AUTHOR: Gabriel Weber

Co-authors: Prof. Dr. Edeltraud Guenther, Martin Nowack

Presenter: Martin Nowack

Title of Paper: Application of real options thinking for the management of climate change risks

Gabriel Weber, Edeltraud Guenther, Martin Nowack,
Technische Universität Dresden
Chair for Environmental Management
01062 Dresden
Germany
Phone: +49 351 463 343 13
Email: bu@mailbox.tu-dresden.de

Abstract

This paper examines real option thinking as a corporate adaptation strategy to dealing with climate change uncertainties. We propose that the core sustainability issue of climate change can be dealt with through the application of real options thinking as an adaptation strategy. This contribution is a conceptual approach which assesses the benefits of real options thinking in risk management at the case of climate change. Thus it offers a tool for decision makers to deal with climate change uncertainties. By applying real options thinking to the assessment of corporate adaptation strategies, this innovative approach brings a financial market discipline to the evaluation of a company's adaptation opportunities. We find that real options thinking is an appropriate heuristic for assessment and treatment of climate change risks. This paper adds to the growing body of literature which advocates the benefits of real options thinking. Furthermore, this paper contributes to the current literature on climate change adaptation and climate change risk.

Introduction

In the last decade, dealing with uncertainty has become a core issue in corporate decision making. Especially with regards to climate change, managers face a wide range of uncertainties concerning physical impacts, such as extreme weather events, as well as regulatory uncertainties, such as future climate change legislation. Real options offer a tool for investment decisions under uncertainty where the value of an investment is increased by the flexibility of future options. In such cases, decisions can be deferred or rescinded to improve upside potential and/ or contain downside losses of the investment. Generally categorised, real options confer possibilities either to purchase assets (call options) or divest assets (put options) in the future at prices that may be attractive relative to those faced by parties not holding options. Whereas financial options assign rights to buy or sell financial assets, real options have physical and knowledge-based resources as their underlying assets. (Miller and Waller 2003: 97).

The actual logic of the real options approach is based on the perception that future investment opportunities are contingent on prior investment commitments. Thus, in contrast to net present value analysis, real options analysis incorporates the sequential nature of choice

processes (Adner and Levinthal 2004: 74). The options approach seeks to remedy the insufficiencies of traditional methods of valuation, net present value and discounted cash flow through the recognition that active management and managerial flexibility can bring essential value to a project (Jacob and Kwak 2000: 294). However the real options approach has evident shortcomings. First, the quantified value of real option analysis is not always intuitively perspicuous (Fichman, Keil, Amritt 2005: 87). Second, it has proved very difficult to obtain a specific monetary value as real options differ from financial options in several respects. Financial option models are based on several key assumptions. The asset is required to have a price, the price ought to be known, and the asset has to be liquid or tradable. Physical and knowledge based underlying assets of real options can be sold or traded, but they are much less liquid than financial options. Third, the real options value could be markedly different from one company to another depending on business objectives and the other assets in the portfolio (Jacob and Kwak 2000: 294). Fourth, real option valuation techniques provide a sophisticated treatment of market risks, but not do deal with firm-specific risks (Steffens and Douglas 2007). And fifth, real options are difficult to identify; multiple types are mixed up together.

Despite these shortcomings, real options analysis offers a lot of advantages. Managers can take advantage of using real options analysis by applying it as a way of thinking. First, the real options approach offers a more affluent framework for designing a project, and brings all decision makers to the table, as well as providing expedient terminology for conferring a project and the contingent sources of value (Alessandri 2004: 758). Second, a real option analysis can add significant value through the procedure of thinking about project flexibility and project design in a more structured way, and not essentially the ensuing valuation (Triantis 2005: 10). Third, real options thinking has a strong future scope and embraces uncertainty as well as flexibility and therefore is a promising heuristic for risk management (Miller and Waller 2003). Risk management is a structured approach to deal with uncertainties. The aim of risk management is to create and assure the maximum sustainable value to all the activities of an organization (Dallas 2006).

Few authors discuss the integration of real options thinking in risk management (Adner and Levinthal 2004a, 2004b; Alessandri et al. 2004; De Schryver and Asselbergh 2003; Fichman, Keil, Amritt 2005; McGrath 2000; Miller and Waller 2003; Steffens and Douglas 2007). However this literature takes into account the structured and holistic approach of risk management only to a limited extent. This contribution assesses the integration of real options thinking in the four steps of the risk management process: risk strategy, risk identification, risk assessment, risk treatment (ISO/ DIS 2007). Furthermore, only some authors scrutinize real options in the field of corporate management in a climate change environment as well (Hertzler 2007; Laurikka and Koljonen 2006; Laurikka 2006; Lin et al. 2007; Reedman et al.; Stronzik 2006; Wirl 2006). However these contributions merely consider rather quantitative real options approaches, when considering climate change issues. In particular, in the field of climate risk management where significant uncertainty exists, real options thinking can enhance flexibility in management decisions. This contribution aims to examine the benefits of real options thinking for climate change risk management. In doing so, the following questions have to be assessed:

- How can real options thinking be used for the assessment of investment opportunities to mitigate carbon emissions?
- How can managers identify climate change adaptation strategies by real options thinking?
- What are the benefits of real options thinking in dealing with climate change uncertainties?

After the introduction, we discuss the integration of real options thinking in risk management. In order to offer a versatile approach for climate change risk management, we employ the risk management process as a systematic framework to deal with uncertainty. Finally we draw conclusions on the usefulness of real options thinking for climate change risk management.

Real options thinking in risk management

In our investigation, we assess an application of a real options heuristic in risk management examining the case of climate change. In order to do so, we integrate real options thinking with the risk management process. The results of this integration will be discussed in the following section.

Risk strategy

Every entrepreneurial activity is associated with a certain level of risk. Nevertheless, in a risk strategy the corporation has to decide how much risk it is willing to accept and how much risk the corporation can take. Derived from the overall strategy a risk strategy and its resources and responsibilities are assigned to the different levels of the corporation from the chief executive to the department manager. Moreover the risk strategy has to be integrated in the general business strategy. Decision makers should evaluate the role that a real option thinking could play within a risk strategy. Part of the risk strategy could be to educate employees with regards to climate change uncertainties using real option thinking as a potential adaptation strategy. The responsibilities for applying a real options analysis for climate change uncertainties in terms of should also be determined.

Risk identification

When identifying risks, the corporation sets up an inventory of all relevant risks. A risk is relevant for a corporation when the achievement of its objectives could be affected. Risks which are not under the control of the corporation are to be identified, as well as risks which can be influenced by the corporation. Only risks which are identified at this stage could be analyzed in depth in the subsequent stages of the risk management process. It is imperative that an unidentified risk is recognized as an incalculable risk. To ensure complete risk identification, it is essential that the employees and the responsible managers deal with relevant and actual information. They must be sensitized to identify risks. A structured and standardized approach is helpful but should be adapted to the requirements of the corporation. In risk identification, decision makers should identify and structure climate change risks in a qualitative manner. On the one hand, companies face uncertainties about physical impacts such as events as droughts, floods, coastal surges or heat waves. On the other hand, there are uncertain government policies on climate change, and uncertain international regimes on climate change mechanisms, which all pose uncertainties to business. Companies also have to deal with litigation uncertainties relating to climate change. Moreover, there are uncertainties relating to a companies' reputation as well as competitive uncertainties. Figure 1 illustrates different climate change uncertainties.

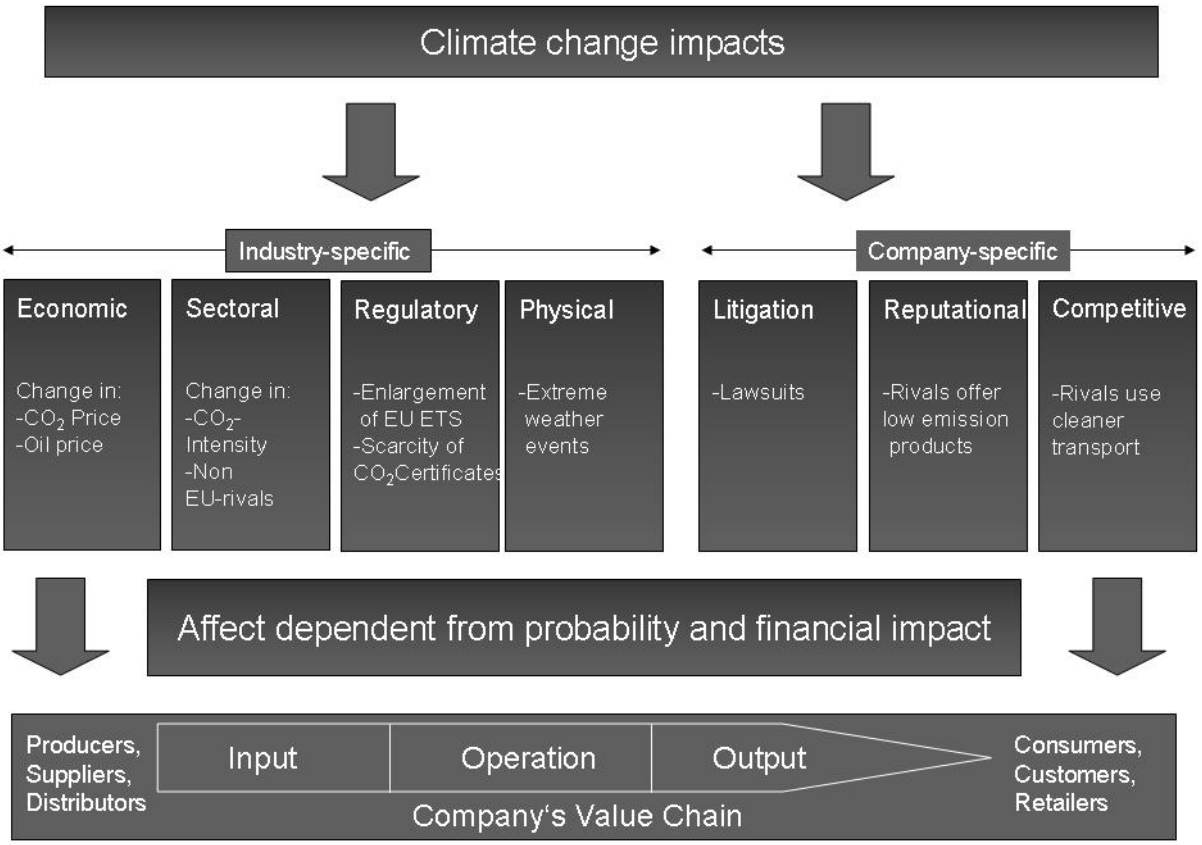

Figure 1: Climate change impacts (derived from Busch and Hoffmann 2007)

Risk management should make sure that a company gain value by delivering products or services that uses lower energy and causes lower emissions than the rivals products or services. The essence of integrated risk management is consideration of the full range of climate change uncertainties which could affect business performance. In risk identification, managers should consider their exposures in each of the two broad categories of climate change related uncertainties: (1) industry specific uncertainties (macroeconomic, depend on industry, regulatory, and physical) and (2) company specific uncertainties (litigation, competition, production, and reputation). Furthermore, real options in dealing with those uncertainties should be considered.

Risk assessment

Risk assessment is defined by the ISO/IEC Guide 73 as the overall process of risk analysis and risk evaluation. Risk analysis identifies the level of exposure to uncertainty while in the risk evaluation the decision is made on how to handle a risk. The range of potential consequences could be expressed in quantitative terms or in qualitative terms as negligible, minor, moderate, major, critical or catastrophic. Also the probability could be expressed in quantitative probabilities or in qualitative terms as certain, likely, possible, unlikely, rare. In a risk matrix, both risk attributes are integrated in one chart. On the abscissa, the consequences of the damage are plotted. The ordinate is assigned to the probability of occurrence. After the risk analysis, the risks have to be compared and evaluated against risk criteria. Risk criteria as associated costs and benefits or legal requirements are used to make decisions about the

significance of risks. Within the frame of the risk, assessment managers can evaluate how the different climate change related uncertainties interrelate and the nature of these effects on performance. Because different businesses face unequal risks, it is promising to use the business units as a starting point for assessing exposures (Miller and Waller 2003: 98). By designing a climate change exposures profile, managers should consider the impact that each of the climate change related uncertainties will have to business unit performance. Moreover this profile can be used as a tool to develop adaptation strategies for business units and the entire company.

In order to design a climate change exposure, profile managers should identify the uncertainties due to climate change related future events, as shown in the first column of Table 1. A next step is to assess the effect of climate change related uncertainty to the business units. The effect can be positive (+1), negative (-1), or insignificant (0). Table 1 summarizes the climate change exposures for a hypothetical firm's three business units A, B, and C.

Table 1: Climate change exposures profile

Uncertainties	**Business A**	**Business B**	**Business C**	**Corporate**
Industry Uncertainty				
Macroeconomic				
Price of CO_2 allowances	1	1	-1	1
Price of oil	-1	-1	0	-1
Price of natural gas	1	1	-1	1
Depend on Sector				
Price elasticity of demand	-1	0	-1	-1
Marginal/average variable cost of production	1	-1	-1	0
Tonnes CO_2 emitted/ marginal unit output	1	1	0	1
Electricity consumed/ marginal unit output	-1	-1	0	-1
Market share of non-EU suppliers	-1	0	1	-1
Regulatory				
Geographical enlargement/ implementation of ETS	1	1	-1	1
Enlargement of ETS to other sectors	-1	-1	0	-1
Stringency of caps	1	1	-1	1
Changes planning codes	-1	0	-1	-1
Regulated industry standards	1	-1	-1	0
Risk disclosure standards	1	1	0	1
Physical				
Extreme weather events (flooding, heat waves)	-1	-1	0	-1
Sea level rise, increase of temperature	-1	0	1	-1
Insurance costs	1	1	-1	1
Heat-related illness	-1	-1	0	-1
Company Uncertainty				
Litigation				
Inadequate disclosure to trading partners of change risks	1	1	-1	1
Inadequate preparation of traded commodity for climate risk	-1	0	-1	-1
Lawsuits, if damages can be traced back to emissions	1	-1	-1	0
Competition				
Changing markets	1	1	0	1
Loss of productivity with respect to competitors	-1	-1	0	-1
Value of assets exposed to climate change	-1	0	1	-1
Production				
Production shortfalls due to physical climate change impacts	1	1	-1	1
Production shortfall due to rise of energy prices	-1	-1	0	-1
Reputation				
Reputation as a large emitter	1	1	-1	1
Reputation of being vocal in scepticism about climate science	-1	0	-1	-1
Weight	**0,5**	**0,3**	**0,2**	**1,0**

Decision makers should furthermore identify a weighting based on the business units share of the company's performance. By using the weighting, managers can assess the entire corporate exposure to the different climate change related uncertainties. The aggregate corporate exposure profile is useful information for shaping hedging strategies through using real options. Furthermore it presents an understanding of how climate change related uncertainties affect the company as a whole.

Risk treatment

Having identified the corporate exposures to climate change related uncertainties, managers can now consider the specific steps they should take to treat risk. With the use of real options, managers can choose to increase or decrease their exposures.

A corporation has different ways to treat its risks. The major elements of risk treatment are avoidance, mitigation, transfer or acceptance of risk. The aim of risk treatment is to reduce the impacts and avoid risks with high occurrence probabilities in order to minimize the expectation value. Compliance with laws and regulations is obligatory. An organization must understand the applicable laws and must implement a system of controls to ensure compliance.

To avoid or mitigate climate change risk, companies can invest in emissions reduction technologies. Thereby various real option investment opportunities exist.

To the extent that it is feasible, managers should scrutinize these real options concurrently, rather than sequentially. This has the benefit that management can evaluate each option's potential risks and payoffs in combination with other potential real options, not just in segregation (Miller and Waller 2003: 101). To exemplify this, the previous given example stated in Table 1 is extended. Implying that a company's management is investigating three different investment opportunities in research and development (e.g., for boosting the efficiency of hard coal fired power stations, carbon capture and storage as well as offshore wind power), each of these is likely to become a self-contained business unit. These primary investments can be seen as real call option acquisitions. Each investment in a new business provides a certain initial exposure to climate change uncertainties unique to a specific business. The investment also assures the company the possibility to further expand in the future. Investments like these are described as "growth options".

Table 2 highlights information about the three real option investment aspirants X,Y,Z (e.g. X for boosting the efficiency of hard coal fired power stations, Y for carbon capture and storage and Z for offshore wind power). The first column (Uncertainties) lists all of the climate change uncertainties impacting the values of the corporate portfolio of already existing businesses and the intended new businesses. The second column (Corporate) replicates corporate exposures from the table 1.

After adopting the details from table 1, managers should evaluate the effects of uncertainties to the real option investments and complete the signs for the relations as done in Table 2. The weights in the bottom row of the table rely on assumed sales of the projected new businesses relative to anticipated sales for the expected portfolio. For example, a weight of 1.4 in the option X column indicates that at a specific time in the future intended sales for that product

line extension will outperform projected sales for the existing portfolio of businesses by 40 per cent(Miller and Waller 2003: 102).

Table 2: Real options exposures

Uncertainties	**Corporate**	**Option X**	**Option Y**	**Option Z**
Price of CO_2 allowances	1	1	0	-1
Price of oil	-1	0	0	1
Price of natural gas	1	1	-1	-1
Price elasticity of demand	-1	-1	0	1
Marginal/average variable cost of production	0	0	0	0
Tonnes CO_2 emitted/ marginal unit output	1	1	0	0
Electricity consumed/ marginal unit output	-1	-1	0	0
Market share of non-EU suppliers	-1	-1	0	1
Geographical enlargement/ implementation of ETS	1	1	0	-1
Enlargement of ETS to other sectors	-1	0	0	1
Stringency of caps	1	1	-1	-1
Changes planning codes	-1	-1	0	1
Regulated industry standards	0	0	0	0
Risk disclosure standards	1	1	0	0
Extreme weather events (flooding, heat waves)	-1	-1	0	0
Sea level rise, increase of temperature	-1	-1	0	1
Insurance costs	1	1	0	-1
Heat-related illness	-1	0	0	1
Inadequate disclosures to trading partners of change risks	1	1	-1	-1
Inadequate preparation of traded commodity for climate risk	-1	-1	0	1
Lawsuits, if damages can be traced back to emissions	0	0	0	0
Changing markets	1	1	0	0
Loss of productivity with respect to competitors	-1	-1	0	0
Value of assets exposed to climate change	-1	-1	0	1
Production shortfalls due to physical climate change impacts	1	1	0	-1
Production shortfall due to rise of energy prices	-1	0	0	1
Reputation as a large emitter	1	1	-1	-1
Reputation of being vocal in scepticism about climate science	-1	-1	0	1
Government appropriations for business X	0	1	0	-1
New technology in business Y	0	0	-1	0
New entrants in business Z	0	0	0	-1
Weight	**1,0**	**1,4**	**0,5**	**0,2**

As a result of the assessment of real options, exposures managers can develop adaptation strategies in dealing with climate change uncertainties. For this purpose, different options should be evaluated. Options with equal exposures reinforce one another. Their potential contributions to company value are additive (Miller and Waller 2003: 102). However, real options with converse exposures mitigate each other and therefore will not be exercised at the same time (Trigeorgis 1996: 232). They are substitutes and, as such, their values are not additives. Purchasing both option X and option Z would indicate the lack of a conclusive strategy because the payoffs to these two options are inversely related. The risk implications of real options can only be treated when elaborating in light of the present corporate portfolio of businesses. Managers seeking to decrease risk should identify real options with payoffs that are contrariwise related to their existing corporate exposures. A real option with likewise exposures to the current corporate portfolio augments upside exposure, but does nothing to diminish the downside exposure of the corporate portfolio of businesses.

In Table 2, option Z offers the greatest potential for reducing existing corporate exposures to climate change. On the contrary, option X would, for to a large extent, reinforce the existing corporate exposures. The value of option Y is mainly autonomous of the variables impacting the value of the actual corporate portfolio. Managers should determine whether their company is uniquely positioned to purchase and exploit certain real options. Some companies may be

better able to more cost-effectively evaluate and purchase real options than others. Furthermore, some firms may have more sophisticated possibilities to forecast future environmental changes. If forecasts indicate the company is positioned to profit from future environmental shifts, management may choose to purchase real options that increase – not hedge – their exposures. Under these circumstances, purchasing option X makes sense, even though its future payoff is closely correlated with cash flows to the firm's existing portfolio of businesses.

Conclusion

In this paper, we proposed the integration of real options thinking in risk management at the case of climate change. We found that real options thinking is a valuable heuristic for the application of climate change risk management. Moreover, we found that, for the most challenging aspects of risk management such as risk assessment and risk treatment, real options heuristic is particularly useful. Real options thinking can be used for the assessment of a company's exposure to climate change risk. In addition, it is valuable to identify and evaluate investment opportunities to avoid or mitigate climate change risks. Moreover, real options thinking could facilitate the identification of business opportunity with regards to climate change.

However, as implicit in a conceptual framework, this research lacks empirical evidence. Hence, further research should empirically investigate the application of real options thinking for climate change risk management. The next step could be a case study which explores the status quo of real options thinking application with regards to climate change. In doing so, researchers should investigate how and why real options thinking is applied. Other avenues for further research lie in the investigation of the applicability of real options thinking to other core issues of sustainability such as water infrastructure projects or green chemistry.

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