private investment in these networks as acceptable and the operating of (parts of) the network as feasible. We have shown elsewhere (Sadowski, de Rooij, & Smits, 2006) until which levels of demand PPP consortia are necessary. What we intend to show here is how decision makers can already opt in the first (build) phase of the PPP for flexible solutions for investment in FTTH networks depending on the development of demand for triple play services. An interesting problem is how the transition from the build to the operate phase can be made depending on the development of demand. However, this question cannot be addressed here.

The question for (local) policy makers has been given highly uncertain and volatile demand for triple play services under what kind of circumstances should investment in building municipal FTTH networks be deferred and under what kind of circumstances is the NPV of the investment project higher than the option to defer it?

3.5 Static versus Real NPV of Municipal FTTH networks[5]

For municipal FTTH networks, there are a number of risks that influence the valuation of these projects over which decision makers do not have any or have only limited influence that affect these investments. With respect to common risks, decision makers are depending on developments in the market. After the contracts over the implementation of these networks are signed, there is limited space to correct for changes in markets for example for demand or the actions of existing market parties. Therefore there is a case for a dynamic approach towards the analysis of these variables.

During the time period of the investment project it can happen that the projected development of the variables provides a wrong picture of reality. The effect of these wrong assessment can be that the value of the NPV calculations will be incorrect. At this point, however, the capital investment in the project has been undertaken according to the static NPV. Trying to correct for these changing conditions will be difficult without consequences for the project as the costs of investment are sunk and irreversible (Dixit & Pindyck, 1994).

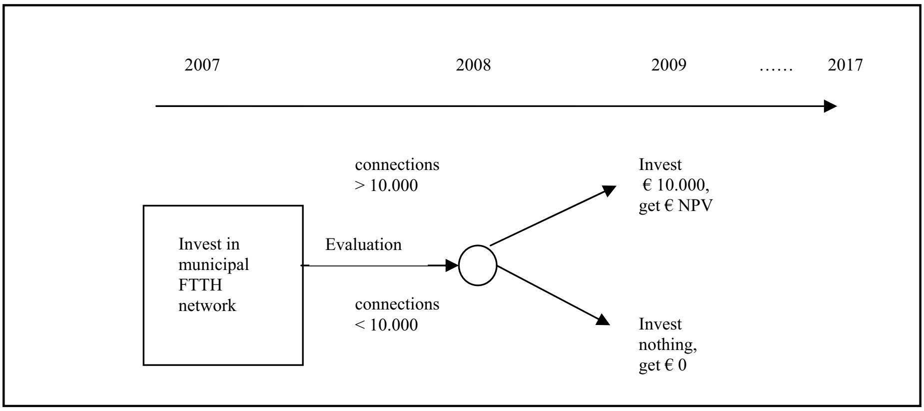
5 This part is mainly based on (Sadowski, van Rijssel, & Smits, 2006, van Rijssel, 2006).

Apart from possible losses due to a much lower NPV of the project as anticipated, there are other shortcomings. During the period of the project, there are possibilities that the investment performs better than expected. In such situation, there are no possibilities for the decision maker to change the course, i.e. to obtain a higher cash flow than anticipated. Therefore a static NPV with its build-in inflexibility and one-time design is in such situations far from ideal. For a decision maker it should be advisable that during the period of the investment the project can be changed depending on particular variables in the model. A positive development of a variable like the development of the demand for triple-play services can, for example, result in a higher NPV of the project. This could be a motive to set up the project on a larger scale with the objective to meet growing demand in the market for these services. Based on a negative scenario, the project can develop worse than initially expected. In such (alternative) situation, it would be worthwhile to correct for the negative effects of lower demand (than initially expected). However, this is just possible at a point when the project is already carried out and (based on a static NPV) cannot be changed anymore. In general based on a static NPF, decision makers cannot correct for negative (or positive) effects of a highly uncertain variable (such as demand for triple play services) and cannot use the negative (or positive) potential provided by these changes. In our example, we found a positive NPV for a project called GlasHaag using a static NPV analysis shows that there are interesting investment opportunities. However, if they NPV analysis takes into account the volatile and highly uncertain demand for new triple play services the pictures changes somewhat (see Appendix 1).

In order to include the dynamics in the market and the derived uncertainty about the future development of a particular variable, the NPV should be constructed in a dynamic fashion and embed flexibility. Such flexibility can be achieved by designing the project in such way, that there is an option to include the possible future positive or negative potential in the model.

Real options analysis can give some guidelines in situations in which demand for new products and services is highly volatile making investment decisions difficult. In the context of telecommunication networks, the adding of new (infrastructure) capacity requires capital investment which must be balanced by uncertain future revenues. We first study the underlying risk factor in the broadband market in order to then apply real options theory to explain the expansion of FTTH networks. The objective of our study is to find for (a given) FTTH network infrastructure, the level of demand for triple-play services (in terms of subscribers) at which it is for a decision maker desirable to invest. Therefore our research question is what is the investment threshold level in FTTH networks (as the expected future size of the market in terms of subscribers) at which new private companies are indifferent between investing immediately and postponing their investment. In our model, we assumed that the option to expand will emerge every other year given that there is a demand for triple play services of about 10.000 connections. The (local) policy maker has therefore the option to invest an additional €10.000 to expand the network and to meet this demand or do nothing (if the demand is below the threshold of 10.000 connections) (see Figure 5).

Figure 6: Real Options and Demand for a Municipal FTTH Network



In our case, the flexibility is build into the dynamic NPV model to take the fluctuations in (volatile and highly uncertain) demand into account. In projects whereby success is determined by such variable, the project can be designed in a way that it starts on a small scale (with the option to expand at a later stage). However, the creation of flexibility comes at a price. The extra costs of implementing this flexibility in the model are similar to buying the right (but not the obligation) to exercise this option at a later stage (a call option in financial terms). Based on such option, additional connections can be gained based on additional investment. In other words, the costs are linked to the introduction of flexibility in the project in order to anticipate the dynamics in a particular variable.

In addition, it is important to characterize that the project has to be designed in a way to include economies of scale. Under such circumstances the costs per unit are declining with a greater size (Dixit & Pindyck, 1994). The cost per unit for a smaller project are therefore initially higher. The difference between the smaller and the larger project are than cost price for the flexibility of the option. This has to be financed with the higher costs per unit for the smaller start project. If during the duration of the project, the development of demand will provide sufficient rationale for expansion, the flexibility option can be utilized. This will be done based on the expansion with additional capacity (10.000 connections). Given that the development of demand will provide no reasons for a possible expansion, this option will remain unutilized and the build up of overcapacity will be avoided (see Appendix 1).

3.6 Summary

Due to the changing legal and regulatory conditions in telecommunication markets, government agencies have increasingly to act like market parties if they intend to invest in this market. However, the demand and supply conditions in this market provide for market failure, i.e. the investment behaviour of existing market parties in (expensive) next generation infrastructure and the demand for advanced triple play services do not match. Therefore there is a case for government intervention in this market. The question is therefore not only if government investment is justified but under what kind of conditions will the NPV of such investment project be positive. For highly volatile and high uncertainty of demand, traditional NPV calculations accounting for these dynamics showed that there might be negative outcomes. Using a real options analysis based on its assumptions of managerial flexibility and the option to wait, the outcome were in general positive and a negative outcome could be avoided. However, the flexibility build into the investment project comes at a price of a higher (in our case 5%) initial investment in the design of the basic FTTH network.

4 Case Study: Wind energy

4.1 Introduction

As part of renewable energy technologies (RET), wind energy technologies are considered by many as a way to comply with the Kyoto protocol of 1997. In the Netherlands, the first research subsidy schemes for promoting renewable energy technologies were set up after the oil crisis in 1973. Wind energy technologies were not only considered as most suited to the nation's geographic and climatic conditions but as building on the existing expertise in wind energy technologies. The promise of success in wind power was based upon the nation's heritage with respect to the construction of windmills. Financial support from the government has been an important factor in explaining the growth of new wind energy projects in the Netherlands over the past thirty years. With the liberalization of the energy market, however, it became increasingly difficult to find private investment for new wind energy technologies even if there have been a number of government supporting schemes ranging from tax incentives to production subsidies (Dinica, 2006).

As government subsidies have been a main driver of investment, approaches towards the calculations of NPV for the deployment of wind energy technologies have included different forms of government subsidies (e.g. in form of favorable tax agreements) (Dinica, 2006, Sauter, Watson, James, Myers, & Bahay, 2006). Even if some authors have included the uncertainty about future demand and demand fluctuations in their calculations, real options approaches towards RET have appeared only recently in the literature (Davis & Owens, 2003, Kumbaroglu, Madlener, & Demirel, 2006). A main advantage of these real option approaches has been that they explicitly include the possibility of delaying an investment and evaluating the value of waiting as part of the decision-making problem. In other words, investment can be considered as an option (or a right) to irreversibly invest in a particular asset (the underlying asset) at a specific price (the exercise price or investment cost) prior to a determined date in the future (the expiration date). This advantage can be important in order to overcome the limitations of traditional NPV calculations based on DCF analysis as some criticism about these limitations has emerged recently (NWEA, 2006).

In the following we will try to find answer to the following question: under what kind of circumstances might real options approaches provide interesting and new insights into the investment behavior in new wind energy technologies and how can public subsidies be better target these new technologies? As shown above the basis to provide a sufficient conceptual framework is to ask the right question. In this context, such question could be: To what extent have companies in the sector been able to take advantage of new growth opportunities provided by new wind energy technologies? The answer to this question might actually paint a different picture about the future of wind energy and the possibilities of government policy to intervene into these markets. We provide one possible conceptual model for analyzing this market.

However, let's first discuss the technological background and the institutional context in the Netherlands.

4.2 Techno-economic Characteristics of Wind Energy Technologies

Electrical wind systems are based on a technological design by which electrical energy is generated by the kinetic energy of the wind which is via the blades of a rotor transferred into mechanical energy, which, in turn, is used to move a turbine connected to an electrical generator. In general, two technological designs have been used to transform wind into mechanical energy: based on the creation of a drag force or using the creation of a lift force. As the direction of the tangential velocity of the rotor is perpendicular to the direction of wind, an aerodynamic lift movement takes place. On the basis of the lift principle, the rotating axis of the rotor can work in parallel with the direction of the wind stream ('horizontal axis systems'). In such system, the aerodynamic drag movement occurs when the direction of the tangential velocity of the rotor is parallel to the direction of the wind flow. If the direction of the wind is perpendicular the rotating axis, the systems is operating on the aerodynamic drag principle ('vertical axis systems'). As both systems have been implemented in the Netherlands, the major distinction between wind energy technologies have according to (small versus large) size of the project.

Declining equipment cost have been an important factor in the development and implementation of wind energy technologies. During the 1990s, for example, the cost for manufacturing wind turbines declined by about 20 percent every time the number of manufactured wind turbines doubled. These savings have been part of decreasing energy cost achieved with wind energy technologies. This let the Danish Energy Agency propose that further cost reductions of 50 percent can be achieved until 2020, and the EU Commission estimate in its White Book that energy cost savings from wind power will be at least 30 percent between 1998 and 2010 (Ackermann & Söder, 2002).

After the start of a national wind turbine research program in 1975, the Netherlands has become one of the leading countries in the world in the implementation of wind turbines (see Table 4). This position has been gained not only in terms of total installed wind energy capacity, but also in relative terms (watts per inhabitants). In 2006, the Netherlands was fifth in total capacity installed (after countries like Germany, Denmark, the United Kingdom and Spain) and seventh in relative terms (here countries like Ireland, Portugal and Austria were utilizing more watts generated by wind turbines per capita). Currently there are a number of wind energy projects in the Netherlands operating or planned ranging from the near shore Windpark IJsselmeerdijk Dronten to the offshore windfarm Q7-WP. The first wind park was one of the first that was set up by Nuon in 1996. It currently contains 28 wind turbines near the IJsselmeer with a total capacity of 600 kW per turbine and 15,6 MW in total. For the second project, construction work started at the end of 2006 after an agreement over the intention to construct and exploit the offshore windfarm was signed between ENECO, EIH and ECONCERN. The objective of this park has been to generate 120 Mega Watt of energy. It will be built 23 km offshore near IJmuiden (in section Q7 of the Dutch continental plate). Despite of these ambitious projects, however, a closer look at Table 4 shows that the international position of the Netherlands (in relative and absolute terms) has deteriorated.

Table 4: Breakdown of Operating Wind Capacity 2006

Country	End 1995	End 1999	End 2006	Watts per capita 2006
Germany	1136	4445	20200	246
Spain	145	1530	11600	294
Denmark	619	1742	3136	592
UK	200	356	1958	33
Italy	25	211	1941	34
Netherlands	236	410	1564	99
Portugal	13	60	1553	155
France	7	23	1478	24
Austria	3	42	965	121
Greece	28	87	746	71
Ireland	7	73	690	186
Sweden	67	220	519	58
Norway	4	13	281	62
Belgium	0	9	188	18
Poland	1	7	108	3
Turkey	0	9	99	2
Finland	7	38	91	18
Ukraine	1	5	70	1
Estonia	0	0	40	29
Luxembourg	0	10	35	88
Czech R.	7	7	28	3
Latvia	0	1	25	10
Croatia	0	0	17	4
Hungary	0	0	14	1
Switzerland	0	3	12	2
Russia	5	5	7	<1
Lithuania	0	0	6	2
Slovakia	0	0	5	1
Bulgaria	0	0	2	<1
Romania	0	1	1	<1
Total	2511	9307	47379	

(Source: Windpower Monthly, 2006)

4.3 National Government Programs in the Netherlands

This part does not attempt to provide a survey on the different national governmental programs on wind energy as this has been done elsewhere (Agterbosch, Vermeulen, & Glasbergen, 2004), but stresses instead the changing perception within the policy arena to adapt these schemes gradually to the realities of a highly uncertain and volatile environment in the Energy industry in the Netherlands.

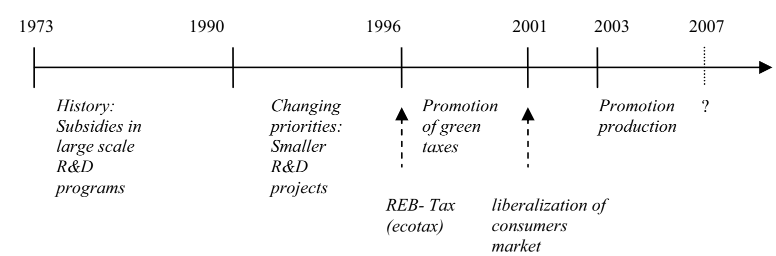
The first efforts of the Dutch government to affect the development of wind energy technologies have been based on science (or technology-) push (Kamp, Smits, & Andriesse, 2004) with R&D subsidies provided to large scale producer and research institutes. These efforts date back to event of the oil crisis in 1973. One year after the oil crisis, the Dutch government came up with its first Energy Policy Plan that stated that the Netherlands should take the lead in the field of wind energy in the world, not only because of economic reasoning but because of the historic achievement in this area in the past. As a result, a national steering group on energy research (LSEO) was established that proposed in 1975 in its first report that the Netherlands should take a leading role in the development of wind turbines. The group announced further a national research program on wind energy. As this programs focused on large-scale production, the primary recipients of subsidies were large national research centers and large companies. At that time, the problem has been which of the type of wind turbines are more promising: the vertical or the horizontal one. After initial trials in the beginning of the 1980s of wind energy technologies, the network of companies involved in the production and implementation of these technologies collapsed due to technical and commercial reasons. The collapse of these large-scale projects let to a reorientation of government policies towards more small scale wind energy projects in the 1990s and involved also other market parties such as wind turbines owners (and not only producers).

From the mid 1980s, a number of governmental programs were introduced aimed at involving other market parties into the development and implementation of wind energy technologies. In May 1986, the Dutch Ministry of Economic Affairs (MINEZ) started its first subsidy program called IPW (Integraal Programma Windenergie) which was aimed at turbine owners. Its objective was to reach 100-150 MW of power by the end of 1990. This program was fostered by an extra subsidy by the Ministry for Housing, Spatial Planning and the Environment (VROM) which provided subsidies (Milieu Premie Windenergie, MPW) for projects at dedicated locations throughout the Netherlands. However these programs did not deliver the expected results as investors were often opting for large scale projects. As a result, a new program TWIN (Toepassing Windenergie In Nederland) was introduced in 1991 which was based on a new methodology to allocate subsidies. However, this program did not achieve the expected growth in capacity as initially planned, therefore it was terminated in 1994.

The year 1996 has been considered as a turning point in the allocation of government subsidies to new wind energy technologies as the emphasis shifted from subsidies to different “green” taxation schemes (Agterbosch, Vermeulen, & Glasbergen, 2004). The first scheme called the ‘Accelerated Depreciation Scheme on Environmental Investments (or VAMIL scheme) was aimed at entrepreneurs who received a financial advantage based on an accelerated depreciation on (wind mill) equipment. A second scheme called the ‘Energy Investment Deduction (Energie Investering Aftrek (EIA)) was provided in order to write off investment in new technologies against taxable profits of the company. In other words, it increased the after-tax profits of companies. Transitory problems in implementing these schemes (e.g. involving not-for-profit parties into these schemes) in conjunction with severe citing problems and weak demand for new "green" energy schemes among consumers let to a decline in the number of wind turbines and the capacity installed (Agterbosch, Vermeulen, & Glasbergen, 2004).

In 1998, renewable electricity and physical imported renewable electricity was exempted from the 'Regulated Energy Tax' ('REB' Tax or publicly known as "eco-tax"). This tax had to be paid by households as well as small- and medium-sized enterprises since 1996 but at the time of introduction it covered both fossil-fuel-based and renewable electricity. In parallel to these changes, the energy market was gradually liberalized starting with energy distributors in 1996 leading to the full liberalization of the market for green electricity by the 1 July 2001 (see Figure 6).

Figure 7: Phases of Public Support for Wind Energy



Source: (van Rooijen & van Wees, 2006), own additions.

In July 2003 the policy of the Ministry of Economic Affairs changed with the introduction of a subsidy scheme called "Environmental Quality of Electricity Production" (Milieukwaliteit Energie Productie or (MEP)). This new system gave suppliers a subsidy for each produced kWh for a maximum of 10 years. It was aimed at reducing investment risks and improving the cost-effectiveness of renewable electricity (van Rooijen & van Wees, 2006). At 18 August 2006, Minister Wijn stated that the Dutch government terminated MEP subsidies for sustainable energy projects as "the Netherlands already reached the EU target before 2010".[6] On 5 December 2006, transitory measures were introduced to limit the negative effects for companies that already invested in sustainable energy projects and were depending on MEP subsidies. Let's leave the discussion about the pro and cons with respect to the termination of MEP subsidies aside and focus on possible governmental measures to subsidize the development of wind energy parks as described in the CPB

6 Financiële Dagblad 21-08-2006, "Minister Wijn Stopt Ontwikkeling van Duurzame Energie"

document *Windenergie op de Noordzee* (2006). The design, building and operation of locations for wind energy (e.g. wind parks) by PPP has already some tradition in the Netherlands see WinWind B.V. which includes a wide variety of partners like municipalities, private companies and investment firms.

4.4 Towards a Real Options Approach: The Compound Option

Real options have recently been used to examine investment in renewable energy technologies also due to the limitations of traditional (static) NPV calculations as these approaches do not include the flexibility of decision makers. In these models, the value of waiting is introduced in the following way: Given that a company invests at time *t*, it will get the expected present value of the revenues minus cost. However, if the company waits and invests at a later time (*t+1*), a real option might arise. If this option is exercised, it might yield a higher net profit. In order to investigate the investment behavior, the sequence of investment decisions has to be broken down into two parts, one considers the immediate choice, and the second is concerned with all subsequent remaining decisions (Kumbaroglu, Madlener, & Demirel, 2006). This compound option (Dixit & Pindyck, 1994) accounts for learning as investments are undertaken sequentially. As it has been shown elsewhere, learning has been very important in the development and implementation of new wind energy technologies (Kamp, Smits, & Andriesse, 2004).

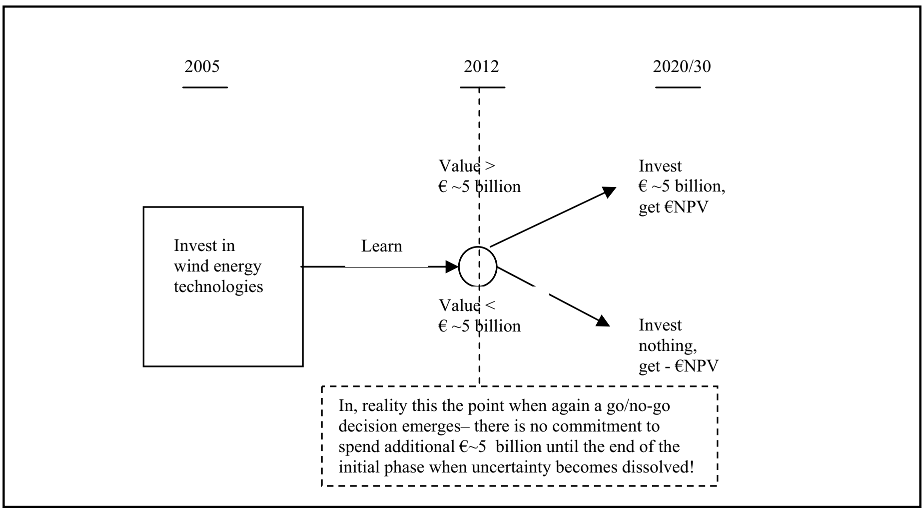
In order to develop a conceptual model based on real options theory that can be used for policy makers, the first question is to whether are not there is a case for government intervention in this market as uncertainty and high risks are not on themselves sufficient reasons. As the history of new wind energy technologies has shown, high uncertainty and risks have a main characteristic of this technology since the 1970s. Another important dimension has been - at least since the 1990s - technical uncertainty which is reflected in changing cost characteristics related to the production and implementation of new wind energy technologies (see 4.2). With market liberalization and the entry of new market parties into the energy market, market uncertainty has increased as energy demand has become increasingly volatile and less predictable (see 4.3). Based on similar assumptions the CPB document *Windenergie op de Noordzee* has argued in favor of a) phasing of wind energy capacity in order to achieve learning effects in the area of renewable energies, and b) flexibility in the development of capacity in the face of technical and market uncertainty. Furthermore, the report proposes that the development of the oil price will be decisive whether or not wind energy will become cost-efficient (and there is no need to further subsidize wind energy technologies). Given a further increase in the price of oil (above $45 and $48 per barrel), government subsidies are not anymore necessary (Verrips, de Vries, Seebregts, & Lijsen, 2005).

One of the objectives of the government has been to stimulate the switchover of energy producers from older to newer environmental friendly technologies such as wind energy under conditions of fluctuating and highly uncertain demand for energy and cost reductions. Under these conditions the question is about the right timing of investment and government intervention. In looking through the real options lens, a compound option based on sequential investment with technical uncertainty seems appropriate as there is a time-to-build nature of the investment problem (Dixit & Pindyck, 1994). The question here is therefore:

To what extent can governmental subsidies be used to stimulate investment in early stages of production of wind energy technologies in order (not) to foreclose investment at later stages?

The compound option can be utilized at a stage at which it allows to switch input parameters in case of favorable cost conditions of competing technologies or favorable output conditions (related to energy prices). Graphically, this can be described as follows (see Figure 7):

Figure 8: Compound Option for Wind Energy Technologies



The dynamics of such real option model would work in the following way: investment of roughly €5 billion (half of the total amount available according to CPB) would create over the period of seven years the opportunity to evaluate the initial investment. In 2012, the government could take another decision: whether or not to undertake an additional €5 billion investment and build, for example, a whole off shore wind energy park. In other words, the initial investment of €5 billion would create some future flexibility for the development of new wind energy technologies. Therefore the real important decision for the government is not today, but somewhere in the future (and is depending on cost reductions as well as on energy price fluctuations). During the period 2005 and 2012, decision makers would have the possibility to learn and respond in contrast to DCF approaches that fully commit to an expected future decision. If NPV in 2012 is above €5 billion additional investment will be undertaken, otherwise there will be no investment. In general, the initial investment (in form of subsidies) creates a strategy. A real options model formulated in such way would provide advantages in terms of higher NPV due to optimal timing of investment and governmental subsidies. For a more extended version of such model (Davis & Owens, 2003).

4.5 Summary

In addition to changing techno-economic characteristics of wind energy technologies, liberalization of energy markets in conjunction with fluctuations in energy prices have let to high technical and market uncertainty in wind energy markets. Due to their static character, traditional investment techniques like DCF are unable to capture these new dynamics and cannot give decision makers the right instruments to undertake investment decisions in these highly uncertain and volatile environments. As the development of wind energy technologies has shown, their decreasing cost characteristics will provide over the long term an alternative to existing (traditional) energy technologies. Another factor which has similarly been important is the extent to which energy prices might lead to a situation in which these technologies will become a cost-efficient energy source. In order to account for these technical and market uncertainty, real options theory provides an alternative to evaluate the real NPV from these technologies. The compound option, which is based on the assumption that sequential investment takes place, allows to account for the adding of capacity at a future time at which more information is available and (policy) decision makers had the possibility to learn. Providing for an initial investment at an early stage gives (policy) decision makers managerial flexibility, i.e. the option to undertake the real important decision at time in the future when there is more known about technical and market conditions in wind energy markets (and better timing for providing subsidies).

5 Case Study: Fonds Economische Structuurversterking (FES)

5.1 Introduction

Governmental subsidies for structural development in different regions coming from the so-called "FES" funds (Fonds Economische Structuurversterking – (FES)) are different from traditional governmental regional subsidies and are probably unique in Europe as they are linked to (additional) financing coming from the natural gas exploitation in the North Sea. In this respect, the extent to which there will be benefits coming from natural gas exploitation is unknown over the long term as they there linked to the fluctuations of gas prices on the world market. If gas prices are above a certain limit, positive benefits will flow into the government budget and will - according to current political objectives - be used for investment in facilitating "structurally" regional economic development. A major part of this investment is used for projects in the area of education, knowledge and innovation.

For 2006, the FES funds contained €1,4 billion. In order to receive out of this funds governmental subsidies, 43 projects in the areas regional economics, research and innovation and education were competing. A central criteria to accept (or reject) these projects has been the extent to which they contribute to social welfare. According to the recent CPB report (2006) *Beoordeling projecten ruimtelijke economie, innovatie en onderwijs* more than half of the projects submitted, did not sufficiently contribute to social welfare (Verrips, 2006). Similar negative results were achieved for projects submitted in 2005 for the FES funds according to the CBP report *Investeren in Kennis en Innovatie* that concluded that only 50 percent of the projects did not provide for positive social welfare gains. One of the major problems with projects competing for FES funding has been that these financial means were only available for a short period of time. That was leading to a situation in which there was not a competition of projects for funding but partly a competition of funding for projects (CBP, 2006). For the projects submitted for the FES funds 2006, the CBP concluded in its report that the social benefits of these projects could be improved if managerial flexibility could have been build into these projects, there would be opportunities for the phasing of these projects and these projects were evaluated based on interim results (Verrips, 2006).

5.2 Background and Current Discussion

Since the initial plans of the Gasunie in 1991 to export 200 billion m^3 until 2013, the question has often been raised in the political agenda on how to spend these additional governmental income. In 1992, the government presented a proposal under which a special funds was created that contained these additional benefits gained from natural gas ("Aardgasbatenfonds"). Additional income for this funds came from extra export of gas by the Gasunie, from the Common Area (on the border between the Netherlands and Germany) and from other income from other natural gas. At the beginning, subsidies from this funds should exclusively be used to finance large-scale investments. that had a national dimension and were aimed at facilitating structural change in the Dutch economy. Initially, projects that received governmental support were in the area of transport infrastructure and telecommunications as well as for the development of technology and knowledge infrastructure. For example, the amount of finance available from the export of natural gas (€1.36 billion or hfl. 3 billion) in 1995 was nearly exclusively been used to finance two infrastructural programs (Hoge Snelheidstrein and Betuwelijn). However, this fund was also used to create employment and facilitate regional structural change. In 1993, the name of this funds was changed into Fonds Economische Structuurversterking (FES). Since its establishment there has been an on-going discussion about the objectives of the fund, the evaluation of FES projects, the size of the projects to be included in the evaluation and in particular the flexibility of projects in the framework of FES projects, etc.

The current FES fund for 2007[7] has been based on 40.9 percent (compared to 42.0 percent in 2006) on the benefits gained from gas exploitation in the North Sea in conjunction with tax exemptions ("rente-vrijval") resulting from the sale of state interests and participations in private investment companies ("verkoop van staatsdeelnemingen"). Given that the political direction in the Netherlands remains unchanged and the benchmarks of macro-economic development provided by CPB will be achieved, funding will be available for investment projects from the FES fund. The size of this funding is cumulative and based on the balance between all already planned expenses and incoming revenues until 2011. For the period after 2011, already planed expenses include provisions for the program "Regional Development and Mobility" ("Ruimte en Mobiliteit"). Until 2020, these provisions will, in total, amount to €18 billion. However, these expenses can be counterbalanced by additional revenues in case of a high(er) price for oil (which is linked to price of natural gas) over a longer period of time and a favourable exchange rate between dollar and euro. (For example, additional revenues will be generated if the price for oil will be about $ 26 and an exchange rate of €/$ 1.20.)

There are a number of criteria laid down in the FES statute ("Fes wet")[8] which have to be taken into account when decisions are taken about (possible) investment projects: First, the projects to be financed by the FES fund should have a national dimension and should facilitate structural change in the Dutch economy; second, these projects can only be financed only once without an extension; third, the projects should fit with the investment agenda for the medium term in the area of regional development, knowledge and innovation. Furthermore, an extended CBA analysis should be undertaken that includes the examination of the legitimacy, the effectiveness and the efficiency of the possible investment. In its advice to the government "Slimmer Investeren van FES-gelden", the AWT (Adviesraad voor het Wetenschaps- en Technologiebeleid) proposed that in addition to these criteria increasingly "strategic and qualitative criteria" should be taken into account to evaluate

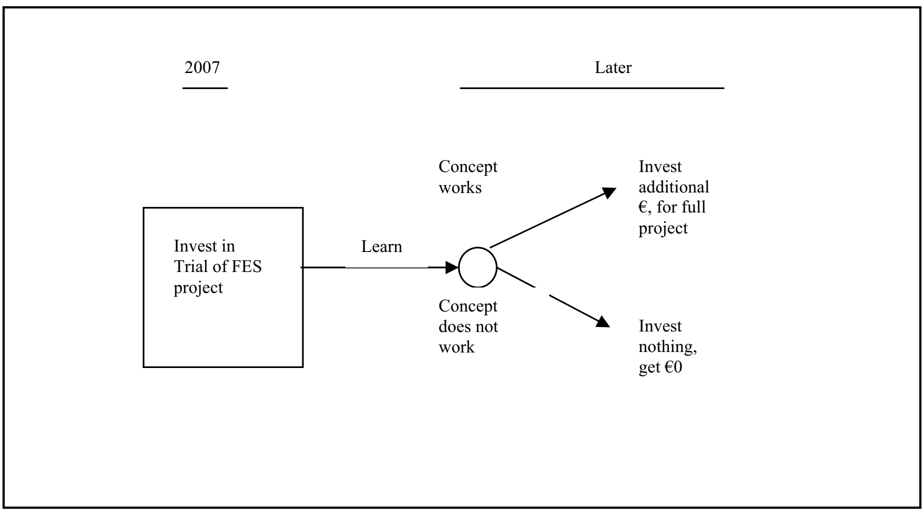
[7] This section is mainly based on an email conversation with Yge ten Kate (23 January 2007).
[8] Published in het Staatsblad 1996, nr. 52

possible investment projects in framework of the FES fund (AWT, 2006). An application of real options theory allows to specify strategic and qualitative criteria of the different projects and to quantify these future benefits (and costs).

5.3 Advantages of a Real Options Approach

Through a real options lens, market uncertainty for these projects is provided, on the one hand, by the fluctuations in gas prices that determine the amount of subsidies available in the framework of FES funding. (The assumption is here that the returns from these investments are higher compared to a situation in which FES funding is used to reduce the governmental debt.) On the other hand, technical uncertainty is provided by the quality of projects submitted for FES funding. A possible way to account for this uncertainty in real option theory is the option to expand as explained in Figure 8.

Figure 9: Option to Expand



Based on the option to expand, a number of small scale projects are started first on a test basis, in order to see if these projects will generate sufficient social benefits in the future (as initially claimed). (This idea has early be discussed in the context of a pre-finance option "voorfinancieringsfunctie"). After the first (test) phase is over, additional information is available with respect to a) the benefits generated from this project, and b) the flexibility provided by the new investment. If investment in the test project created the ability to learn about the demand for such concept, decision makers can respond by either a new investment and expanding the project (given a positive NPV) or zero NPV leading to a termination of the project. A real options analysis has, in addition, to account for the different expansion options and value each of the strategic pathways for a project. In this respect, lattice evaluation of the underlying value can provide useful insights (see also Figure 4).

5.4 Summary

Real options analysis can provide advantages and value in situations in which different projects should be identified, prioritized, valued and selected. Using real options theory, the assumption is that these projects should not only be evaluated based on their current state, but all their future opportunities should be evaluated as well. The "option to expand" in the case of FES subsidies which allows to select between a number of different competing projects on the basis of the future growth potential and initial investment at an early (test) stage. Given that the concept is working, additional investment can be allocated.

6 Summary and Limitations

As has been shown, real options approaches take a dynamic perspective on evaluation of investment which is in particular appropriate in highly uncertain and volatile environments. They enable policy makers to include managerial flexibility in the evaluation of these investments, this flexibility comes from the option to wait with an investment (until NPV is higher than the option to wait). Therefore decision makers can "buy" an option to invest in the future and, at the same time, are able to observe and to learn about the dynamics in particular markets and industries. Government should only provide subsidies in cases in which some kind of market failure coexist in conjunction with uncertainty and irreversibility.

Based on a real options approach a different research question has to be asked which includes different options to wait like compound options or options to expand. Real options theory approaches can be considered as a complement to static NPV calculations as DCF calculations are mostly undertaken first. To examine the potential of real options analysis, we were looking an application of the "option to wait" in the case of municipal investments in telecommunication networks and concluded that this option will enable local municipalities to avoid the drawbacks of a negative NPV. The option to wait in the case of municipal networks allows to re-evaluate new investment decisions at each stage of expansion of the network depending on the demand for new telecommunication services (section 3). We further discussed the utilization of a "compound option" in the case of wind energy technologies, which enables decision makers to postpone the important (future) investment decision and start on a smaller scale with an initial investment than can be extended at a later stage (when technical and market uncertainty has been resolved) (section 4). Finally in section 5, we applied the "option to expand" in the case of FES subsidies which allows to select between a number of different competing projects on the basis of the future growth potential and initial investment at an early (test) stage. Given that the concept is working, additional investment can be allocated.

The focus in this report has been on applying the heuristics of real options theory to some 'real life' situations. Building on this heuristics more advanced real options models can be developed that are multi-stage (not just single period investment) and therefore have to include option valuation lattices. In addition, there are a variety of other more advanced options like the strategy setting approach mentioned in section 2 that are build on the combination of different real options. Furthermore, the applications of real options in section 4 and 5 need some further calibration with respect to the underlying parameters. As this requires in-depth knowledge about the energy industry (section 4) and over the workings of the allocation process for FES projects (section 5) additional research is needed.

There are three different roads running from here to possible extensions of the different models in this report. The first one is aimed at characterizing the underlying theoretical framework for a dynamic approach towards real options. Evolutionary theories in economics in conjunction with capability based approaches seem better suited to capture the dynamics in markets and industries compared to more neo-classical approaches. However, survey articles in this area have been scarce. The second extension has been to develop and solve dynamic optimization models that account for the dynamics of real options. Even if a large variety of these models have recently been developed, industry specific applications that account for the policy interventions have been limited. The third extension is related to the calibration and application of different models (including the model in section 3). In this area, further progress seems most valuable for practical policy analysis as these ‘applied’ models can more easily capture the dynamics in different markets and industries as they add another dimension to static NPV calculations.

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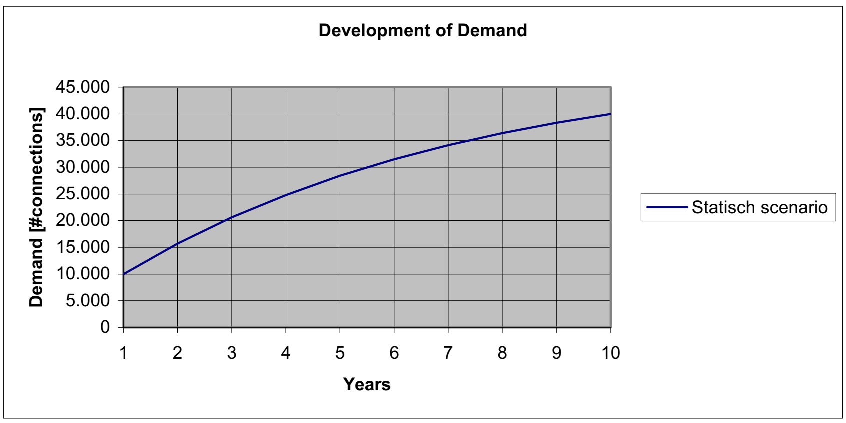
Appendix 1: An application of real options analysis

Project A: GlasHaag using a static NPV

The future development of demand for connections, i.e. the number of final consumers who wants to receive services via the network of GlasHaag is an important variable in this calculation. This variable is crucial in determining the feasibility of the project. For this project the expectation is that in the first year 10.000 connections will be provided. After ten years, the number of connections should have linearly been grown to 40.000. The growth in the first years is larger than in the last years. This reflects the assumption that at the beginning of the project it is highly attractive to be connected to the FTTH network. At a later stage, final consumers will join the network who adopt late. Such growth trajectory will be expected if the growth of broadband connections is taken as a historical benchmark case. The growth of broadband connections in the Netherlands shows a similar pattern even if there is at the moment no pattern of saturation. Based on these assumptions the development of demand for connections follows the curve in Figure x.

Figure 10: Static NPV in the Case of a Municipal Network



Capacity of the network: In order to reach the expected number of connections over a ten years period, the GlasHaag builds a network with a capacity of 40.000 connections.

Cost per connections: The cost per connections are €1000,00.

Gross profit: GlassHaag can realize a gross profit of €19,00 per activated connection.

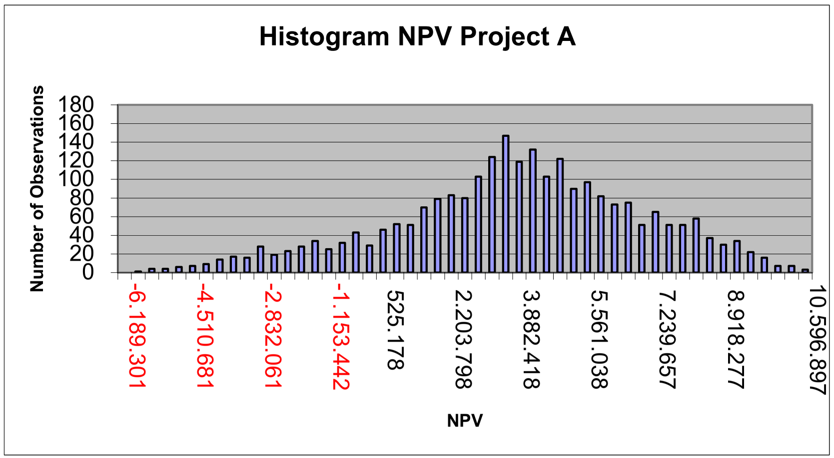
Project duration and interests: The duration of the project is 10 years and the nominal interest rate is 7 percent.

Based on these assumptions the static NPV of Project A is €3,5 million and a IRR of 7,31 percent.

Table 5: Static NPV calculations for municipal network GlasHaag

Year	0	1	2	3	4	5	6	7	8	9	10
Demand		10.000	15.710	20.605	24.801	28.399	31.482	34.126	36.392	38.335	40.000
Capacity	0	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000
Cost of connections	40.000.000										
Sales	0	2.400.000	3.770.400	4.945.200	5.952.240	6.815.760	7.555.680	8.190.240	8.734.080	9.200.400	9.600.000
Costs of Sales	0	480.000	480.000	480.000	480.000	480.000	480.000	480.000	480.000	480.000	480.000
Cashflow	-40.000.000	1.920.000	3.290.400	4.465.200	5.472.240	6.335.760	7.075.680	7.710.240	8.254.080	8.720.400	9.120.000
DCF	-40.000.000	1.814.131	2.937.538	3.766.544	4.361.488	4.771.288	5.034.687	5.183.696	5.243.336	5.234.110	5.172.120
NPV cashflow	3.518.937										

Table 6: Dynamic NPV based on simulations



Modeling uncertain demand based on dynamic fluctuations, however, paints another picture. To characterize these fluctuations, we used instead of the geometric Brownian motion (mostly used in real options theory), a continuous logistic function with the following form:

$$g(t) = \frac{a}{1 + be^{-rt}} \tag{4}$$

where *α* is the asymptotic or limit value of *g* when t → ∞, *α/(*1-*b*) is the initial value of *g* when *t* = 0 and *r* is the relative rate of growth. Such form describes better than the geometric Browian motion the rate of growth of connections as it is asymptotical.

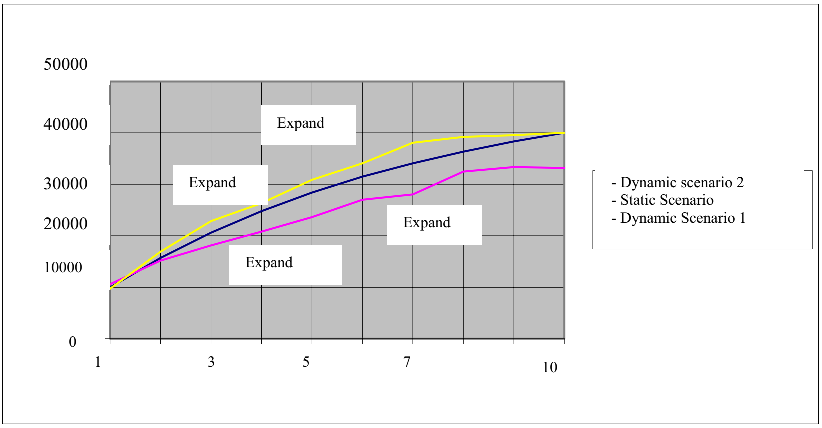
Table 5 shows how the project A can develop if demand is estimated based on the dynamic development. In a negative scenario, the NPV can be € -6.1 million and in the positive scenario € 10.3 million. Even if the value at risk (VaR) analysis showed that with a 95 percent confidence level it can be concluded that the NPV will be not lower than € -3.8 million, it became clear that there should be other ways to deal with volatility and uncertainty of demand and to avoid the risks of a negative NPV.

Project B GlasHaag using real NPV

In order to avoid the problems in project A, the FTTH network in project B will be based on flexibility. The flexibility is built into the network as it starts with a basic network (year 2007) which can be expanded if demand picks up utilizing extra activated connections. The design of the network is such that it takes into account future volatility and uncertainty in demand (Banerjee & Sirbu, 2005). However we need additional assumptions for project B: First, in the first year the project starts with a network of 10.000 connections. This flexibility can be achieved by preparing the central active components for expansion, e.g. by developing overcapacity in the central equipment in conjunction with smart architecture of the basic network. Second, the creation of flexibility is achieved similarly to buying a financial option. GlasHaag has now the right, but not the obligation to expand the network at a later stage. The “call option on stock” of this real option is the same as the sum of the investment costs necessary for future expansion. This option will be fixed at 5 percent of the investment costs for the first 10.000 connections (€10 million): € 500.000. Third, this option enables to expand gradually the network with 10.000 connections until it reaches the maximum of 40.000 connections.

Based on the introduction of flexibility in the basic network, the network can be expanded by 10.000 connections at a later stage. There are two different scenario’s to define the development of demand: 1) a first scenario based on a negative demand growth (scenario 1) and 2) a second scenario based on a positive demand growth (scenario 2) (for scenario 1, see Figure).

Figure 11: Option to Wait in the Case of Municipal Network



Because the demand for connections increases above 10000 connections the network will be expanded at the end of year one. As a result, the capacity increases to 20000 connections. As there is not much difference in the first year, in the following year there is a difference between both scenario's becomes larger. As the growth of demand is during the second period above expectations, the option to expand is utilized and the network is expanded to 30.000 connections. This repeats itself in year 4. During each expansion the option to expand is utilized.

Based on the scenario 2 with slower demand growth, expansion takes place in the years three and seven. In this scenario, the real demand growth remains behind the statistic predictions for demand growth. Given that the network was not planned in a flexible way, the uncertainty has irreversibly caused losses. The design of the project B with its build in option to wait allows to delay investment until demand has reached the expected level.

The interesting results of project B are that the possible losses due to high uncertainty and volatile demand can be avoided. Even in the most negative scenario the NPV still is € 1.5 million and € 13.6 million in the most positive scenario, with an average NPV of € 8.3 million (see Table 6).

Table 7: Results for option to wait

PROJECT B		
	Minimum	Maximum
NPV	€ 1.5 million	€ 13.6 million
IRR	6.6%	14.8
VaR	€ 3.0 million	

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