CEREG UNIVERSITE PARIS DAUPHINE CNRS UMR 7088
CENTRE DE RECHERCHES SUR LA GESTION

New Boundaries to Real Options Valuation?[1]

Exploratory Research Based on a Case Study

Henri PHILIPPE[2]

CEREG (CNRS-UMR 7088), Université Paris-Dauphine

Working paper n° 2004-03

March 22, 2004

Abstract:

Despite a large body of literature on the topic and the continuously improving understanding of professionals, real options are not widely used to value firms. Numerous assumptions have been raised to explain the various obstacles to their adoption. Limits concerning the relevance of option valuation models outside financial markets are the most salient, but they are not the only ones: carrying out a valuation implies other assumptions on the nature of the firm, as well as on its strategy. Including real options in the value of the firm raises numerous difficulties. We support our arguments with a case study based on a real life valuation of an R&D firm.

JEL Classification: D81, D23, G34, L22, O32

Keywords: REAL OPTIONS, THEORY OF THE FIRM, CORPORATE VALUATION, CORPORATE GOVERNANCE, CASE STUDIES, R&D

---

[1] This text is based on a PhD research under the supervision of Laurent Batsch (CEREG – Université Paris IX Dauphine). I am grateful to Delphine Inesta and Richard Carr for editing an earlier draft. All remaining errors are mine.

[2] The author is manager in the Valuation and Strategy group of PricewaterhouseCoopers Corporate Finance. This working paper reflects the opinions of the author and do not necessarily express the views of PricewaterhouseCoopers.
Correspondence: CEREG, Université Paris-Dauphine, place du Maréchal de Lattre de Tassigny, 75775 Paris cedex 16
E-mail: henri.philippe@fr.pwc.com

1. Introduction

Boundaries to the use of real options are multiple. A lot of attention has been paid recently to understanding the limitations of applying option pricing models (OPM) outside financial markets to value real assets. Even if these limitations are the most salient, they are not the only ones.

Financial models valuing firms are based on various kinds of assumptions. Some relate to the financial markets, such as their completeness, or the lack of arbitrage opportunity. These assumptions are obviously the main concern of researchers in corporate finance. But other assumptions about the theory of the firm, as shown by Zingales [2000], or about the strategy of the firm are also implicit in financial valuation models. We show that by introducing real options in the valuation process of the firm we might be less comfortable with some of these implicit assumptions.

We base our demonstration on a case study extracted from a valuation encountered in a professional context[3]. Key elements are presented in the Appendices.

The remainder of this paper is composed as follows. Section 2 details the main limitations of the real option valuation models as presented in the literature. Section 3 details the main concerns when valuing real assets with OPM. Section 4 describes the valuation of a French R&D company including an option to abandon. Section 5 highlights the implicit assumptions in the real option models that concern the theory of the firm. It also shows why, in this perspective, introducing real option in the value of the firm might be a source of limitations. Section 6 concludes on new research opportunities in the field of real options.

3 Names and various elements of the context have been changed to preserve confidentiality of the information provided to us.

2. Literature review

For the past ten years, research on real options has significantly expanded in various directions, leading to quantitative as well as analytical developments. Real options are now widely present in corporate finance literature, academic journals, financial books, and even the financial press[4]. They form a consistent theory to answer some crucial questions of corporate finance: how to include flexibility in the value, why risk can be valuable for firms, how finance may reconcile with strategy, etc. This academic success also has its roots in the quantitative finance interest for these new exotic options.

Lander and Pinches [1998] have realized an extensive survey of the literature. It shows that real options have been applied in most economic fields: natural resources, strategy, operations, real estate, international studies, research and development, merger and acquisitions, corporate governance, etc. Beside this prolific body of research, several articles have recently tried to set up a framework to use real options (Durand, Gomez and Monin [2000], Borison [2003]), and a few have even debated on the relevance of the theory (Kobrak and Spieser [2000]).

While publications in professional journals or introductory articles on real options are numerous[5], implementation by professionals seems to be rather limited. At the same time, authors have searched for the empirical validity of real option models (Berger, Ofek and Swary [1996], Quigg [1993]), as well as the emerging use of practitioners (Busby and Pitts [1996], Triantis and Borison [2001]). The number of empirical studies is still rather limited. A first explanation is the difficulty in gathering the massive quantity of information that is necessary to value real options. In the French context, it might also be explained by the scarce numbers of professionals that have actually implemented the method on real cases. Most firms we have met have 'tried' to apply the concepts on an example.

Triantis and Borison [2001] have surveyed 34 firms that use real options. Not surprisingly, energy, high technology and biotechnology firms are over-represented in

4 Hence the most common corporate finance handbooks dedicate a complete chapter on real options (e.g. Brealey and Myers [2000]).

5 Titles of these articles are unambiguous: Luehrman [1998] « Investment opportunities as real options: getting started with numbers », Mauboussin [1999] « Get real – using real options in security analysis », etc.

their sample. This is consistent with the number of case studies in these industries[6]. They share a few common characteristics:

- Large capital expenditures with uncertain return.
- All have experienced recent structural change. Therefore traditional valuation tools are difficult to use in these industries (e.g. impact of the New Economy or of deregulation).
- These industries rely on engineering skills and are used to implementing sophisticated analytical tools in their daily management.

This survey gives general indications of industries where real options have been welcomed. But it is more uncertain that these industries satisfy all conditions necessary to value these options. This interest for real options could also be explained by some 'fashion' trends in firms with deeply rooted engineering cultures, and large capital expenditure budgets justifying in-depth studies. It is therefore dangerous to jump to the conclusion that the characteristics of these industries they satisfy all conditions necessary for the implementation of real options.

The gap between theoretical research and management practice might also be explained by the techniques used that are not yet well known by professionals. But Bernstein [1992] has shown, in the Black & Scholes formula's case, that professionals may implement financial models quickly when they see immediate interest, even if they do not master the underlying techniques. Busby and Pitts [1996] have questioned managers in the United Kingdom on their perception of real options. Their study (using questionnaires on a limited sample) shows the interest of professionals for the topic even if they do not really master the underlying concepts.

Academic critiques aimed at real option models may also explain this gap. Some of these critiques are common to most decision-making models. Lander and Pinches [1998] sum up the following:

- Assumptions may be inaccurate or irrelevant;
- Parameter assessment methods are not satisfactory;
- The model offers only short term insights;
- The model is over-optimistic or –pessimistic;
- The model is too abstract and/or inapplicable.

6 Other industries represented are industrial and consumer goods, financial services, real estate, transport. One firms is anonymous.

Even if these weaknesses are important when valuing real options, they are not specific to real options and are relevant for most financial models. We show in the following section the specific critiques aimed at using OPM outside financial markets to value the flexibility of real assets.

3. Option Pricing Models to Value Real Assets

Real option literature has paid considerable attention to the limitations of applying OPM outside financial markets. Since the origins of real options, their technical limits have been underlined (Mason and Merton [1985]). Lander and Pinches [1998] note three different explanations for the lack of success of real options, two of which are directly linked to technical concerns:

- Real option theory is based on knowledge and competences that are not yet widespread;
- Mathematical assumptions necessary for the real options model to be tractable limit their field of usage;
- Formal assumptions of the models are rarely applicable in the real world.

Most studies have been dedicated to the difficulties of using real option models on real life examples, as well as to the discrepancies between the modelling assumptions and the actual conditions encountered in real life, essentially from a financial point of view. This is particularly striking when we try to value Internet firms or R&D projects. These firms show little historical data and almost no comparable companies on which to base our financial analysis. Therefore it is not surprising to encounter difficulties in valuing these companies with traditional tools (discounted cash flows or market multiples) or with real options. But to use OPM, we need to gather complementary financial data such as the underlying asset of the option and its behavior, and we also need to estimate new exotic parameters (such as the expected volatility of the underlying asset return).

More interestingly, when looking at natural resources firms,a field where real options have been used traditionally, we also face significant difficulties. In this context, determining the underlying asset of the option is straightforward: most natural resources

are traded commodities with various derivatives to infer parameters of the real option valued. But we still have to face many difficulties: some concern the assumptions of the option valuation model, others the characteristics of the real option.

The main assumptions common to most OPM are based on portfolio replication or risk neutral probabilities to value the option. At first glance, these assumptions seem rather restrictive when applied to real assets. The main difficulty is to identify and make assumptions on the traded asset that could be the underlying asset of the real option.

Academics have tried to loosen these assumptions to reflect real options' specific characteristics. A first way to circumvent this difficulty is when the underlying asset is not traded but its risk is[7]. Then it is possible to value the market price of that risk, and any derivative supporting it (Hull [2000, chapter 19]).

A second approach is to consider that the underlying asset is itself contingent on another traded asset. Therefore using arbitrage valuation theory, it is possible to consider that the real option valued is contingent on a first asset (not quoted), which, in turn, is also contingent on a second (quoted) asset (Rolando [1995]).

Both approaches mentioned above rely on traded securities and on the completeness of the market. Therefore they rely on the ability of financial tools to price market risks. But when valuing real options, it seems also relevant to try to value private risks as much as market risks[8]. Smith and Nau [1995] model this issue by mixing arbitrage valuation theory and decision science.

These are existing approaches that circumvent some of the technical issues raised when valuing real options. These approaches show different ways to loosen the restrictive assumptions of traditional OPM used on financial markets. But, even with these tools in hands, practitioners still have other difficulties to face:

- How should practitioners assess the parameters? On financial markets, analysts are struggling with the parameters of their models. For real options these parameters are usually not directly observable on the markets, but also their definition might be ambiguous. For example, in the case we present in the following section, we have

7 A reason for that would be with the existence of derivatives on that asset, or on that risk (e.g. weather derivatives, catastrophe bonds).
8 'Market risks' are covered/traded on the markets, whereas 'private risks' are all other risks beared by investors.

assessed the value of abandoning the project, but contrary to a financial option on the market, there is no contract detailing this option. Therefore we have to make reasonable subjective assumptions to define what is, for example, the exercise of an option to abandon this project, and how it may be assessed.

- Are the market conditions as described in the option valuation model valid? Most OPM usually assume, for example, that continuous trading is possible, that markets are complete, and that there are no transaction costs. In the case, the option is based on the value of an asset, which does not exist (a project is valued by its future cash flows), which is not quoted, where no comparable traded assets exist. In these conditions, as shown by Borison [2003] we can either value the option as if the conditions were present, value it subjectively or use other tools (e.g. decision analysis).

- Is the way uncertainty is modelled relevant? Most real options are subject to private and market risks. Only the latter are included in OPM. Private risks may be assessed by relying on subjective analysis (Smith and Nau [1995]). Borison [2003] shows how real option models might be ranked based on the way they deal with these two kinds of risk. The question then is to understand the link between market and private risks and to use relevant models depending on the objective of the valuation.

- Are real options too exotic to be valued? Lastly, most real options may be considered as 'exotic' options, where parameters are highly interdependent[9] and uncertain. OPM used to value financial options may deal with exotic options, but it seems that sometimes, real options are too exotic to be directly valued and simplifying assumptions have to be made.

All these issues are true limits to the use of real options, but they do not seem to be the only explanation accounting for the fact that practitioners do not use real options. As discussed earlier in Black & Scholes' case, practitioners would implement those models, even if they were to face technical limits, if they perceived some value in using it. Busby and Pitts [1996] have shown that practitioners see value in real option analysis. Moreover, for most practitioners, we might assume that these debates are too technical to define relevant limits to their use of real options. Therefore there might be

[9] e.g. there is usually a relationship between the exercise price and the underlying asset value.

other reasons to account for their reluctance to use this approach besides their difficulties to master the tool, and the technical issues.

We argue in the rest of this paper that practitioners face other issues when implementing this tool. These issues are partly linked to how the firm is modelled in traditional valuation tools: implicit assumptions on the nature of the firm behind traditional valuation models are more questionable when we introduce real option in the value of the firm. We argue that even if practitioners are not necessarily able to explicity define these implicit assumptions, they have a broad understanding of the boundaries of the firm and its value, and therefore might be reluctant to attribute the full value created by real options to the firm.

In order to get a better understanding of these difficulties, a case study based on a real life example has been performed. We sketch in the following section the main elements of this case study.

4. Case study: an R&D Firm

Nikopol is a Research and Development firm specialized in chemical research. It was founded by a team of 15 researchers who have a long experience of fundamental and applied research. The firm has already developed numerous international patents; some may have potential industrial uses in several fields, such as the food business, the chemical industry and other related sectors.

The main growth opportunities of the firm seem to depend on its discovery capacity, and hence on its human resources (researchers), as well as on its existing patented discoveries.

The founders of Nikopol have granted free shares to its researchers. Therefore, shareholders and managers are the same persons in Nikopol. Patents have also been filed in the name of persons that are obliged to do so in their employement contracts. Consequently, with these capital and legal links, Nikopol's founders have attempted to ensure that the property of any growth opportunity would remain within the firm.

Nikopol is managed by worldwide reknowned experts who have the necessary expertise not only in research, but also in the industrial implementation of R&D projects[10]. They have already experienced the industrial implementation of an R&D process in the past. But they would prefer no to do so again with their new projects, and therefore would like to sell their company with its technologies and patents. Therefore, the objective of our mission in this context was not so much to value the business rather than to create a selling business plan.

- **Valuation process**

The business plan of the firm has been designed while valuing the firm in a contradictory process: Nikopol's management has proposed assumptions, supported by external and internal analysis, that we have discussed.

Our work has followed three steps:

- Identifying uncertainties and existing options (Analysis);
- Design of a dynamic financial model able to deal with these uncertainties and options (Modelling);
- Discussion of the model's outputs (Interpretation).

Information has been gathered during a rather long period (several weeks). Numerous secondary and primary sources have been consulted: market analysis, industrial forecasts, expert interviews and weekly meetings with Nikopol's management.

- **Product and markets**

Nikopol has filed numerous patents; several are based around a new chemical formula called 'π (Pi)'. It may be useful in a wide range of applications, especially in the chemical business and in the food industry.

These markets seem particularly promising to Pi, since experts forecast an explosion of the demand for chemical formulas like Pi (called 'Z-type') in the next 20 years. On top of that, existing formulas ('Y-type') have some undesirable effects that may cause

[10] Researchers from the French National Center for Scientific Research, experts with a long experience at top management level in the industry, etc.

their banishment in the near future[11]. Other Z-type existing formulas, that may compete with Pi, are so expensive to produce, based on current industrial knowledge, that mass production is rather improbable. As such the discovery of Pi is a great success for Nikopol and opens a wide new market for the next few years.

In order to limit its risks and capital expenditures, Nikopol has the opportunity to licence its technology to other industrial partners in various markets (e.g. in Asia) and various segments. This strategy is rather common in the industry and offers a quick way to enter a market with a critical mass production at a lower cost. Moreover it offers an opportunity to cut potential support to competing technologies.

The main difficulties to value Nikopol are linked to the projections of the company's future revenues. A wide range of uncertainties might affect the future of Nikopol:

- market acceptance (regulation, industrial, end users);
- delays in terms of client acceptance, technology implementation, etc.
- market share in the various market's segments;
- speed of penetration of the various segments;
- since most patents have a finite life, market shares that could be gained by competitors on each segment in the future;
- price of the formula,

These uncertainties have been modelled in Nikopol's business plans in consecutive steps:

- projections of the market volumes in each segments where Pi could be sold (chemical industry, food industry, diet food industry)
- projections of Pi's market share in each of the segments of the market.
- projections of Nikopol's share of this market share (100% at the beginning and declining whith the entry of competitors with Pi-like products in the future)
- initial prices on each segment, and price evolution.

[11] Around 2005 according to Nikopol's management.

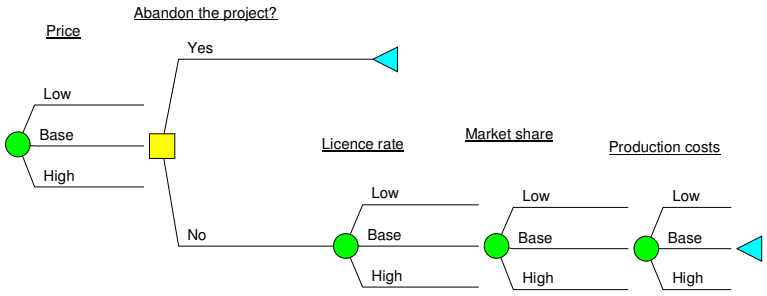
It has been considered that the most significant uncertainties[12] could be described by two or three discrete states in the future (e.g. the market share evolution could be defined by three different curves) with an associated probability to each of these states[13]. These probabilities have been assessed subjectively by Nikopol's management based on the 10%, 50% and 90% confidence percentile[14].

An option to abandon the firm has also been considered: if Nikopol's results are less satisfying than expected, or if the management receives disappointing information from the market, it has the opportunity to go bankrupt (i.e. an option to abandon). This option is common to all shareholders and has been described by Myers [1977].

By 1 January 2005, at the lastest, Nikopol's management must decide wether or not to build the plant to produce Pi on a mass scale. They assume that at this date they will have a better knowledge of the market, and especially of the price they might offer on the market.

We assume that based on the sole knowledge of the uncertainty on price, management will exercise or not their option to abandon. Liquidation costs are considered as nil. The uncertainty on price is solved in 2005 before the decision regarding construction.

All these assumptions have been modelled using the following decision tree[15]:



[12] 4 of them have been selected: Price, licence rate, production costs, market shares in the diet market.
[13] See appendix for an example of how we model the uncertainties.
[14] We asked Nikopol's management to assess the price that they are 90% sure that the product should have in order to enter the market. Then these assessments have been transformed in discrete probabilities assuming that they are normally distributed (Miller and Rice [1983]).
[15] This decision tree is a simplified one for illustrative purposes. A more complete decision tree is presented in Appendix 3.

A business plan has been designed on the 2002-2015 period. It computes discounted cash flow calculations for each scenario. A terminal value has been computed based on the Gordon-Shapiro formula assuming 2015 would be the first 'normative' year for Nikopol.

The uncertainties have been modelled in a dynamic spreadsheet on Microsoft Excel. All the above uncertainties have been considered as variables in the model with different potential values. In order to include flexibility in the decision tree we have solved it by backward induction[16]. We begin the analysis with the final branches, and compute backward the value, by assuming that each time we encounter a decision node, management will make the decision that maximizes the NPV.

- **Discount rate**

We have considered that, in a transaction context, the cost of capital could be based on the return expected by venture capital investors. European funds, as shown by the European Venture Capital Association (EVCA) studies[17] have a return between 20% and 25%. We have assumed that Nikopol's future shareholders will bear similar risks to those supported by the upper quartile of the EVCA study.

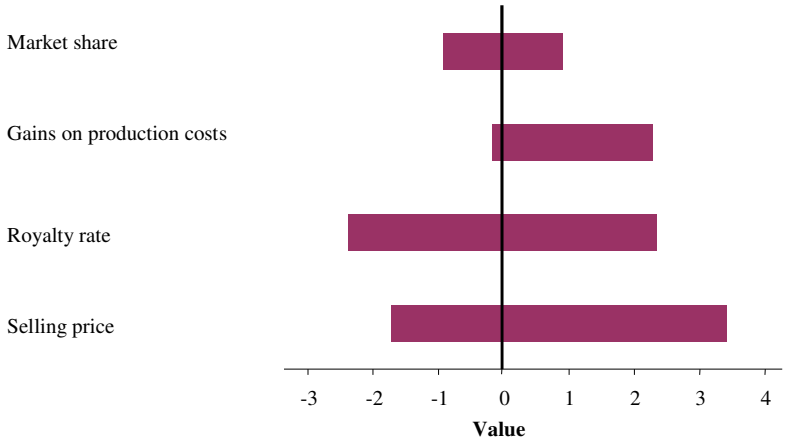
This assumption is debatable:

- The return is directly linked to the maturity of the project: the earlier it is the higher the expected return.
- The performance of the fund is necessarily different from the expectance of investors when they have invested. The return offers just an approximation of what investors might expect based on past returns but not necessarily of future expectations.

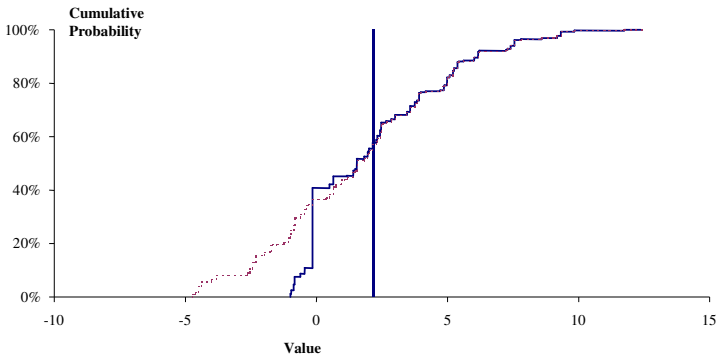
- **Results**

The graph below shows the sentivities of the static value to the uncertainties, all other things being equal. There is a clear asymmetry between gains and losses due to the option to abandon if things turn bad for shareholders:

[16] A complete formal description of the method is detailed in Bancel and Richard [2002, 115-164].
[17] Studies available on http://www.evca.com.



Based on the decision tree, the expected value of Nikpopol is 2.2 including the option to abandon, and 1.6 excluding the option. The risk profile of the value is shown in the following graph (the dotted graph corresponds to the value without the option to abandon, the vertical bar correspond to the expected value):



The option to abandon offers a valuable flexibility to the owners of Nikopol (around 34% of the total value).

Numerous criticisms might be raised against the method we used to solve the case (how we came up with the discount rate, how we have assessed the probabilities, how we have valued the flexibility, etc.). We concentrate in the following section on the criticisms relating to the nature of the firm that we have implicitly considered in the valuation. We show how and why including real options in the value raises new issues.

5. Real Assets in Real Firm: the Nature of the Firm Valued

Nikopol's balance sheet presents virtually no assets and liabilities, except some tools and equipment and a marginal net working capital. Like most R&D companies its investments are expensed and not capitalized. A major part of its future revenues should be generated by current projects.

When valuing this company, it seems natural to consider that its value is generated more by growth options than by assets in place (Myers [1977]). The question is then why do we attribute the full value of these options to the company (i.e. to it shareholders)? A first answer is that residual value is granted to shareholders because they are the only stakeholders of the firm that have not been granted guaranteed revenues from the firm (Tirole [2001]. This compensates the fact they have been granted a decision right on the future decisions and management of the firm. If this reasoning seems relevant for companies where value comes froms assets-in-place, it is questionable in firms where it is generated by growth options.

When considering real options in Nikopol's case, growth opportunities[18] could be subject to hold-up from some of the firm's employees (e.g. its researchers) since they are the first to identify thoses options. So why attribute the value of these options directly to shareholders?

There is a legal response to that question: some growth options (e.g. a new chemical formula to be launched on the food market) are linked to patents, legally protected in various markets, in various countries. But this is only a partial answer since some projects are not based on patented products. Moreover, Nikopol's management does not protect several projects in order to preserve secrecy on its research stream.

A second way to protect the firm from a hold-up of its growth options value is to align researchers interests with those of the firm: in Nikopol's case, all researchers are shareholders of the firm. To some extent, the traditional hold-up issue disappears… The limit of this approach is that, when a researcher foresees a project that has such a value on a standalone basis that it could be worthwhile for him/her to pursue this project outside the firm, that he/she would abandon the value of the shares he/she owns.

[18] e.g. the opportunity to develop other patents based on an earlier one.

A third way to protect the firm from the hold-up of one researcher is to broaden the view of the firm: the company is not only a nexus of explicit contracts as described above (employees contracts, patents, shareholders agreement), it is also a nexus of implicit contracts as well as well as a bundle of knowledge and competences that are not readily available on the market. Researchers are banned from taking over the value of these growth options because of these implicit contracts. But in that case, attributing the full residual value, and hence of the option, to the shareholders seems questionable.

What this case tells us is that the traditional 'nexus of explicit contracts' view of the firm is probably not always relevant for a common firm, but it seems that it is even more questionable when we try to assess the value of firms that are essentially composed of growth options. We detail the main difficulties in the following paragraphs.

- **The status of real option**

Since the origin of the concept, Myers [1977] has highlighted the problematic status of real options: are they assets on their own or only characteristics of other assets-in-place within the firm? According to Myers, only in very specific cases can real options be considered as independent assets (e.g. patents and licence). These options are identifiable and clearly separated from other assets, and can eventually be traded on secondary markets. But most real options are more complex[19]: they might be considered as characteristics of assets-in-place and valued as such, just like the conversion right of a bond can be valued by using contingent claim analysis. As we have seen, the corollary question is then to determine if this value has to belong to the shareholders.

Real options are generated by real assets management: their underlying asset corresponds to future cash flows that the firm would earn if the option were to be exercised. This value to come and this conditional exercise generate difficulties to determine who owns the real options: future cash flows have an uncertain outcome and the parties involved are unkown. In Nikopol's case, the company 'owns' a growth option to develop a new promising chemical formula, this project depends partly on the firm's assets (tangible and intangible), but also on organizational factors (competences,

[19] Myers [1977, pp. 146-147].

knowledge, know-how, etc[20]) and on its partners (employees, suppliers, customers). Managing this growth option is not part of an explicit agreement between partners, neither is it related to any specific asset. If this real option's value was to be attributed solely to shareholders, other stakeholders could prefer to hold-up their share of the value. Therefore, it seems that part of these real options value has to be shared between the firm's partners.

A way to avoid this issue is to consider 'real options' as only those options relating to the management of contracts, such as suspending activity, abandoning a project, etc. This seems a rather restrictive approach since the panel of potential real options is significantly wider. Real options can be classified on a scale based on their relative complexity[21]: operating real options are directly related to tangible and intangible assets in the balance sheet of the firm. Any contract has some kind of flexibility, such as to delay it, to stop the contract, to abandon it, etc. At the other end of the scale, strategic options, such as growth options, seem less linked to contracts of the firm, but rather to their resources, such as their human capital.

It is possible to limit real option by using a restrictive definition for it, such as limiting it to options for which identifiable assets or contracts within the firm do exist (e.g. patents). The firm in this case is still a 'black box' and we introduce only a limited flexibility in the management of the firm.

At the other end, if we try to enter the black box, by better taking into account, for example, its investment process (Charreaux [2001]), the conception of the firm as a nexus of contracts is not satisfying anymore. Understanding the ownership of the value created by real options is linked to the understanding of how real options themselves are created[22]. This should in turn lead to a better knowledge of how firms develop and grow.

When we look at the firm as a nexus of contracts, we have a static view of the problem whereas real options are dynamic by nature. It seems rather simple to include

---

[20] All these concepts of resources, competences need to be properly defined in this context and can be considered here has *ad hoc* explanations of the origin of real options. Conner and Prahalad [1996, p. 477]: « (…) *privately held knowledge is a basic source of advantage in competition.* »

[21] The level of 'complexity' described here is based on the option valuation difficulties, as described by Lautier [2002-a].

[22] Identifying the agent which has created the option is not necessarily enough to answer the question of option's ownership. Koenig [1996, p. 226-227] shows that a firm that has created a rent is not necessarily the one who benefits from it.

in the value operating options that are linked to existing contracts management. In the case of an oil field, for instance, the real options valued are directly embedded in the contract the firm has with the governement.

In Nikopol's case, the value created by the growth options is not directly related to any existing (or future) contracts but more to projects, ideas, resources, etc. It seems rather difficult to include these strategic options in the firm's value; they may be included as exogeneous assumptions, as a supplementary value to be added to the firm value. The value of these strategic options is directly related to the past history of the firm, these are path-dependent 'assets': because the company has hired several researchers, because its founders have already been successful in the R&D business, it has been decided to create Nikopol. The people owning Nikopol have gathered assets, people, information, knowledge, etc. and all these elements have created the conditions to generate growth options within the firm.

Myers [1977] considers real options as a given exogeneous data, and therefore does not include in its model any other assumption concerning their creation/acquisition or development within the firm. But he raises several hypotheses to understand how firms may create these options: by investing in real assets, with specific expenditures (e.g. R&D, advertising, training), and by learning. If the first two may be understood in a firm seen as a nexus of contract, the last one is more problematic. To understand learning we need to base our reflection on new concepts and assumptions (e.g. knowledge, competence). These are difficult to implement in most economic models since they rely on path-dependencies and historical analysis, whereas economic and financial models are usually time-independent by nature. Therefore it seems that understanding complex real options creation might be solved by modelling these path-dependent mechanisms and by replacing the financial models in their 'historical' background.

- **Real Options and the Boundaries of the Firm**

When a real option is not clearly linked to a specific contract or asset, the next question is to understand who owns this option, and how the value it creates is shared between partners of the firm who generate its value. These questions are raised because of the particularities of real options. For example, shareholders are usually not those who decide to exercise the option. Sometimes managers do (because they are agents for

the shareholders mandated within certain limits to do so), but in some cases, other partners of the firm make the decision (e.g. employees of the firm). Therefore a complementary question is to understand if these options are optimally exercised (on behalf of shareholders, or of all partners of the firm).

This difficulty is valid for all partners of the firm (shareholders, employees, customers, suppliers, etc.) and concerns the understanding of:

- the ownership of real options,
- the exercise of the option.

Zingales [2000, p. 1641] considers Saatchi and Saatchi's case, a famous advertising agency. This case presents similar features with the case Nikopol presented earlier: when Mr. Saatchi decided to quit his company, following some disagreement with the company's shareholders, he left it with his competences, his team and his reputation. When considering the value created by Mr. Saatchi's projects (growth opportunities), does it belong to the owners of the rights on residual profits (i.e. shareholders) in a firm where most of the assets are intangibles, not even on the accounting balance sheet, and that are not part of any explicit contract?

Shall we share the value created by the growth options between shareholders, or shall we share it also with the employees, which are able at first to identify these options, and may even exercise them for their own purpose? In Nikopol's case, employees may compete for the value with the firm[23]. Real options are, in general, and this is a major difference with financial options, not explicitly defined in a contract. Therefore they are not part of the nexus of explicit contracts that form the firm.

According to Zingales [2000], modern corporate finance has solved this issue by assuming that possessing assets gives ownership of the growth opportunities generated by the firm[24]. While this assumption seems reasonable for 'brick-and-mortar' type firms, it seems rather questionable for firms in the new economy where tangible assets, and even assets booked in the balance sheet, are a minor part of the value.

We may consider real options as particular assets, owned at the same time by several partners and therefore having a total value shared between the different partners contributing to its value. A first constraint to the use of the real option concept is the

[23] We are neglecting legal protections such as patents, non-compete agreements, etc.
[24] We may refer to the Ownership Rights Theory to understand the essential role non-human assets in firms (Hart [1995]).

cost of the 'option': if anyone may 'own' the real option without any expense, any investment, any specific resource, then it seems that this 'option' is not really an option.

If the firms possessing the option have effectively 'bought' it (one way or the other), the next question is to identify its underlying assets and estimate its exercise price. In some cases, firms may own an option whose strike price, underlying asset value and maturity are contingent on the behavior of others. This is the case for most R&D projects where firms compete to enter new markets.

In the case, the firm foresees an opportunity to create a new market (Nutritive elements dedicated to the food market in France). It has the possibility to build a plant by first investing in preliminary studies (low cost) and then in larger costs to actually construct the facility. The firm's return is directly contigent to the development of diet food in France. Let's assume that the first firm to enter the market will be the only one to gain market shares significant enough to ensure an acceptable return. The question in this example is not so much on the existence or not of the market but on the behavior of other competitors. Assuming that all competitors have the same level of information, all have identified the opportunity. Even some firms may have done some preliminary studies. The next question is shall we attribute the value created by this growth option to all firms, when we know that the behavior of others may impact the value of the option?

In financial option terms, the value of the growth option underlying asset is highly contingent on the interaction between competitors. For a financial option, this would be equivalent to an option on an 'exceptional' asset, i.e. an asset that would not be available any more if anyone buys it[25]. Morevoer, if for a financial option, exercising the option has no impact on the value of the underlying asset, this is not necessarily true for a real option (Kobrak and Spieser [2000]). Hence for a multinational firm, entering a new market, in a new country, and therefore exercising a growth option, will necessarily alter the rules of the game in this market[26], and in turn change the value of the underlying asset of this option (i.e. the value of the market for the firm).

This incentive to exercise real options earlier can be express through a strategic 'convenience yield' that reflects the interest for the owner of the option to launch the project as soon as possible rather than wait and see the value of the project decrease

[25] This asset is particularly illiquid.
[26] By altering reactions of competitors in the market for example (or suppliers' relationships within the industry, or customers' behavior).

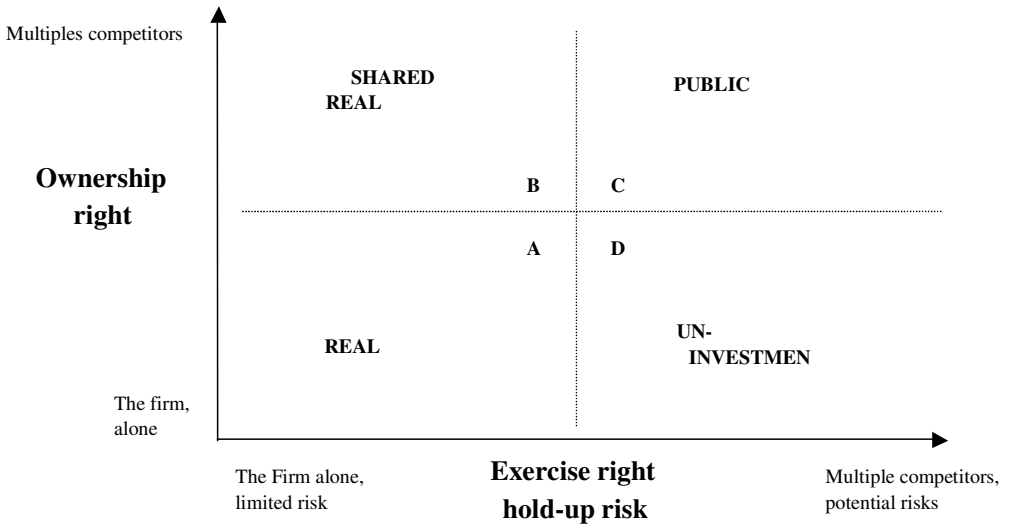
because of its competitors' behavior[27]. But this seems to be rather unsatisfycing since it offers a simplistic view of competitive interactions; moreover the assessment of the yield itself is rather problematic.

These characteristics (several firms may exercise similar real options, circular reference between strike price and underlying asset value) highlight the absence of specific ownership rights on some real options. If we consider for instance a call option on VivendiUniversal, striking this option will offer the ownership of a share of the company. In the case of a real option, exercising the option will offer the ownership on a 'virtual' asset (cash flows to be) whose value and ownership rights are less well defined than in the case of a share of stock. Competing firms or even employees may exercise equivalent real options and obtain also a share of this virtual asset… In this case, the value of the real option should take into account theses alternatives.

If we include real options within the firm boundaries, considering the shareholders as the sole owners of the control on asset revenues, and protected by contracts, is no longer completely satisfying, because real options' value can be shared or impacted by all partners of the firm. The theory of the firm implicitly included in the value should be able to explain why and how some real options may be created and exercised within the firm, whereas others may be exercised for instance by employees for their own wealth outside of the firm.

The following graph summarises the preceeding paragraphs and shows a matrix with the two main factors impacting real options: who owns the option and who exercises it. We can infer from this matrix the relevance of the real option concept depending on the degree of rights (exercise and ownership) of the firm on the real option valued.

[27] This is equivalent to the dividend paid to the owner of a share and not paid to the owner on an option on a share.



In the traditional 'nexus-of-contracts' view of the firm, real options seem the most relevant when firm's ownership and exercise rights are the strongest. In this case (A), the asset studied has got characteristics close enough to traditional financial options so that the use of option valuation models may be relevant.

On the other hand, use of real options is questionable when ownership and exercise rights are rather low, i.e. case (C), what we call 'public domain'. At best in this case, real options can be used as a pure analogy because, as a valuation tool, it is not really useful, since neither the underlying asset value nor the exercise price assessments are easy. Png [1998, 392-395][28] defines 'public' ownership based on the notion of 'congestion': when several agents may use the same asset at the same time, without affecting each other's use, then this asset is 'public' and can be obtained freely. As noted by Dapena Fernandez [2001, p. 5], public property becomes private when congestion occurs and agents are competing to use the asset and are ready to pay to be the sole user. The same reasoning may be applied to real options that can be considered as public if anyone may access it freely whitout affecting the use of others. Therefore anyone may exercise the option without affecting the value of the option for others. In competitive markets, these cases seem rare.

[28] Quoted by Dapena Fernandez [2001, p. 5].

Case B concerns options for which ownership is shared by several agents but exercise rights are not. Hence, in Nikopol's case an employee may foresee the possibility to launch a new chemical formula, and therefore has a growth opportunity in his hands, but its exercise is limited by legal constraints[29]. The option value is then significant for the firm, which is the only agent to have the ability to exercise freely the option and obtain its value.

The opposite case (D) concerns an option that has only one owner but may be exercised by several agents. In this case the question is to understand if the option is exercised optimally for the firm. Therefore it questions the relationship between corporate governance and real options.

➢ Real Options and Corporate Governance

In Nikopol's case, the main researchers have been associated as shareholders of the firm for a long time. Moereover, based on the expected development of the firm, a capital risk company has invested in the firm. It has imposed conditions in a shareholders agreement, some of them indicating constraints on management's and researchers' use of their shares. Basically, it has attempted to make sure that key people would be retained and incentivized to stay in the firm, and increase its value.

Up to now we have assumed that the primary goal of the firm was to maximise shareholders' wealth and that the firm's agents (and, in particular, managers) aim to achieve the same goal. This assumption, common in corporate finance, is criticized (Tirole [2001]). There are alternative views, such as considering that other partners of the firm (stakeholders) will try to maximise their wealth also. Tirole shows that the traditional coporate finance view is linked to the assumption that all partners of the firm are protected by explicit contracts and paid at their opportunity cost. Only the shareholders who do not have guaranteed revenues should be protected by corporate governance mechanisms.

In the preceedings paragraphs we shave shown that including real options in the firm value, increases value it for all partners of the firm. At the same time, it is not certain that excercising options, and increasing the firm's value, will necessarily increase

[29] e.g. a non-compete clause in an employement contract.

shareholders' wealth. The case seems to confirm that shareholders are aware of these issues and try to align shareholders' and employees' interests.

Real options present a particular case of agency relationship: it concerns not only the capturing of value when creating real options, but also their optimal exercise. An agency relationship exists when there is a difference between ownership and control rights. When shareholders ('principals') and managers ('agents') are different persons, managers may make decisions, for their own benefit, that are sub-optimal for shareholders. To avoid this, the latter have a number of tools to control agents to whom they have delegated the firm's management (Tirole [2001, p.5]):

- Controlling structure: it includes all monitoring tools implemented by shareholders. For example, in Nikopol's case, investment funds have increased their impact on day-to-day management by using their voting rights and monitoring decisions taken by management (active monitoring). There are also passive monitoring tools that consist of controlling results of decisions already taken by management (e.g. financial analysts and rating agencies).
- Explicit incentives include salaries, but also bonus plans, stock options, free awards of shares, etc.
- Implicit incentives include all other elements that can influence managers. Hence career management and image are factors that may affect management's decisions and influence them so that they respect shareholders interests, more than their own financial interests.

When considering real options, people that may affect their value (when creating or exercising the option) are usually at higher levels of the firm or in specific areas (e.g. Research and Development). Therefore, to the traditional separation between management and shareholders, we may also add other agents: those that are able to hold-up the value of the options (those are defined as 'key people' in merger and acquisition contracts).

There are two different agency relationships here: when creating/identifying real options and when exercising them. In the former case, shareholders have to monitor managers and ensure they do not appropriate options for their own wealth. In the latter, shareholders have to ensure that options are optimally exercised to maximize their

wealth[30]. It is worth understanding how each of the three mechanisms presented above are efficient for these two relationships. The table below summarized these distinctions:

	Controlling tools		
	Explicit incentives	Implicit incentives	Monitoring
When creating the option	(+)	(++)	(?)
When exercising the option	(+)	(?)	(?)

Introducing real options in the firm's valuation complicates the analysis of agency relations within the firm. Explicit incentive tools seek to align managers' interests with those of shareholders by linking their respective financial gains. They seem to be equally efficient when creating or exercising real options. In both cases, financial criteria are the same for managers and shareholders, and mechanisms aimed at to identify the best decision from a financial point of view for the managers' wealth should also offer the best decision for shareholders. The difficulty then is to design an appropriate incentive scheme: when studying the case, it seems that offering shares or share derivatives is the most appropriate way since their value is supposed to include those of all growth opportunities of the firm[31].

Conclusions are harder to infer for implicit incentives. The incentive may be founded on the recognition obtained by management from an operation or its impact on their career According to Tirole [2001, p.27], these tools should be a substitute for explicit incentives when there are no easy ways to define precisely the performance criteria *ex ante*, but these criteria may be defined *ex post* with new information. Creation of real options may fall into this category: financial criteria might not be sufficient to incentivize managers to follow an active real options development strategy. In the case, the value of the project is rather difficult to assess (and to agree on) *ex ante*. Management and shareholders acknowledged this and decided to seek an independent valuation of the firm. At the same time, analyzing management strategy using career goals and image offers new ways to understand how managers may be incentivized to invest in real options, because of personal benefits that they gain from the operation. But it is not obvious that options would be exercised optimally if implicit monitoring

[30] For example, exercising a growth option might be justified by managers looking for image and recognition, not necessarily in shareholders best interests.

[31] This is not necessarily the case for other incentive schemes such as bonus paid based on results achieved (Sales or EBIT objectives).

tools are implemented. For example, Royer [2001] has shown in the case of options to abandon that it is rather difficult to decide to abandon a project, even if financial criteria recommend to do so, and that a 'champion' within the firm is usually needed to make the decision.

Monitoring tools seem to be less efficient at aligning management's and shareholders's interests when indentifying or exercising real options. Managers, as well as other key people within the firm seem to be in the best position to identify them early. However other employees are also in a good position to alter information on these real options in the monitoring process.

Tirole's analysis offers interesting ways to understand agency relations between management and shareholders. It should be adapted to other relations within the firm, e.g. with other employees. But it is worth noting also that this analysis should be extended to other partners (stakeholders) of the firm, such as customers or suppliers.

Introducing real options in the valuation should go along with a better understanding of agency relations at different levels of the firm and therefore of how the value created by theses options is shared between the firm's partners.

6. Conclusion

Real option models are based on a solid theorical background at the edge of financial theory. These models have been welcomed by practicionners and academics as a better way to model flexibility and uncertainty. But the implementation of these models has raised numerous difficulties.

Limitations linked to applying OPM outside financial markets have focused most of the attention. We have argued in this paper that there might other be limitations, several of which are related to the nature of the firm implicit in the financial valuation models. In order to highlight these difficulties, we have studied a real life case where a real option model has been applied. It seems that the ownership of real options and the way their value is attributed or shared between the various stakeholders of the firm might create agency relationships that have to be understood carefully. Therefore we have highlighted the need to deepen the understanding of the relationships between real options, corporate governance and firm boundaries.

REFERENCES

BANCEL (F.), RICHARD (A.) [2002], *Les choix d'investissement – Méthodes traditionnelles, flexibilité et analyse stratégique*, Editions Economica Gestion, 203 pages

BERGER (P.), OFEK (E.), SWARY (I.) [1996], « Investor valuation of the abandonment option », *Journal of Financial Economics*, n° 42, (257-287)

BERNSTEIN (P.L.) [1992], *Capital Ideas* [1992], The Free Press, New York – we refer to the French version of the text when available

BLACK (F.), SCHOLES (M.) [1973], « The Pricing of Options and Corporate Liabilities », *Journal of Political Economy*, vol.81, mai-juin, (637-659)

BORISON (A.) [2003], « Real Options Analysis: Where are the Emperor's Clothes?», *7th Annual International Real Options Conference,* Whashington DC, USA, 10-12 July*,* 30 pages

BREALEY (R.A.), MYERS (S.C.) [2000], *Principles of Corporate Finance*, Mc Graw Hill, 6th ed., 1093 pages

BUSBY (J.S.), PITTS (C.G.C.) [1996], « Real Options in Practice: An Explanatory Survey of How Decision Makers in Industry Think about Flexibility », *Warwick Business School Research Paper*, University of Warwick, n° 210, January, 24 pages

CHARREAUX (G.) [2001], « Variation sur le thème 'A la recherche de nouvelles fondations pour la finance d'entreprise' », *Presentation to the AFFI congress*, 7 December, Paris, 57 pages

CONNER (K.R.), PRAHALAD (C.K.) [1996], « A Resource-Based Theory of the Firm: Knowledge Versus Opportunism », *Organization Science*, vol.7, n°5, September-October, (477-501)

DAPENA FERNANDEZ (J.P.) [2001], « On the property of real options and the assets that give rise to them », *papier de recherche*, Universidad del CEMA, April, 17 pages

DURAND (R.), GOMEZ (P.-Y.), MONIN (P.) [2001], « Real Options Strategies », *Working Paper Lyon Business School*, n°1, 21 pages

HART (O.) [1995], *Firms, Contracts, and Financial Structure*, Clarendon Press, Oxford, 228 pages

HULL (J.C.) [2000], *Options, Futures, & Other Derivatives*, 4th ed., Prentice-Hall International

KOBRAK (C.), SPIESER (P.) [2000], « The Use and Abuse of Real Options for Project Evaluation and Management », *Presentation to the European International Business Academy Congress*, 10-12 December, Maastricht, 32 pages

KOENIG (G.) [1996], *Management stratégique – Paradoxes, interactions et apprentissages*, Nathan, 544 pages

LANDER (D.N.), PINCHES (G.E.) [1998], « Challenges to the Practical Implementation of Modelling and Valuing Real Options », *Quarterly Review of Economics and Finance*, vol.38, numéro spécial (537-567)

LAUTIER (D.) [2002-a], « Les options réelles : une idée séduisante, un concept utile et multiforme, un instrument facile à créer mais difficile à valoriser », *Working paper CEREG Paris IX Dauphine*, n°5, 25 pages

LAUTIER (D.) [2002-b], « Il y a des loups dans la forêt des options réelles », *Working paper CEREG Paris IX Dauphine*, n°6, 32 pages

LUEHRMAN (T.A.) [1998], « Investment Opportunities as Real Options: Getting Started with Numbers », *Harvard Business Review*, July-August (3-15)

MASON (S.P.), MERTON (R.C.) [1985], « The Role of Contingent Claim Analysis in Corporate Finance » in ALTMAN (E.), SUBRAHMANYAN (M.), *Recent Advances in Corporate Finance*, Richard D.Irwin, Homewood, (7-54)

MAUBOUSSIN (M.) [1999], « Get Real – Using Real Options in Security Analysis », *CSFB Equity Research*, June 23, 1999, 30 pages

MILLER (A.C.), RICE (T.R.) [1983], « Discrete Approximations of Probability Distributions », *Management Science*, vol.29, n° 3, mars (352-363)

MYERS (S.C.) [1977], « Determinants of Corporate Borrowing », *Journal of Financial Economics*, n°5 (147-175), reproduit *in* SMITH (C.W.Jr.) [1989], *The Modern Theory of Corporate Finance*, McGraw Hill (138-166) – we refer to this edition

PNG (I.) [1998], *Managerial Economics*, Blackwell Publishers

QUIGG (L.) [1993], « Empirical Testing of Real Option-Pricing Models », *Journal of Finance*, vol.48, n° 2, juin (621-640)

ROLANDO (T.) [1995], « De la valeur actuelle nette à la valeur d'arbitrage », *Working paper Lyon III University IAE*, Lyon, 25 pages

ROYER (I.) [2001], « Stopping-Champions of Failing Projects », *Academy of Management Conference*, Washington DC, 23 pages

SMITH (J.E.), NAU (R.F.) [1995] « Valuing Risky Projects: Option Pricing Theory and Decision Analysis », *Management Science*, vol.41, n°5, May (795-816)

TIROLE (J.) [2001], « Corporate Governance », *Econometrica*, n°69, vol.1, January (1-35)

TRIANTIS (A.), BORISON (A.) [2001], « Real Options: State of the Practice », *Journal of Applied Corporate Finance*, vol.14, n°2, Summer (8-24)

ZINGALES (L.) [2000], « In Search of New Fondations », *Journal of Finance*, vol.55, n°4, August (1623-1653)

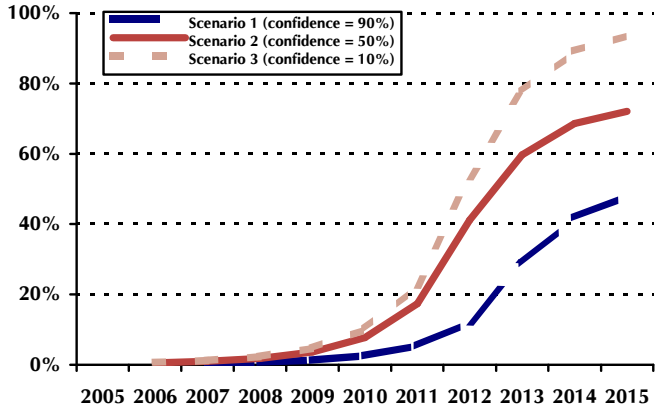
Appendix 1: Business plan

(in m of units)	2003	2004	2005	2006	2007	2008	2009	2010	2015	Terminal year
g produced	-	-	-	18,158	72,392	246,842	917,451	2,920,194	4,750,000	
Sales	-	-	-	658	2,276	7,055	24,000	74,435	117,313	121,429
Net sales	**-**	**-**	**-**	**658**	**2,276**	**7,055**	**24,000**	**74,435**	**117,313**	**121,429**
Cost of sales	-	-	-	(278)	(1,110)	(3,784)	(14,063)	(44,761)	(72,808)	
Direct production costs	-	-	-	(807)	(765)	(1,450)	(3,435)	(10,416)	(12,435)	
R&D costs	(115)	(96)	(101)	(106)	(112)	(212)	(720)	(2,233)	(3,519)	
Other costs	-	-	-	(550)	(883)	(2,076)	(6,160)	(11,322)	(17,726)	
EBITDA	**(115)**	**(96)**	**(101)**	**(1,083)**	**(593)**	**(467)**	**(378)**	**5,703**	**10,824**	**12,143**
Depreciation	-	-	(70)	(70)	(140)	(350)	(1,120)	(1,470)	(1,820)	(1,674)
EBIT	**(115)**	**(96)**	**(171)**	**(1,153)**	**(733)**	**(817)**	**(1,498)**	**4,233**	**9,004**	**10,469**
as a % of sales				*-175.2%*	*-32.2%*	*-11.6%*	*-6.2%*	*5.7%*	*7.7%*	*8.6%*
Income tax	-	-	-	-	-	-	-	-	(3,152)	(3,664)
NOPLAT	**(115)**	**(96)**	**(171)**	**(1,153)**	**(733)**	**(817)**	**(1,498)**	**4,233**	**5,853**	**6,805**

Appendix 2: Modelling of uncertainties

For illustrative purposes, we describe below how we modelled the uncertainty on the market share obtained by Nikopol[32].

We have assumed it could follow three different discrete scenarii that have been estimated by Nikopol's management based on their experience and on similar products' past performance. Probabilities have also been assessed on a subjective basis by the management : we have asked the management to estimate scenario 1 assuming that they would be 90% confident that the actual figure would be above the scenario (50% and 10% respectively for scenarii 2 and 3).



Assuming that the uncertainty is normally distributed, the discrete probability distribution for the three scenarios is then respectively 30%, 40%, 30% [33]:

[32] The same kind of reasoning has been applied to all uncertainties.

[33] An approximation of the relation between continuous and discrete normal distribution is described in Miller and Rice [1983]

Appendix 3: Full Decision tree