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# DEVELOPMENT PATH AND CAPITAL STRUCTURE OF BELGIAN BIOTECHNOLOGY FIRMS

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The views expressed in this paper are those of the authors and do not necessarily reflect the views of the National Bank of Belgium.

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## Editorial

On May 27-28, 2002 the National Bank of Belgium hosted a Conference on *"New views on firms' investment and finance decisions"*. Papers presented at this conference are made available to a broader audience in the NBB Working Papers no 21 to 33.


## Abstract

This study investigates the relationship between the evolution of real options values and associated financing policies for Belgian companies in the sector of bio-industries. Each firm's situation regarding the relevant types of real options is stylistically represented through a scenario tree. The consumption of a time-to-build or a growth option is respectively considered as a success or a failure in company development. Empirically, several variables enable us to locate each company along the tree at any time. The study of transitions leads us to discover that failures tend to trigger higher leverage, unlike in the trade-off theory. Yet, the increases in debt maturity, in lease and in convertible financing confirm our predictions. Overall, we emphasize evidence of undercapitalization and of proper, yet insufficient, use of hybrid financing by biotech companies.

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# 1 Introduction

For the last 20 years, the classical tool used for the analysis of investment decisions, namely the net present value approach (NPV), has been fiercely questioned by both practitioners and researchers. As Trigeorgis (1993a) points out, the main critiques are related to the fact that the NPV fails to capture the value of flexibility associated with many investment projects.

The real options approach aims to address the challenge of valuing investments with significant operating and strategic options. These options, that are embedded in investment decisions, can be of various types. The main categories are the option to defer the project, the time-to-build option, the option to switch outputs or inputs, the option to expand, contract, shut down or restart a project, the option to abandon and the growth options (see Trigeorgis (1999) for a review). Moreover, a lot of real-life projects involve multiple options interacting together (see Trigeorgis, 1993b).

The basic idea behind the real option approach is that the value of a project is no longer seen as only the discounted value of its expected cash flows: its inherent flexibility can be characterized and thus valued almost like financial options. The parallel with financial and real options is apparent in Dixit and Pindyck (1994), who derive theoretical valuation methods for different categories of real options, using a methodology in some points similar to the derivation of the Black and Scholes formula (1973).

In spite of the great theoretical advances made with the real options approach of investment decisions, early research in the field did not take into account the challenges of implementing the theoretical models with respect to specific investment projects (Lander and Pinches (1998); Perlitz, Peske and Schrank (1999)). Actually, recent empirical studies devoted to the testing of real option pricing models are extremely scarce and mainly focus on clinical approaches to the pricing of individual projects (see Kellogg and Charnes (2000); Jägle (1999); Pennings and Lint (1997)).

In particular, the inherent characteristics of R&D projects often make them difficult to value with a classical discounted cash-flow analysis. Per se, every R&D investment involves a lot of uncertainties: a project can fail at any stage of its development; cash flows at commercialization are very uncertain; new information can completely change the future cash-flows, etc. The shortcomings of the classical valuation tools are therefore extremely prejudicial to intensive R&D sectors.

Pennings and Lint (1997) view the R&D decision as the acquisition of an option to market a new product. They claim that NPV is inappropriate for valuing R&D projects because those with negative NPV would be rejected, even if in a real option perspective it might be interesting to un-

dertake them as they could provide valuable information about future cash flows of a project. In other words, the R&D decision is viewed as a growth option. The principle of such options was first exposed by Kester (1984), but its theoretical modelling has been mainly proposed by Pindyck (1988) and Kim and Maksimovic (1990).

Another complementary view comes from the finding that an R&D project usually has a sequential nature (Dutta, 1997). The investment is often made up of a number of stages, each one involving the possibility of going further in the development process or of abandoning the project. Majd and Pindyck (1987), Carr (1988) and Milne and Whaley (2000) developed the valuation framework of time-to-build options. More recent contributions can be found in Alvarez and Stenbacka (2001) and Panayi and Trigeorgis (1998).

The sequential nature of R&D can be recognized in a lot of projects; but it is especially visible in the field of biotechnologies. Jägle (1999) and Kellogg and Charnes (2000) give examples of biopharmaceutical R&D projects that can be analyzed as a sequence of real call options, similar to a time-to-build option. Each call option gives the right to go to the next phase of the development process of a drug, if the current stage is successful; conversely, if the current stage is a failure, then the option is not exercised and the company can liquidate the project. This framework corresponds to a compound option. On the other hand, Ottoo's (1998) valuation of a biotechnology firm uses a growth option approach. In his model, the R&D project is seen as an option to acquire a patent protection of the discovery, which will enable the biotechnology company access to monopoly rents. He manages to introduce the potential rivalry between similar firms in the option valuation framework. In a similar vein, Reiss (1998) analyzes the use of the option to patent in a competitive setup. She provides the strategies underlying the decision to patent an innovation before, after or at the same time as the R&D investment.

While the first type of options is especially suited to the case of the biopharmaceutical industry, growth options introduce a flexibility that is particularly adequate to the sub-sector of technology platform companies in the biotechnological industry.

In both approaches, R&D investment does not breed one, but a multiplicity of real options. In this case, Trigeorgis (1993b) shows that the presence of multiple options does not necessarily bear the additivity of the individual option values. Furthermore, Lander and Pinches (1998) mention that the assumptions necessary in order to make the model tractable may limit the scope of applicability of a real option model. Hence, relying on analytical formulas for real option values is not necessarily an asset when one wants to track real applications.

Adding to the complexity of the analysis on the investment side, the pres-

ence of real options influences financing decisions too. In his review paper, Trigeorgis (1993a) examines the relationship between real and financing options. He shows in the case of the option to abandon how the financing flexibility offered by a venture capitalist can improve the present value of the cash flows to equity.

In contrast with a large body of literature, our paper does not directly focus on pricing issues. Rather, we study interactions between investment and financing decisions of R&D-intensive firms. This is the reason for our choice of a very young sector like the biotechnology sector, with a large majority of companies that have not yet turned out to be profitable, as the ideal laboratory for this study.

On the investment side, its starting point is the integration of time-to-build options and corporate growth options together in a global lattice framework. Encompassing in a stylized way a variety of situations and developmental stages that a biotech company is likely to experience, the scenario tree proposed in the paper aims to identify its successive creations and exercises of real options over its early lifetime – from company creation to profitability.

With the help of this material, the second aspect covered in the paper is the empirical analysis of the consistency between biotech firms' financing decisions, in terms of their cost-flexibility trade-off, and the pattern of their investments in real options. The output of this delicate process ought to be both positive and normative. On the positive side, it represents the first empirical attempt to identify the link between the existence of options on both sides of the balance sheet. On the normative side, the objective of this paper is to improve managerial awareness of the need for consistency between a firm's stage of development and its associated financing vehicles. This has implications for the companies themselves, but also for the structure of the venture capital financing that provides most of the funds needed for their growth.

The paper will be organized as follows. Section 2 introduces the model used to locate biotech companies in a lattice framework. Section 3 proposes the implications of real options for the financing choices of R&D intensive companies. Section 4 presents the data and methodology used for empirical validation. Section 5 discusses the results. The final section concludes the paper and presents different sets of suggestions.

# 2 Identification of the development stage

## 2.1 Modelling principles

The first step in our theoretical modelling effort consists of characterizing the different operational stages a company may go through during its early lifetime.

Although every biotechnology company is unique, the whole sector can be characterized by several key features as far as real options are concerned. Firstly, the nature of R&D-intensive companies leads to the prevalence of time-to-build and growth options in their strategic value. Other types of real options may be present, but not to a systematic extent. Secondly, the sector is traditionally split into two parts: the biopharmaceutical industry, dominated by drug-producing companies, and the technology-based companies, which aim to develop proprietary techniques and services rather than therapeutics. However, the negative attitude of financial markets towards the latter subsector at the turn of the century has triggered a progressive evolution towards the emergence of mixed product-and-technology oriented companies, so that the distinction is no longer as clear as it was in the previous century.

As indicated in the introduction, time-to-build options perfectly fit the biopharmaceutical sector, while R&D effort itself for the development of proprietary knowledge is naturally addressed by growth options. In order to account for the whole sector, our modelling approach has to integrate both types of options in a single framework.

In this approach, the company creating a time-to-build option is considered to hold a real compound option: the passage from one state to another leads it to exercise a call option on another call option, and this process continues until the profitability stage is eventually reached. Therefore, the firm's stage of development can be situated along an asymmetric decision tree with one upward branch (corresponding to a whole series of successes) and many small downward branches (each corresponding to the failure of one stage).

Conversely, the growth option at a given stage can in fact be thought of as a portfolio of mutually exclusive options on the time-to-build option itself. The failure of a research, development or commercialization effort leads to the abandonment of the existing time-to-build option and the activation of a new option on a similar time-to-build option, but with a lower moneyness. It means that, for each stage of the time-to-build option, the firm moves along a long downward branch (corresponding to a series of up-front investments leading to no applicable result) with many small upward branches (each one representing the possible application of an initial investment).

Combining these two sets of options creates a global tree where each node

corresponds to a certain stage of development of the company. The mapping of successive instances of exercising or abandoning real options by the biotech company, from its creation to its maturity, on this scenario tree provides valuable information on the intensity of its use of time-to-build and growth options. It represents the first necessary step towards the identification of the relationships between its investments in intangible assets – mainly R&D – and its financing policy.

## 2.2 Construction of the tree

The construction of a workable scenario tree requires the following assumptions:

1. The company has to succeed in three sequential stages before becoming a mature company. The first stage consists of investing in basic research in order to find a product or service to be developed. At the end of this first stage the company possibly patents these results. The second stage is the development of this product or service, followed by the third stage of commercialization. If this is successful, then the company eventually becomes profitable.

2. At each stage there are three possibilities: the investment may be successful and the company moves one stage further; the investment does not lead to positive results and the company has to restart the same stage with a failure; or the investment has not given any conclusive result over the period considered and the firm remains in status quo.

3. Each branch of the tree corresponds to a new, substantial capital expenditure, either in order to move one stage ahead (in case of success), or to purchase a new growth option with an additional investment in the current stage.

4. Whenever the company succeeds in one stage, irrespective of the number of failures it has experienced before, it begins the next one with a renewed growth option.

We denote as $i = 0, 1, 2, 3$ the number of distinct stages fulfilled in the first part of the life cycle of the company – i.e. until it becomes profitable, and as $j = 0, 1, 2, ...$ the number of failures experienced by the company in its investments in a given stage. Furthermore, the periodicity of observation is one year.

The tree including the growth and time-to-build options is likely to be partially non-recombinant. However, its stylized representation - for empirical purposes - will display a reduced number of nodes. Moreover, the existence of a growth option also enables the company to abandon the project after a given number of successive failures. Without loss of generality, we set the maximum number of successive failures as two.

In order to determine what path each individual company has followed since its inception and at what stage it is situated, we look at the variation of the following four variables:

$a_{ij}$ = R&D expenditure at node $ij$

$r_{ij}$ = Revenue at node $ij$

$\pi_{ij}$ = Profit at node $ij$

$p_{ij}$ = Probability of success at node $ij$

Figure 1: *Scenario tree with growth and time-to-build options*

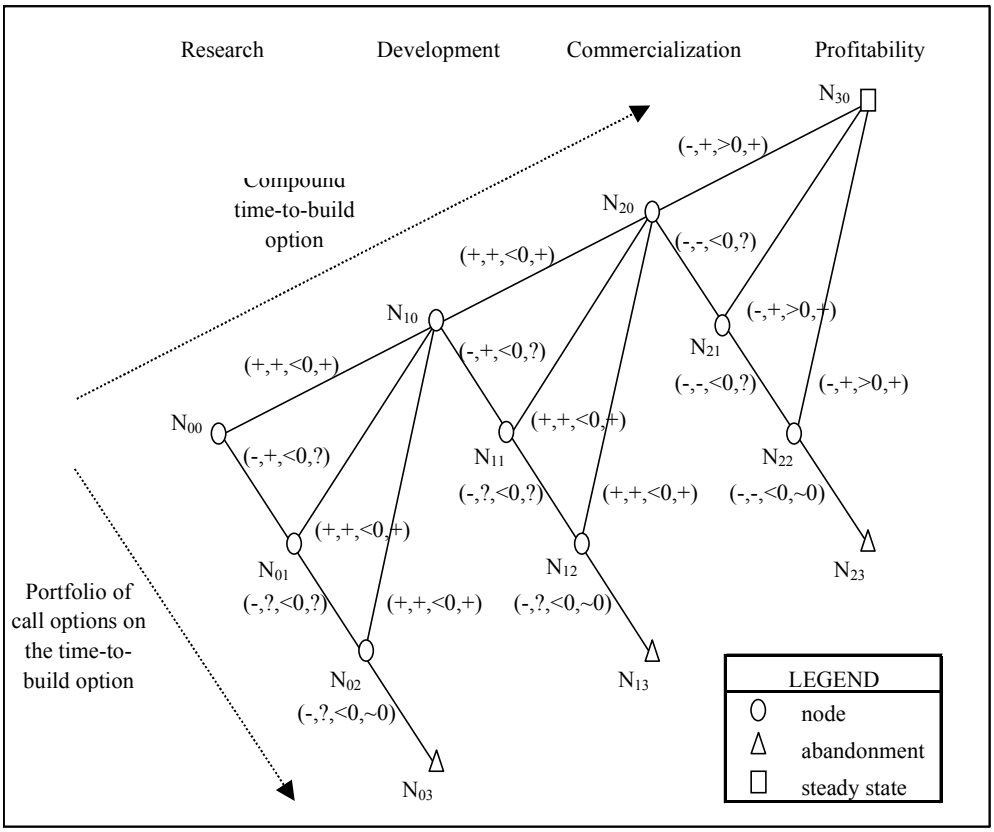



Figure 1 presents a stylized version of the scenario tree in the case of growth and time-to-build options and incorporates the sign of the expected

variation of the four key variables described above from one node to another. The order within each parenthesis is the same for each branch and corresponds to: ($a_{ij}$,$r_{ij}$,$\pi_{ij}$,$p_{ij}$). A positive (negative) sign corresponds to an increase (decrease) in the variable, except for the profit variable, for which we only mention the sign of its monetary value.

We apply the following rules to determine the evolution of these values:

1. At the research and the development stages, any success is associated with a substantial increase in the R&D effort, whereas in case of a failure, the subsequent effort to restart the same stage is lowered thanks to the growth option. The ex-ante probability of success following a failure is indeterminate, but it tends to zero as the number of failures becomes large.

2. At the commercialization stage, relative R&D expenses obviously decrease, whatever the outcome of the marketing effort. At this stage the investment of the company will mainly be made in tangible assets.

3. Revenues are considered to increase with the number of successes, except in case of a failure at the commercialization stage.

4. Similarly, profits are assumed to be negative as long as the company has not reached the mature state.

By analyzing this sequence of signs at each branch, we notice that the research and the development stages have similar features. Therefore the tree could be shortened for companies where the research and development stage are mixed (for example, if no patent is issued after the research efforts, it is difficult in practice to differentiate between the two stages), or where the basic research has already been made before the company's incorporation. Similarly, the tree could be expanded for companies where the development stage is composed of easily identifiable sub-stages, as in the drug-discovery process.

## 2.3 Evolution of real option values

Once company profiles are reported on the tree, a second step is now to look at how the values of the real options vary along each branch.

Define $B_{ij}$ and $G_{ij}$ (the value of the time-to-build and growth options respectively) at node $i, j$. Let $\Delta_j B_{ij} = B_{ij+1} - B_{ij}$ be the difference in the value of the time-to-build option from node $i, j$ to node $i, j+1$. The expression $\Delta_j G_{ij}$ is similarly defined. Due to the particular structure of the tree, every

success leads to a passage from node $i, j$ to node $i+1, 0$. Therefore, the expression $\Delta_i B_{ij}$ corresponds to the difference $B_{i+1,0} - B_{ij}$ and similarly with $\Delta_i G_{ij}$. The *relative exercise value* of these options, denoted $B^e_{ij}$ and $G^e_{ij}$ for the time-to-build and growth options respectively, represents the ratio of the option value if it were immediately exercised over its total value. Similarly, we can also define the *relative volatility value* of the options, denoted $B^\sigma_{ij}$ and $G^\sigma_{ij}$ respectively, as the ratio between the volatility value of the option (defined as the difference between the total value of the option and its exercise value; see Hull (2000)) and its total value. Obviously, $B^e_{ij} + B^\sigma_{ij} = 1$.

The total value of real options held by the firm, $V_{ij}$, is just the sum of the two individual options[1]:

$$V_{ij} = B_{ij} + G_{ij}$$

Thanks to this specification, we can characterize the evolution of these options with the following stylized analysis:

- According to this partially recombinant tree, every step upwards is considered as a success: it consumes one stage of the time-to-build option. Considering that this is essentially a compound option, it results in an increase of the moneyness of the remaining option while sharply reducing its relative volatility value. Therefore, we find that, in general, $\Delta_i B_{ij} > 0$, $\Delta_i B^e_{ij} > 0$ and $\Delta_i B^\sigma_{ij} < 0$.

- In case of success, the existing growth option is replaced by a new one at the next stage, irrespective of the number of successive failures experienced. Due to the scale enhancement following each success, the new growth option value is likely be greater but, as the effort is less R&D intensive, the output of the investment is likely to be less volatile than at the previous stage. Therefore, we can write $\Delta_i G_{ij} > 0$, $\Delta_i G^e_{ij} > 0$ and $\Delta_i G^\sigma_{ij} < 0$.

- When the company experiences a failure, it decides to postpone (or abandon) the exercise of its time-to-build option. This is due to the fact that the odds have decreased, and the firm must exercise part of its growth options in order to let the project continue. By becoming less in the money, the compound option value decreases but its relative volatility value increases: $\Delta_j B_{ij} < 0$, $\Delta_j B^e_{ij} < 0$ and $\Delta_j B^\sigma_{ij} > 0$.

[1] In this case, the options are perfectly complementary and so additive because their values are considered node by node, taking into account the interactions between them as successes and failures occur.

- The failure at a development stage involves the possible exercise of a growth option if the firm wants to keep its time-to-build options alive. However, unlike the time-to-build option, growth options are not compound options: they represent a portfolio of options on the time-to-build option ranked by decreasing value order. The exercise of one of them induces a decrease in total option portfolio value. The remaining ones are less in the money. Hence, we can write $\Delta_j G_{ij} < 0$, $\Delta_j G^e_{ij} < 0$ and $\Delta_j G^\sigma_{ij} > 0$.

Consequently, the occurrence of a success or a failure leads to an unequivocal variation in total real option values: for a success, $\Delta_i V_{ij} > 0$, $\Delta_i V^e_{ij} > 0$ and $\Delta_i V^\sigma_{ij} < 0$. For a failure, $\Delta_j V_{ij} < 0$, $\Delta_j V^e_{ij} < 0$ and $\Delta_j V^\sigma_{ij} > 0$. This leads to the following workable hypothesis:

**Proposition 1** *Each success on the scenario tree increases total option value, but reduces its relative volatility value; the reverse holds for each failure on the scenario tree.*

*Proof.* Follows from the above discussion.

For each path, we are thus theoretically able to characterize whether the firm has increased or decreased the optional component of its investments from the previous stage. This must be related to the aim of the paper, which is primarily to link the investment process of these firms with their financing policies.

## 2.4 A note on status quo

Proposition 1 provides clear-cut interpretations for movements along the tree with respect to their impact on real option values. Unfortunately, it does not provide any satisfactory explanation for the situation where a firm fails to move from one period to another, i.e. it remains in its status quo.

In fact, the effect of such a lack of development is indeterminate. One can interpret it as a failure: in this case, the immobility of the company would indicate its inability to turn a project into a success, forcing it to undergo an undesirable delay in its development. This kind of explanation is likely to be more relevant in the case of an advanced stage such as commercialization or profitability. On the other hand, status quo could be interpreted as similar to success where there is a long development process that requires several years of effort. The absence of movement along the scenario tree indicates that the project has not been abandoned early, which is quite good news.

Of course, one cannot unequivocally associate a status quo with a success or a failure for a given stage on the tree. However, the above discussion

suggests the possibility of a more favorable interpretation of immobility at the R&D stage than at the commercialization stage. However, this is a conjecture rather than a hypothesis, and also needs to be checked against real data.

# 3 Identification of financing needs

This section reviews theoretical as well as empirical evidence on capital structure decisions in the presence of real options, with a focus on the foreseen implications for the nodes and branches of the above developed scenario tree.

## 3.1 Traditional theories of capital structure

The traditional theories of capital structure, namely the so-called 'trade-off theory' and the 'pecking order theory' do not explicitly address the presence of real options and the subsequent need for financial flexibility. They mainly focus on the role of debt and equity, and do not explicitly account for the role of hybrid financing instruments – such as convertible bonds, preferred stocks or warrants – in capital structure decisions.

### 3.1.1 Trade-off theory

This theory is the historical extension of the seminal papers of Modigliani and Miller (1958, 1963). In the presence of taxes, Modigliani and Miller (1963) conclude, in their Proposition 1, that firms should entirely finance their investments with debt. Of course, the underlying motivation for using debt is the deductibility of interest expenses. In particular, a young company that has not yet reached profitability may not fully benefit – or even not at all if tax loss carry-forwards are never used – from the tax shield of debt. In this case, the pure no-tax model claims the irrelevance of capital structure decisions.

In the presence of direct as well as indirect costs of financial distress (see Booth, Aivazian, Demirguc-Kunt and Maksimovic (2001) for a recent review), which are assumed to grow more than proportionally with the debt ratio, actual firm leverage is likely to decrease and be set to a target level.

In the context of this theory, the presence of real options is only indirectly represented through the factors that influence the costs of financial distress. In particular, a specific form of agency conflicts, namely between shareholders and debtholders, predicts that the presence of growth options in the investment prospects of the firm has a strong influence on the optimal level of debt.

The underinvestment issues due to the debt overhang problem (Myers, 1977) tend to preclude managers of highly risky firms from investing in positive NPV investments if they fear that the cash flows to equity would not be sufficient due to excessive debt costs; on the other hand, the asset substitution problem (Jensen and Meckling, 1976; Galai and Masulis, 1976) leads shareholders to expropriate value from bondholders by adopting over-risky investment projects. In the presence of debt, these two types of issue increase, and debt becomes more costly in order to protect bondholders against misbehavior by managers, who represent shareholders. The relevance and intensity of these problems is directly related to the volatility of future cash flows: for a growth firm, they are likely to be more serious, making debt less attractive (Myers, 1977; Green and Talmor, 1984). Along the same lines, Miguel and Pindado (2000) empirically show that the indirect bankruptcy costs of debt are positively related to the proportion of intangible assets, whose liquidation value are lower than tangible assets, while volatility of asset value is also likely to induce a greater probability of default (Anderson and Sundaresan, 1996).

Since the tax shield argument is hardly relevant for young firms in the biotechnology sector, one would expect a low target debt ratio. Moreover, these firms exhibit a risk profile that makes them prone to debt-related agency problems. In particular, every failure that leads to a higher relative volatility value of the real options is likely to increase the intangible proportion and volatility of these companies' assets. Conversely, the partial exercise of time-to-build options reinforces the asset base and the intrinsic value of real options, calling for higher leverage. Consequently, on the basis of the trade-off theory, we expect that each failure at the R&D stage will reduce leverage while each success will trigger a positive variation of the gearing ratio. The theory is inconclusive on status quo situations.

### 3.1.2 Pecking order theory

Donaldson (1961) discovered that firms tend to primarily finance new investments with internal cash flows, and if they have to go to the financial market, they first rely on new debt, then on convertible bonds, then on additional equity. Based on the information asymmetry between managers and the financial markets, Myers and Majluf (1984) formalized this finding, under the term 'pecking order theory'.

There is a considerable debate in the literature about the implications of the pecking order theory for growth firms with little internally generated cash flows and high financing needs. As previously mentioned, the trade-off theory predicts low leverage levels; however, on the basis of the pecking

order, the first available source of funds for these companies should actually be debt. Shyam-Sunder and Myers (1999) empirically document that, while evidence of a target leverage may be sustained for the cross-section of listed firms, their dynamic behavior more closely corresponds to the hypotheses of the pecking order theory.

Since the scenario tree implies that firms are observed in their dynamic financing decisions, the ordering of financing sources is a relevant issue. Along the tree, firms hardly generate internal cash, so that their new financing needs do usually force them to ask for outside funds. The pecking order theory predicts that the lower the need, the more likely it is that firms will issue mainly debt. For larger needs, debtholders alone may not be able provide sufficient funds, so that the company has to turn to the shareholders. Since a failure requires less funds than a success, leverage is predicted to be lower in the latter situation. As stressed by Fischer, Henkel and Zechner (1989), convertible debt is located between debt and equity in the preference ordering underlying the pecking order theory. Therefore, when outside funds are required, it is predicted that firms will try to issue convertibles before going to the stock market.

It must be stressed, however, that this theory is relevant for situations where information asymmetries are likely to be serious, i.e. for relationships between firms and the outside market. When fund providers monitor the firm closely, as in the case of bank or venture capital financing, moral hazard is less relevant to the analysis. Therefore, this result is mostly salient for public debt.

## 3.2 Private financing vehicles

### 3.2.1 Venture financing

The financing of biotechnology companies in their early development stage is typically dominated by the recourse to equity issues subscribed to by business angels and venture capitalists (henceforth VCs). This recourse is motivated by two main reasons: young firms with high R&D expenses and a high proportion of intangible assets face high incentive problems related to serious information asymmetries (see Helwege and Liang (1996) for an empirical validation), making monitoring extremely valuable for the reduction of agency issues (Lerner, 1995); and their exit strategy does not put a high emphasis on the valuation of majority stakes, which allows entrepreneurs to value their call option on control (Bergemann and Hege, 1998; Black and Gilson, 1998).

In this agency framework, Bergemann and Hege (1998) show that VC financing provides better monitoring than arm's length (i.e. outside) eq-

uity. VCs acquire information on the firm's quality in connection with their investment. In this context, successes release positive information on the quality of the firm, resulting in greater expected value to be shared among the entrepreneur and the VCs. It is predicted that the equity share of the entrepreneur is likely to steadily decline. All in all, financing by VCs will thus mix new debt and equity as successes pile up.

If failures in the R&D process accumulate, the liquidation value of the firm is likely to decline, and VC monitoring will become closer, because the entrepreneur will only be rewarded in case of success. Therefore, the model predicts that the firm will then issue more debt than equity or, more conveniently, convertible debt, which better fits the needs of both parties. Leverage may then increase because of this greater control required by VCs, contradicting the common argument of the trade-off theory, which would suggest that the gearing ratio should become lower.

### 3.2.2 Debt structure

Given that most firms in the biotechnology sector are not listed, the bulk of their debt structure is private. In the spirit of the analysis of Bergemann and Hege (1998), private debt offers more flexibility than arm's length debt (see Anderson and Makhija, 1999).

Krishnaswami, Spindt and Subramaniam (1999) empirically show that firms with high contracting costs tend to use mostly private debt. As put forward by James (1987), public debt typically has a longer maturity than private debt. Datta, Iskandar-Datta and Patel (2000) argue that high growth firms tend to issue shorter-term, private debt in order to mitigate Myers' underinvestment problem. These findings, together with the study of Barclay and Smith (1995) relating contracting costs to the presence of growth options in the asset structure of the firm, suggest that the relative importance of growth options calls for private debt financing with a shorter maturity than public debt when the relative growth option value is high; i.e. when the firm moves down on the scenario tree. By contrast, the extension of maturities and the relatively higher proportion of tangible assets in case of exercise of time-to-build options would lead to a shift towards public investments with longer average debt maturities.

### 3.2.3 Debt maturity

Although the preceding subsection suggests that the optional component of the asset structure calls for higher amounts of private debt with shorter average maturities than public debt, it does not provide insights into maturity

structures inside debt classes.

Bergemann and Hege (1998) show that longer maturities provide a greater scope for renegotiation, and that short-term refinancing on a competitive basis can never be optimal. The consumption of growth options in case of failures reduces the value of the total growth options portfolio while increasing its relative volatility value, leading to this need for greater financial flexibility. In the scenario analysis of Trigeorgis (1993a), the ability to renegotiate debt is shown to provide a valuable source of flexibility for the entrepreneur experiencing a failure in a development stage. As failures lead to an increase in the relative volatility value of the growth as well as time-to-build options, this suggests that average debt maturity – irrespective of the optimal debt level – should increase for a company moving down the scenario tree.

### 3.2.4 Leasing

The role of lease financing for start-ups should not be underestimated. For small, high-tech start-ups, debt monitoring by banks may prove to be less easy than for more mature businesses. When the firm experiences a shortage of funds, e.g. after one or a series of failures, it may be led to obtain new cash through the least costly source of outside funds in terms of information asymmetry. The debt contract that provides immediate guarantee to the lender in case of liquidation is the leasing contract. Not surprisingly, empirical evidence, although limited, documents that leasing is a favored source of debt in the pecking order theory for the compensation of a shortage of funds (Huyghebaert, 2001). This suggests a relatively heavy use of lease financing for companies experiencing failures in their R&D process.

### 3.2.5 Hybrid financing

The role of hybrid financing for small growing companies is particularly well documented for convertible debt. Preferred equity is the least favored source of financing in the pecking order theory (Fischer, Henkel and Zechner, 1989). Debt with warrants shows some similarities with convertible bonds, but with a greater focus on its ability to kick new equity upon exercise of the options. This technique is most suitable for listed companies with an active secondary stock market, and seldom used for small start-ups.

A common argument in the literature is that the issue of convertible securities is an excellent financing vehicle for high growth, young firms whose riskiness is hard to assess and who are thus able to sell their volatility through an option-related financial security (Brennan and Schwartz, 1992). When straight debt becomes more expensive, i.e. after some failures have taken

place, convertible debt becomes an increasingly favored solution for issuing securities that do not have to send negative signals to the market. This "pooling equilibrium" explanation to the issue of hybrids is validated by Bhabra and Patel (1996) and Munro (1996).

Consequently, when the relative volatility value of the option increases, the issue of convertibles is an efficient way to avoid signalling a failure to the market. This financing vehicle is thus consistent with downward movements on the scenario tree.

This argument is somewhat formalized by Trigeorgis (1993a) and Mayers (1998), who heuristically show that the presence of real options makes the availability of flexible financing instruments valuable. On the other hand, in the absence of real options, the traditional trade-off theory suggests that basic financing vehicles like debt or equity are preferable to hybrid securities in terms of tax shield and bankruptcy considerations respectively.

## 3.3 The role of patenting

In this framework, protection of intellectual property may be interpreted differently, depending on whether the company has gone up or down on the tree.

It is commonly argued that R&D investment creates real options for patenting. According to Takalo and Kanniainen (2000), protecting intellectual property through the issue of a patent has the immediate consequence of decreasing the relative volatility value of the existing options, but also creates an additional option to wait. Therefore, patenting leads to a slow-down in the market introduction of the commercial product, and calls for longer-term but also flexible financing. In addition, the patent transforms intangible research into a tangible asset, inducing debtholders to require relatively less exigible financing devices such as short-term debt, especially after a failure in R&D.

Hence, the observation of patent adoption at a given stage or between two stages would be consistent with a relatively high amount of convertible debt or equity, and certainly a reduction of short-term debt financing.

## 3.4 Summary

From all these theories and empirical validations, it is now possible to stylize the likely developments of the capital structure in the case of a failure and of a success in the R&D or commercialization process.

The discussed models predict the following differences with respect to successes:

H1. higher leverage in case of success (subsection 3.1.1); lower leverage in case of failure except for higher debt financing by VCs (subsection 3.2.1)

H1a. among public financing sources, the issue of more debt than equity in case of failure; the reverse in case of success (subsection 3.1.2)

H1b. higher debt financing by VCs in case of failure; the reverse in case of success (subsection 3.2.1)

H2. lower equity ownership (in %) by VCs in case of failure; the reverse in case of success (subsection 3.2.1)

H2a. more private debt financing than public debt financing in case of failure; the reverse in case of success (subsection 3.2.2)

H3. longer debt maturity in case of failure; the reverse in case of success (subsection 3.2.3)

H4. more lease financing than other types of debt financing in case of failure; the reverse in case of success (subsection 3.2.4)

H5. more convertible financing than other types of debt financing in case of failure; the reverse in case of success (subsection 3.2.5)

Overall, therefore, available research predicts a reduction in leverage with a reshuffling of debt instruments when the firm experiences failures in R&D in comparison with the situation where the company evolves to the profitable stage. However, VC financing may turn towards debt instruments for monitoring purposes as the firms' projects become more hazardous.

Hypotheses H1a, H1b and H2a are sub-hypotheses that look more closely at the structure of ownership (public, private and VC) rather than at their nature. We will see later how difficult – and even impossible – it is to test these with Belgian data.

Furthermore, firms that patent from one stage to another are likely to use more flexible and long-term financing, such as convertible debt (H6).

In the next section we will detail the methodology used to tests these six hypothese empirically.

# 4 Data and methodology

We come now to the second aspect of our study: the empirical analysis of Belgian biotechnology firms' capital structure with respect to the theoretical proposals elaborated in the first part of the paper. In order to perform this empirical study, we first describe the sampling process. Then we detail how we define and construct the variables needed for the hypotheses tests on capital structure. The end of this section is devoted to the empirical equations used to test these hypotheses.

## 4.1 Sampling process

The Belgian biotechnology sector is not recognized per se in the NACE industry codes system; this is explained by the fact that biotechnology can lead to various applications. Indeed, the bio-industry is traditionally split into three segments. The bio-pharmaceutical segment includes drug development, diagnostics and medical devices, medical services and bio-informatic firms. In the bio-agro segment, biotechnology is used in agriculture and the food industry. Finally, the bio-environmental segment uses biotechnological processes for waste treatment and recycling. Given this broad range of applications, it is not straightforward to identify the companies active in the biotechnology sector. This is why we did not use company selection criteria based on a formal sector classification; rather, we selected firms[2] on the basis of various listings established by different associations or public organisms supporting biotechnology in Belgium. More precisely, we used information from the Belgian Bio-Industry Association, the DGTRE of the Walloon Region and the VIB of the Flemish Region, as well as secondary sources[3]. By integrating these various sources of information, we obtained a list of 80 companies representing the population of Belgian biotechnology firms.

The theoretical model is set up in order to characterize a young growing biotech company from its inception and to look at how its path from early research to profitability is financed. The aim of this research therefore highly influences the sampling process and leads to the elimination of a certain number of firms.

First, our population contains both stand-alone companies and biotech subsidiaries of large multinational biotechnology or pharmaceutical companies. These subsidiaries were excluded from our sample partly because they do not fit into our model of young growing biotech companies, but also be-

[2]By firms, we mean commercial and industrial corporations. This therefore excludes university or public laboratories.

[3]Our company list emerges from the integration of the following primary sources:

- Belgian Bio-Industry Association (BBA), www.bba-bio.be (2001);
- Directorate General for Technologies, Research and Development (DGTRE), *Wallonia Homeland for Biotechnology* (June 2001);
- Flanders Interuniversity Institute for Biotechnology (VIB), www.vib.be (2001).

These primary sources were supplemented and/or compared with various secondary sources:

- Brandeleer M., L'or des gènes: promesses belges (October 12, 2000), *Trends-Tendances*, pp.20-28.;
- Briquet L., Biotechnologies: "Le" secteur du XXIe siècle? (November 14, 2000), *L'Echo*, p. 4.;
- Rentier B., Biotechnology in Wallonia: recent initiatives (May 2001), presentation at the *Bioforum,* Liège.

cause their affiliation to a mother company precludes relevant comparisons with stand-alone companies and makes their capital structure dependent on their mother company, both on the equity and the liabilities side. Second, part of our population is made up of very young companies for which we do not necessarily have the annual accounts data, or only one year of data. Consequently, a few companies were excluded for data availability reasons. Third, some companies labelled nowadays as biotechnology firms are in fact older agro-food or pharmaceutical firms that only switched to biotechnology-oriented activities in recent years. In the case of three of these, the activity switch date is clearly mentioned in their annual report. But for other companies, the timing of the activity switch is unclear, and consequently leads to their exclusion. Moreover, these companies were usually created before 1984, the first year of the current format of annual accounts. These companies therefore also have to be excluded because of data availability and comparability problems. Finally, some firms were eliminated because their activities did not in our opinion obviously classify them as part of the biotechnology sector.

In summary, our final sample includes forty Belgian companies with an average life of nine years. The distribution of this sample across regions and bio-segments and the names of the companies are presented in the appendix.

## 4.2 Variables definition and construction

Two sets of variables are needed for the empirical analysis. The first set contains positioning variables used to locate each company along an empirical tree. The second set is made up of financing variables necessary to test the capital structure hypotheses.

### 4.2.1 Positioning variables based on an empirical tree

The first step in the empirical study consists of locating, for every accounting year, each biotech firm along an empirical tree (bearing in mind that they may stay for several periods at each node). In order to perform this location, we define four criteria variables representing binary information about the sign of either the absolute value or variation of a number of asset and income variables. These criteria then allow us to build up a simplified version of the theoretical tree and to derive a number of rules in order to associate with each observation one of the three stages depicted in the empirical tree. Among the R&D and commercialization stages, we refine the rules to discriminate between a failure and a status quo situation. Finally, the evolution of each

company from one node of the tree to another enables us to construct a "branch" variable.

**Definition and construction of the criteria variables** The most basic classification of the observations is the cutoff point between the profitability state and the other stages. For this purpose we build a discrete variable indicating whether the company is profitable or not. The profitability dummy is equal to 1 when the operating result is positive and greater than in the previous year.

A second classification level concerns the distinction between commercialization and R&D. Several variables can be used for this purpose: R&D expenses, revenues, and acquisition of tangible assets. Nevertheless, we choose to construct a criterion based only on the variation of the acquisition of tangible assets. It is reasonable to link the commercialization stage with an increase in tangible asset investments, as at this stage the company needs to set up the production tools. The tangible assets dummy is defined as being equal to 1 when the acquisition of those assets is greater than in the previous years.

We do not use the evolution of R&D expenses or revenues for the second classification level because they are needed at a third level, in order to detect failures within the R&D and commercialization stage. The R&D binary variable is equal to 1 if R&D expenses or investments in intangible assets is greater than in the previous years. We also include intangible assets in this criteria because such items, when they do not directly consist of R&D expenses, are nevertheless closely related to the research and development activity of the firms. In our sample, the majority of intangible assets other than R&D expenses are patenting costs. The revenue variable is equal to 1 when operating revenues, sales or added value are greater than in the previous year. The use of added value as a measure of the activity evolution is motivated by the fact that this is the only measure that has to be released in abbreviated versions of Belgian annual accounts. Table 1 summarizes the annual accounts data sources for each positioning variable[4].

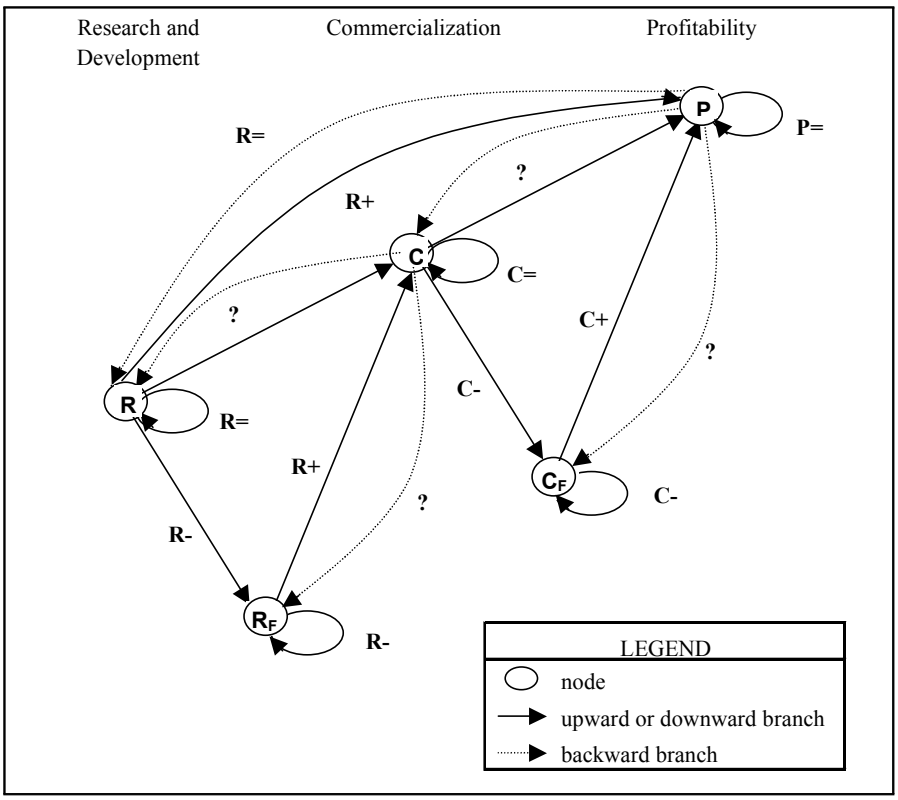
[4]We benefited from accounting data provided by NBB (Brussels). This data was then updated by the Liège branch of NBB. We would like to thank the NBB staff, and particularly J. Devrecker at the Liège branch, for their precious help.

Table 1: *Definition of the positioning variables*

| **Positioning variable** | **NBB accounts item** |
|---|---|
| Profitability dummy | $70/64_t$ and $\Delta 70/64_t$ |
| Tangible assets dummy | $\Delta 8169_t$ |
| Revenue dummy | $\Delta 70_t$, $\Delta 70/74_t$ or $\Delta 9800_t$ |
| R&D dummy | $\Delta RD^5{}_t$or $\Delta(8029 + 8049)_t$ |

**Location on the empirical tree** Figure 2 depicts a simplified version of the theoretical tree.

Figure 2: *Empirical tree*




Comparing to Figure 1, the research and development stages have been merged. Moreover, this tree allows for "comebacks" along the tree. For the empirical study,we need to distinguish only three stages for success and one node for all failures in one stage:

[5] The definition of R&D will be detailed later in this section. Our R&D variable contains more information than the amount of item 8021 in the annual accounts; it has been supplemented from various secondary sources.

- Stage 1: Research and development, represented by nodes R and $R_F$ (for R&D after a failure);

- Stage 2: Commercialization, represented by nodes C and $C_F$ (for commercialization after a failure);

- Stage 3: Profitability, represented by node P.

**Construction of the "node" variable** In order to associate every accounting year with a single node of the empirical tree, we build up a set of rules derived from the values the positioning variables defined above. Most rules are straightforward with respect to the definition of the stages. Node P is associated with a positive profitability dummy. Nodes C and $C_F$ are both associated with a positive tangible assets dummy. Nodes R and $R_F$ derive naturally from a zero value in both of these first two dummies. Node $C_F$ is selected when the revenue dummy is nil and node C is selected otherwise. Finally, a failure in the R&D process has been associated in the first part of the study with a reduction of R&D investments. Therefore, node $R_F$ is associated with an R&D dummy equal to 0, node R being selected otherwise.

As these rules derive mostly from variables specified in terms of variations, they cannot be applied per se to the first observation of each firm. This is why we use a second set of rules for the initial node. Per definition, the initial node cannot be one of the "failure" nodes $R_F$ and $C_F$, but is not necessarily the R&D stage. Three supplementary rules are therefore needed. To detect a stage P initial node, we use only the sign of operating profit. The distinction between the first and second stage cannot be made with the help of a tangible asset variable. Instead, we use another accounting item characterizing the commercialization stage: the presence of positive inventories. If inventories are nil, then the initial stage is R&D.

All these rules allow us finally to create a discrete position variable that can take three possible values according to the stage the company is engaged in. We will use this position variable in the empirical study to describe static capital structure characteristics of the three stages under consideration in our study.

**Construction of the "branch" variable** The last step in this locating procedure consists in detecting successes, failures and status quos in the first two stages. Again, a set of simple rules allow us to detect the dynamic aspect in the tree. Most rules are straightforward when ones looks at the empirical tree. A success in commercialization is always related to the change from stage 2 to stage 3. A similar rule holds for a success in R&D, with one supplementary case: a direct route from stage 1 to stage 3 must be interpreted

in the same way as one from stage 1 to stage 2. The detection of failures in stages 1 and 2 is directly linked to a position on nodes $R_F$ and $C_F$. Finally, a status quo situation in stages 1 and 2 arises when the company either begins on the tree in these stages or remains in these stages from one year to another.

Some special branches that can arise in the data set must be taken in to account. First, when a company goes back from stage 3 to 1, we interpret this as a new start and associate a status quo situation in stage 1 with this branch.

Second, one step backward (from stage 3 to 2 or 2 to 1) is more difficult to interpret. It can mean a failure or a status quo situation in the "arrival" stage. For this reason, we decided to leave this issue for interpretation with empirical tests.

We summarize the dynamic information in a discrete evolution variable, which can take eight different values: failure, success, or status quo in R&D or commercialization (6 values), profitability, and undetermined evolution.

**A note on R&D expense data** [6] The R&D expense measure used for the positioning variable does not solely correspond to the amount of R&D acquisitions in the annual accounts. Measuring the R&D effort of a company is quite difficult in the current version of annual accounts. R&D may of course be found within intangible assets once they are capitalized. But it may also remain in the income statement, where it becomes virtually impossible to discriminate between expenses according to their purpose.

This identification problem can be partly solved by reading the "management report" included in the complete annual accounts. Belgian company law requires firms to detail their R&D activity in this report. Nevertheless, as Art. 96 of Belgian company law does not clearly state what kind of information the management report has to give about R&D policy, the information provided in the management report is not always useful for gaining insight into R&D expenses in the income statement. Despite this limitation, all quantitative data in the management report was taken into consideration in the R&D expense variable.

We also checked the R&D measure using non-accounting information. For instance, R&D investment data has to be released by companies if they want

[6] We are grateful to the partners of Fiduciaire Integrity (Liège) for their precious help in the data collection stage. They provided us with invaluable explanations about how R&D expense data is recorded in annual accounts. They also put us in contact with the government officials in the three regions of Belgium responsible for overseeing R&D investment tax deductions, enabling us to complete the R&D database. Our data collection would have been incomplete without their help.

to be entitled to an increased tax deduction for this type of investment[7]. Given the R&D intensity in the biotech sector, a significant part of our sample (almost 50%) applied to the Belgian regional authorities for this tax deduction. We were therefore able to supplement our R&D measure with data from the Regions.

Finally, a last concern is about data in the abbreviated version of annual accounts. This version only provides total amounts of intangible assets. This problem can be solved by using information in the "valuation rules" section of the annual accounts, where firms should normally indicate the amount of R&D within intangible assets.

### 4.2.2 Financing variables

In order to control for firm size, financial structure variables are expressed in the form of ratios rather than absolute values. We therefore need to make a choice. A frequently used size variable is the amount of total assets. However, we do not want to use a variable containing information coming from the income statement, because this information was already used to position the observations on the empirical tree. This explains why we prefer constructing our own size variable, which does not take internal financing into account. Moreover, we are not interested in non-costly short-term debt such as accounts payable. In summary, the size variable only takes into account total costly external financing. Table 2 defines the various capital structure variables used in the empirical study.

[7] The Royal Decree of April 17, 1990 details this tax incentive.

Table 2: *Definition of financing variables*

| **Variable** | **NBB accounts item or data source** | **Definition** |
|---|---|---|
| TOTFIN | $(10+11+15+17+42+43)_t$ | "Total financing" = capital + share premium + investments grants + total debt |
| EQUITY | $(10+11+15)_t$ | Total amount of external equity |
| LEVERAGE | $(17+42+43)_t$ | Total debt |
| LTDTOT | $17_t=(8912+8913)_t$ | Total long-term debt = debt payable after 1 year or more |
| LTD | $8913_t$ | Long-term debt = debt payable after 5 years or more |
| MTD | $8912_t$ | Mid-term debt = debt payable between one and 5 years |
| STD | $(42+43)_t$ | Short-term debt = debt payable in the year |
| MATURITY | $\left(\frac{42*0.5+8912*3+8913*7}{42+17}\right)_t$ | Average maturity of long term debt issued |
| CONV | $8740_t$ | Amount of convertible debt outstanding |
| LEASE | $25_t$ or $172_t$ | Lease debt [8] |
| VCPERC | Non codified annual accounts data[9] | Percentage of capital held by Belgian venture capitalists |

### 4.2.3 Patent variables

The previous part of the paper also sheds some light on the influence of patenting on capital structure. In order to test their relationships, we need to construct a variable containing patenting information. Thus for each company in the sample we checked for the existence of patent filings in the European Patent Database[10]. We therefore constructed a binary variable,

[8] The amount of lease debt financing is only detailed in the complete versions of Belgian annual accounts. This is why we have to use the lease asset value as a proxy for lease financing. Nevertheless, this influences only marginally the results, as we checked that items 25 and 172 are very strongly correlated when available together.

[9] The data source is the Belfirst database. The discrimination criteria between venture capitalists and other shareholders is the belonging of corporate shareholders to the Belgian Venturing Association (www.bvassociation.org) or to the European Venture Capital association (www.evca.com).

[10] The Espacenet Database of the European Patent Office (www.european-patent-office.org/espacenet) contains information about European patents, as well as covering

PATENT, that is equal to 1 when the company filed for a patent during the year under consideration.

## 4.3 Hypotheses tested and empirical equations

The hypothesis tests are performed by means of OLS regressions of one financing variable, either in form of a ratio or a ratio variation, on a series of dummy variables containing either information about the location along the empirical tree or patenting information.

### 4.3.1 Relationships between financing variables and positioning variables

The main goal of the empirical study is to test whether the stylized evolutions of the capital structure presented in the first part of the paper are observed in our sample of Belgian biotechnology firms. In order to test the various hypotheses concerning the relationship between financing patterns and the evolution of option value on the asset side, we perform several regressions of one financing variable on a series of dummies representing the different branches of the empirical tree. These dummies are defined as follows:

- $B_{R-} = 1$ if the company experiences a failure in R&D.
- $B_{R=} = 1$ if the company experiences a status quo in R&D.
- $B_{R+} = 1$ if the company experiences a success in R&D.
- $B_{C-} = 1$ if the company experiences a failure in the commercialization stage.
- $B_{C=} = 1$ if the company experiences a status quo in the commercialization stage.
- $B_{C+} = 1$ if the company experiences a success in the commercialization stage.
- $B_P = 1$ if the company remains in the profitability stage.
- $B_U = 1$ if the company is in an "undefined" branch, i.e., goes back from profitability to commercialization, or from commercialization to R&D.

the World PCT patent system and a large number of foreign countries.

Due to data availability problems and the nature of accounting data, some of the theoretical developments of capital structure cannot be directly tested. These include all developments related to public debt, not observable in abbreviate schemes of Belgian annual accounts. Public debt can mostly be found only in the case of a listed company. As only three firms are listed in the Belgian biotechnology sector, it may be expected that public debt is very scarcely used in our sample. Another problem concerns VC debt financing. As the origin of private debt is not given in accounting data, it is not possible to test any hypothesis about VC debt financing.

The empirically testable hypotheses and the dependent variables used for each test are defined in Table 3.

Table 3: *Financing hypothesis tests and expected outcomes*

| **Hypothesis tested, with respect to a success** | | **Dependent Variable** | **Expected outcome** |
|---|---|---|---|
| H1 | A failure lowers leverage | $\Delta\left(\frac{LEVERAGE}{TOTFIN}\right)_t$ | $\beta_{failures} < 0 < \beta_{successes}$ |
| H2 | A failure lowers equity ownership by VCs | $\Delta VCPERC_t$ | $\beta_{failures} < 0 < \beta_{successes}$ |
| H3 | A failure increases debt maturity | A)$\Delta\left(\frac{STD}{LEVERAGE}\right)_t$<br>B)$\Delta\left(\frac{MTD}{LEVERAGE}\right)_t$<br>C)$\Delta\left(\frac{LTD}{LEVERAGE}\right)_t$<br>D)$\Delta MATURITY_t$ | $\beta_{failures} < 0 < \beta_{successes}$<br>$\beta_{failures} > 0 > \beta_{successes}$<br>$\beta_{failures} > 0 > \beta_{successes}$<br>$\beta_{failures} > 0 > \beta_{successes}$ |
| H4 | A failure increases lease financing | $\Delta\left(\frac{LEASE}{TOTFIN}\right)_t$ | $\beta_{failures} > 0 > \beta_{successes}$ |
| H5 | A failure increases convertible debt financing | $\Delta\left(\frac{CONV}{TOTFIN}\right)_t$ | $\beta_{failures} > 0 > \beta_{successes}$ |

### 4.3.2 Relationships between financing variables and patents

In order to test the theoretical hypothesis about the influence of patents on the capital structure, we perform two regressions of financing variables on a dummy reflecting the existence or not of a patent filing, PATENT. The two hypotheses tests are detailed in the next table.

Table 4: *Hypotheses tests about the influence of patents on financing*

| **Hypothesis tested** | | **Dependent Variable** | **Expected outcome** |
|---|---|---|---|
| H9A | Patents increase long term debt financing | $\left(\frac{LTDTOT}{TOTFIN}\right)_t$ | $\beta_{PATENT} > 0$ |
| H9B | Patents increase convertible debt financing | $\left(\frac{CONV}{TOTFIN}\right)_t$ | $\beta_{PATENT} > 0$ |

# 5 Empirical results and discussion

This section presents and discusses the empirical results relating to the capital structure of the Belgian biotechnology firms sample. We first analyze a number of capital structure ratios in the light of the sample distribution across stages and branches in the empirical tree. A second part is devoted to formal empirical tests of the theoretical proposals relating to the evolution of capital structure with respect to failures/successes along firms' development path. A third part presents empirical tests about the role of patents in capital structure.

## 5.1 Static capital structure analysis

The static analysis involves estimating and testing the mean values of a number of capital structure ratios[11]. By contrast, the dynamic analysis relates to the evolution of these ratios across time.

We compute mean values for static capital structure ratios in three cases. First, the values for the whole sample can be found in Table 5, as well as a second set of results for the research and development, commercialization and profitability stages. Table 6 completes the static analysis by detailing a third set of results when the sample is distributed across branches of the empirical tree (see Figure 2).

The capital structure ratios taken into consideration can be split into three groups. A first group contains the external equity ratio and its three components: capital, share premiums and investment grants. The second group similarly contains the total debt ratio and its three components: long-term debt, amount of long-term debt payable within one year and short-term financial debt. The final group is composed of three variables that will be

[11]The capital structure ratios are all computed with respect to a common denominator: the total financing variable TOTFIN. To avoid unnecessary repetition, we denote by "variable name + R" the ratio values of each financing variable.

used in the dynamic analysis: the convertible debt ratio, the lease debt ratio and the percentage of equity held by venture capitalists (VCs).

Table 5: *Mean values of capital structure ratios for the sample and across stages* [a] [b]

| **Variable** | **Sample** | **Stage1:** R&D | **Stage2:** Commercialization | **Stage3:** Profitability |
|---|---|---|---|---|
| Number of observations | 364 | 133 | 109 | 122 |
| EQUITY_R: | 0.689 | 0.717 | 0.732 * | 0.621 *** |
| 1) 10_R | 0.595 | 0.619 | 0.603 | 0.562 |
| 2) 11_R | 0.064 | 0.056 | 0.105 *** | 0.035 ** |
| 3) 15_R | 0.031 | 0.042 * | 0.024 | 0.025 |
| LEVERAGE_R: | 0.311 | 0.283 | 0.268 * | 0.379 *** |
| 1) 17_R | 0.192 | 0.190 | 0.164 | 0.219 |
| 2) 42_R | 0.039 | 0.031 * | 0.035 | 0.052 ** |
| 3) 43_R | 0.079 | 0.062 * | 0.070 | 0.107 ** |
| CONV_R | 0.003 | *0.001* | 0.007 | *0.002* |
| LEASE_R | 0.028 | 0.017 ** | 0.032 | 0.036 |
| VCPERC | 0.041 | 0.040 | 0.055 | 0.028 |

[a] Numbers in italics indicate that the mean is not significantly different from zero at the 10% level

[b] *,**,*** indicates that the stage mean is significantly different from other stage means at 10%, 5% and 1% level respectively

The analysis of sample mean ratios provides some interesting insights into sample capital structure patterns. The mean equity ratio for the whole sample is almost equal to 0.7. This implies that equity financing is used about twice as much as debt financing. Moreover, equity capital represents about 60% of the total amount of external and costly financing sources, followed by long-term leverage (19%) and short-term financial debt (8%). Among the different forms of debt financing, convertible debt accounts only for a minor proportion; the 0.003 ratio sample mean is not significantly different from zero at the 5% significance level. This finding is not surprising when one looks at the frequency of use of convertible debt: it is only used in 13 observations. Lease debt is not an important source of debt financing, either. Finally, the average VC equity percentage is only equal to 4.1% across the whole sample. But this observation hides the fact that for a vast majority of the sample, the VC percentage is equal to 0. When we restrict the mean to the observations with positive values, we obtain a VC percentage mean of 28%. In conclusion, sample mean ratio analysis reveals the overall

characteristics of growth companies, though not necessarily those that typify biotechnology companies in particular.

This finding is confirmed by the analysis of some noticeable differences between stages. At the profitability stage as compared with other stages, the leverage ratio increases, mainly due to short-term leverage. This obviously has the effect of reducing the equity ratio. Convertible debt, whenever it is used, is concentrated at the commercialization stage. Lease financing plays a less important role in the R&D stage than in other stages. This is not surprising given that it is mainly used to finance investment in tangible assets. Finally, the VC ownership percentage is slightly lower at the profitability stage (though not significantly so), suggesting that venture capitalists are more present at the early stages of development.

Table 6 uses the same capital structure ratios as Table 5, but details results for the different branches defined in section 4.3.1. Panel A presents mean values for capital structure ratios across branches, whereas panel B contains F-values for a number of difference tests between these means.

Table 6: *Mean values of capital structure ratios and difference tests across branches* [a] [b] [c]

| Panel A: Mean values of capital structure ratios across branches [a] [b] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **$B_{R-}$** | **$B_{R=}$** | **$B_{R+}$** | **$B_{C-}$** | **$B_{C=}$** | **$B_{C+}$** | **$B_P$** | **$B_U$** |
| Number of observations | 26 | 64 | 73 | 7 | 36 | 21 | 61 | 76 |
| EQUITY_R: | 0.662 | 0.743 | 0.731 | 0.790 | 0.734 | 0.539 ** | 0.590 *** | 0.705 |
| 1) 10_R | 0.562 | 0.661 * | 0.645 | 0.620 | 0.608 | 0.436 ** | 0.543 | 0.580 |
| 2) 11_R | *0.054* | 0.038 | 0.063 | 0.160 | 0.104 | 0.091 | *0.023* ** | 0.087 |
| 3) 15_R | 0.046 | 0.044 | 0.023 | *0.010* | *0.021* | *0.012* | 0.024 | 0.038 |
| LEVERAGE_R: | 0.338 | 0.257 | 0.269 | 0.210 | 0.266 | 0.461 ** | 0.410 *** | 0.295 |
| 1) 17_R | 0.227 | 0.192 | 0.183 | 0.175 | 0.165 | 0.210 | 0.245 ** | 0.156 |
| 2) 42_R | 0.035 | 0.030 | 0.037 | *0.027* | 0.038 | 0.072 ** | 0.050 | 0.033 |
| 3) 43_R | 0.075 | 0.035 *** | 0.049 ** | *0.009* | 0.063 | 0.179 *** | 0.115 ** | 0.106 * |
| CONV_R | *0.004* | *0.001* | *0.002* | *0.000* | 0.018 *** | *0.000* | *0.003* | *0.000* |
| LEASE_R | *0.010* | 0.019 | 0.016 | *0.032* | 0.046 | 0.065 ** | 0.037 | 0.028 |
| VCPERC | *0.038* | 0.052 | 0.045 | *0.040* | 0.080 ** | *0.029* | *0.017* | 0.032 |

[a] Numbers in italics indicate that the mean is not significantly different from zero at the 10% level

[b] *,**,*** indicates that the branch mean is significantly different from other branch means at 10%, 5% and 1% level respectively

| Panel B: Tests of mean differences between branches (F-values) [c] | | | | | | |
|---|---|---|---|---|---|---|
| **Variable** | **$B_{R=}$ vs $B_{R-}$** | **$B_{R=}$ vs $B_{R+}$** | **$B_{C=}$ vs $B_{C-}$** | **$B_{C=}$ vs $B_{C+}$** | **$B_{R-}$ vs $B_{R+}$** | **$B_{C-}$ vs $B_{C+}$** |
| EQUITY_R: | 4.369 ** | 0.096 | 1.164 | 14.404 *** | 1.289 | 4.619 ** |
| 1) 10_R | 5.709 ** | 0.160 | 0.042 | 9.661 *** | 1.607 | 2.133 |
| 2) 11_R | 0.602 | 1.410 | 3.729 * | 0.209 | 0.069 | 1.109 |
| 3) 15_R | 0.045 | 3.679 * | 0.631 | 0.391 | 1.843 | 0.006 |
| LEVERAGE_R: | 4.369 ** | 0.096 | 1.164 | 14.404 *** | 1.289 | 4.619 ** |
| 1) 17_R | 1.554 | 0.081 | 0.068 | 1.374 | 0.951 | 0.162 |
| 2) 42_R | 0.370 | 0.688 | 1.006 | 8.717 *** | 0.020 | 3.042 * |
| 3) 43_R | 4.744 ** | 0.520 | 5.002 ** | 23.294 *** | 0.863 | 9.699 *** |
| CONV_R | 0.601 | 0.065 | 11.951 *** | 11.951 *** | 0.110 | 0.000 |
| LEASE_R | 0.935 | 0.071 | 2.322 | 1.307 | 0.199 | 1.383 |
| VCPERC | 0.783 | 0.318 | 3.693 * | 6.128 ** | 0.079 | 0.060 |

[c] *,**,*** indicates that the F-test for differences between means is significant at 10%, 5% and 1% level respectively

A vertical analysis of the insignificant ratios (in italics in Table 6, Panel A) shows that these insignificant ratios can mostly be found in R&D and commercialization failure branches. This can be partly explained by the low number of observations on these branches. Nevertheless, a closer look at these insignificant ratios is still interesting for the second branch. On this branch investment grants and short-term financial debt are almost non-existent. The only significant financing ratios are equity capital (with share premiums) and

long-term debt. This finding may suggest that external stakeholders in the company, such as bankers and public authorities, no longer trust companies experiencing a failure in commercialization.

Taking a horizontal look at insignificant ratios, we notice that investment grants are not present on any of the commercialization branches and are the most important on R&D branches. Convertible debt presents only one significant occurrence, on the commercialization status quo branch. VC ownership percentage is another variable with a large number of insignificant ratios. Lease debt and VC percentage are both insignificant on the two failure branches. While this finding may be due to the sample size, it is still puzzling.

The analysis of significant differences between branches adds further detail to the results presented in Table 5. The equity ratio is the lowest on the profitability and commercialization success branches, which both correspond to an arrival at the profitability stage. At the same time, the share of equity capital is lowered on those two branches. This is particularly true for companies that experience a success in the commercialization stage: they have the lowest equity ratio.

Table 6 Panel A also shows that the short-term financial debt varies a lot between branches. Compared with its mean value of 0.079, it is two times higher for companies experiencing a success in commercialization, while it is two times lower for the R&D status quo branch. The R&D success branch is also associated with a higher ratio mean value, while companies along the profitability branch tend to have higher mean values. The reverse applies to the equity capital ratio on these branches. This may suggest that trusting relationships with bankers, signalled by high short-term financial debt, are built up mainly at late stages when companies have proved successful in their development.

Finally, we note that lease financing is higher on the commercialization branches, which can be related as in Table 5 to the nature of leasing itself.

We turn now to the analysis of tests concerning mean differences between branches. Table 6 Panel B shows the F-values for a number of difference tests. The tests presented in the first four columns try to answer the question of the nature of status quo branches. As the theoretical analysis suggests, a status quo in the R&D stage does not necessarily have the same meaning as a status quo in the commercialization stage. This is why we analyze both situations separately.

Concerning the R&D status quo branch, in the first two columns we test whether the mean values of capital structure ratios on this branch are significantly different or not from each of the two other R&D branches. First, a high proportion of mean difference tests are significant when comparing sta-

tus quo with failure, implying that a status quo in R&D cannot be compared with a failure in R&D. Second, all but one mean difference tests between status quo and success are insignificant. In other words, mean capital structure ratios cannot be differentiated in the R&D status quo and success branch. As expected from the theoretical discussion, from now on we may assimilate the R&D status quo branch with the R&D success branch.

Mean difference tests in the commercialization branches lead to the opposite conclusion. On the one hand, there are only two significant differences in means between status quo and failure[12], and these do not in any case mainly relate to the most important ratios, such as equity capital and leverage. On the other hand, status quo and success branches present a majority of significant different ratio means. Therefore, in the following sections we regard a status quo in commercialization as a failure in commercialization.

The last two sets of tests in Table 6 Panel B are related to mean differences tests between failure and success branches. At the R&D stage, tests fail to differentiate capital structure means. Even though this does not imply that there is no difference, these are not important enough to be significant. This disappointing finding may be a sign of a problem in the location of the companies within the R&D branches. However, this should be viewed in the context of the huge problems we experienced with the measurement of the R&D effort. Section 6.2 will come back to this issue. By contrast with the R&D situation, F-values are higher on the commercialization side. This is not surprising given the analysis of Panel A for the commercialization failure and success branches.

## 5.2 Dynamic capital structure analysis

This section presents the results of several multiple regressions aimed at testing various hypotheses about the evolution of biotechnology firms' capital structure. Given that the analysis is now dynamic, in the sense that it looks at variations of capital structure ratios across time, we concentrate our analysis on the dynamic aspects of the empirical tree, that is, its branches.

As a preliminary step to the formal hypothesis tests, Table 7 details the regression results of the variation of one capital structure variable[13] re-

[12] We exclude from our analysis the differences tests between convertible debt ratios. The F-values are meaningless here as there is no occurrence of a positive convertible debt ratio in both the commercialization failure and success branches.

[13] See Table 3 for a detailed definition of each hypothesis and variable used. Note that in addition to the regressions presented in this table, we also used a proxy for public debt financing variation, defined as the ratio of unsubordinated debentures to total external financing. However, this ratio can be established only for the complete versions of annual

gressed against a series of dummy variables representing the various existing branches. The fact that there is no constant term included in the regressions allows us to interpret each dummy coefficient as the mean value of the dependent variable for the branch under consideration. As compared to the static analysis, the use of variations of variables implies a loss of 40 observations, corresponding to the first observation for each company.

An extensive analysis of each regression is developed in Table 8; this table presents the same kind of regressions as Table 7, but for groups of branches. Some of the findings in Table 7 are nevertheless worth pointing out .

Table 7*: Capital structure hypotheses tests across branches* [a] [b] [c]

| Independent variables | | | | | | | |
|---|---|---|---|---|---|---|---|
| $B_{R-}$ | $B_{R=}$ | $B_{R+}$ | $B_{C-}$ | $B_{C=}$ | $B_{C+}$ | $B_P$ | $B_U$ |
| **H1: dependent variable = $\Delta$ LEVERAGE_R $_t$** | | | | | | | |
| 0.022 | 0.000 | 0.028 | 0.015 | 0.120 *** | 0.074 ** | 0.015 | -0.015 °° |
| (0.032) | (0.024) | (0.019) | (0.062) | (0.033) | (0.036) | (0.023) | (0.019) |
| **H2: dependent variable = $\Delta$ VCPERC $_t$** | | | | | | | |
| 0.013 | 0.012 | 0.006 | -0.030 | -0.004 | -0.006 | -0.006 | 0.002 |
| (0.020) | (0.015) | (0.012) | (0.038) | (0.020) | (0.022) | (0.014) | (0.011) |
| **H3A: dependent variable = $\Delta$ (STD/LEVERAGE) $_t$** | | | | | | | |
| 0.032 | 0.050 | -0.030 | -0.203 ° | -0.033 | 0.086 | -0.022 | 0.079 ** |
| (0.065) | (0.049) | (0.039) | (0.126) | (0.067) | (0.073) | (0.048) | (0.038) |
| **H3B: dependent variable = $\Delta$ (MTD/LEVERAGE) $_t$** | | | | | | | |
| -0.076 ° | 0.066 | 0.030 | -0.030 | 0.065 | -0.041 | 0.070 * | 0.002 |
| (0.055) | (0.041) | (0.033) | (0.105) | (0.056) | (0.061) | (0.040) | (0.032) |
| **H3C: dependent variable = $\Delta$ (LTD/LEVERAGE) $_t$** | | | | | | | |
| 0.006 | -0.052 ** | 0.029 | 0.232 *** | 0.075 ** | 0.002 | -0.002 | -0.007 |
| (0.035) | (0.026) | (0.021) | (0.067) | (0.035) | (0.038) | (0.025) | (0.020) |
| **H3D: dependent variable = $\Delta$ MATURITY $_t$** | | | | | | | |
| 0.014 | -0.400 ** | 0.055 | 0.709 | 0.254 | -0.060 | -0.120 | -0.104 |
| (0.240) | (0.180) | (0.157) | (0.510) | (0.247) | (0.247) | (0.189) | (0.146) |
| **H4: dependent variable = $\Delta$ LEASE_R $_t$** | | | | | | | |
| -0.002 | -0.006 | 0.003 | 0.030 | 0.025 ** | 0.011 | 0.000 | -0.001 |
| (0.010) | (0.008) | (0.006) | (0.020) | (0.011) | (0.012) | (0.008) | (0.006) |
| **H5: dependent variable = $\Delta$ CONV_R $_t$** | | | | | | | |
| 0.003 | 0.000 | 0.002 | 0.000 | 0.021 ** | 0.000 | 0.003 | -0.010 ** |
| (0.009) | (0.007) | (0.005) | (0.017) | (0.009) | (0.010) | (0.006) | (0.005) |

[a] Numbers in parentheses below the estimated coefficients are the corresponding standard errors

[b] *,**,*** indicates that the coefficient is significantly different from 0 at 10%, 5% and 1% level

[c] °,°°,°°° indicates that the coefficient, although not significantly different from 0, is significantly different from other coefficients at respectively 10%, 5% and 1% level

accounts, leaving out a large number of observations. The regressions based on this independent variable were not conclusive. This is why we do not mention them in Table 7 or 8.

The results of regression 1 show several interesting patterns. First, leverage increases significantly on the commercialization status quo and success branches. Second, leverage does not vary significantly on the R&D branches, implying that debt is not the financing vehicle increasingly used at this stage. This is also true at the profitability stage, where leverage no longer varies significantly. Fourth, the only branch where leverage decreases is the "one-step-back" branch. Taken together, these observations suggest that debt financing is used as an incremental financing source mainly at the commercialization stage.

Concerning the second regression showing the development of the VC ownership percentage, no coefficient proves to be significant. We come back to this finding in the discussion of Table 8. Nevertheless, an interesting pattern occurs: coefficient signs are all negative on the commercialization at profitability branches, suggesting that VCs mostly leave at those stages.

Finally, it is interesting to analyze the results of regression 3C, which presents the evolution of long-term debt. On the commercialization status quo and success branches, the portion of long-term debt out of total debt increases greatly. This can be related with some of the results of regression 1, where total debt increases along those two branches. The increase in leverage is therefore mainly explained by an increase in long-term debt financing.

We turn now to the core of the empirical results, presented in Table 8. This table has a similar structure to Table 7, except that the branches are now grouped according to their classification as a success or as a failure. In addition, the last column of Table 8 presents the estimated F-values of difference tests between failures and successes, which enables formal hypothesis tests of a differential evolution of capital structure ratios in case of a failure as opposed to a success.

Table 8: *Capital structure hypothesis tests with grouping of failure and success branches* [a] [b] [c]

| Independent variables | | | | F-value |
|---|---|---|---|---|
| $B_{R-}+B_{C-}+B_{C=}$ (failures) | $B_{R=}+B_{R+}+B_{C+}$ (successes) | $B_P$ | $B_U$ | failures vs successes |
| **H1: dependent variable = Δ LEVERAGE_R $_t$** | | | | |
| 0.063 *** | 0.025 * | 0.015 | -0.015 | 3.080 * |
| (0.022) | (0.014) | (0.023) | (0.019) | |
| **H2: dependent variable = Δ VCPERC $_t$** | | | | |
| 0.001 | 0.006 | -0.006 | 0.002 | 0.183 |
| (0.013) | (0.008) | (0.014) | (0.011) | |
| **H3A: dependent variable = Δ (STD/LEVERAGE) $_t$** | | | | |
| -0.024 | 0.014 | -0.022 | 0.079 ** | 0.757 |
| (0.044) | (0.028) | (0.048) | (0.038) | |
| **H3B: dependent variable = Δ (MTD/LEVERAGE) $_t$** | | | | |
| -0.010 | 0.031 | 0.070 * | 0.002 | 1.247 |
| (0.037) | (0.023) | (0.040) | (0.032) | |
| **H3C: dependent variable = Δ (LTD/LEVERAGE) $_t$** | | | | |
| 0.063 ** | -0.002 | -0.002 | -0.007 | 7.610 *** |
| (0.024) | (0.015) | (0.026) | (0.021) | |
| **H3D: dependent variable = Δ MATURITY $_t$** | | | | |
| 0.190 | -0.127 | -0.120 | -0.104 | 3.728 * |
| (0.164) | (0.107) | (0.190) | (0.146) | |
| **H4: dependent variable = Δ LEASE_R $_t$** | | | | |
| 0.013 * | 0.001 | 0.000 | -0.001 | 2.902 * |
| (0.007) | (0.004) | (0.008) | (0.006) | |
| **H5: dependent variable = Δ CONV_R $_t$** | | | | |
| 0.010 * | 0.001 | 0.003 | -0.010 ** | 2.524 |
| (0.006) | (0.004) | (0.006) | (0.005) | |

[a] Numbers in parentheses below the estimated coefficients are the corresponding standard errors

[b] *,**,*** indicate that the coefficient is significantly different from 0, or that the F-test is significant, at 10%, 5% and 1% level respectively

[c] The last column indicates the value of the F-test on differences across groups of branches

Hypothesis 1 states that the leverage ratio should be lowered in case of a failure as opposed to a success. The first regression in Table 8 shows that in the cases both of a success and a failure, leverage increases significantly. But although they have the same sign, the failure coefficient is significantly higher than the success coefficient. In other words, leverage increases more in case of a failure than in the case of a success, which is contrary to the theoretically expected outcome on the basis of the trade-off theory. This important finding suggests that over the period under consideration, Belgian biotechnology firms tend to finance a failure with increased recourse to debt financing, whereas the natural financing candidate when a failure occurs is

rather equity capital. The only matching explanation would be a shift of VC financing from equity to debt, but this particular point does not prove to be testable. It means however that although *companies* would need more equity – as suggested by trade-off theory, the main available resource of funds from *investors* is debt. This finding raises the question of the undercapitalization of young growing biotech companies. We will come back to this issue later in Section 6.1.

The second regression examines the evolution of the VC ownership percentage. As there is no significant coefficient for this regression, we cannot draw any conclusion about the hypothesis that the VC ownership percentage should decrease in case of a failure as opposed to a success. This inconclusive result is mainly explained by the stability of VC ownership over time – or its absence. Indeed, the vast majority of observations for this dependent variable are equal to 0.

The third testable hypothesis states that a failure should be associated with higher maturity than a success. We test this hypothesis in two ways. First, in regressions 3A to 3C we look at the evolution of three segments of debt according to their maturity, with respect to the amount of total debt. On the one hand, short-term and mid-term debt are reduced in case of a failure, while they increase when a success takes place. Although consistent with the predictions, the difference between both coefficients is not significant. On the other hand, the long-term debt failure coefficient is significantly positive and different from the slightly negative success coefficient. This suggests that maturity increases when a failure takes place, corresponding to the interpretation of greater flexibility from debt instruments. Second, in order to synthesize the evolution of debt maturity in a single regression, in regression 3D we use the evolution of a proxy for maturity as a dependent variable. The results confirm what is found in hypotheses 3A to 3C: maturity increases for failure branches and decreases for success branches. Although the coefficients are not significantly positive or negative, they are nevertheless significantly different from each other. This finding is in line with the evolution expected on a theoretical basis.

The fourth hypothesis is related to the test for whether lease debt increases when a failure takes place. The coefficient on failure branches is indeed positive and significantly different from the success coefficient, which confirms the theoretical predictions. It is interesting to notice the virtual absence of any lease financing for firms in a more successful stage, implying that leasing can really be interpreted as 'last recourse financing' in the context of biotechnology companies.

Finally, the last testable hypothesis states that convertible debt financing should increase in case of a failure as opposed to a success. Despite the very

small number of observations where convertible debt is positive, it increases mainly when firms experience a failure. However, the difference test between failures and successes is not significant. This finding suggests that although convertible debt is very rarely used by Belgian biotechnology companies, it is used at the right time from a theoretical viewpoint by the few companies that do actually use it.

## 5.3 The influence of patenting

The last hypothesis presented in the theoretical part of the paper relates to the influence of patents on capital structure ratios. Table 9 presents the results of two formal tests of this influence. The first regression tests whether the companies that have filed for at least one patent issue more long-term debt. The second test looks at the influence of patents on the use of convertible debt financing.

Unlike previous hypothesis tests, both regressions presented in Table 9 incorporate a constant term. The role of this term is to capture the mean value of the capital structure ratios in the case of no patent filing. The coefficient on the patent dummy can therefore be interpreted as the mean variation of the ratio for companies having filed for at least one patent.

Table 9: *Capital structure hypothesis tests with respect to patent filing information* [a] [b]

| **Independent variable** | |
|---|---|
| **Constant** | **PATENT** |
| **H6A: dependent variable = LTDTOT_R $_t$** | |
| 0.159 *** | 0.088 *** |
| (0.015) | (0.024) |
| **H6B: dependent variable = CONV_R $_t$** | |
| 0.000 | 0.008 ** |
| (0.002) | (0.003) |

[a] Numbers in parentheses below the estimated coefficients are the corresponding standard errors

[b] *,**,*** indicates that the coefficient is significantly different from 0 at 10%, 5% and 1% level respectively

Hypotheses 6A and 6B state that the existence of a patent filing should have a positive impact both on leverage and on convertible debt. As the coefficients on the patent dummy are both significantly greater than zero, we can conclude that patents play the role expected from the theoretical discussion, in that they call for more flexible and longer-term financing.

The magnitude of these effects is very strong and informative. On average, patenting companies use 50% more long-term financing than non-patenting corporations. When one looks at convertible financing, the relative size of this financing instrument for patenting companies is two times higher than the mean ratio for the whole sample. This indicates a consistent recognition, both from investors and from corporations, of the option to wait embedded in the patent filing and the associated relevant financing vehicles.

# 6 Policy recommendations

The aim of this section is to bring out recommendations for policy makers, mainly related to two topics. The first topic concerns the data problems we experienced in the empirical study. If available data had been more accurate, then tests on capital structure would have been more robust and our findings more balanced, allowing us to draw stronger and more contrasted conclusions. The first part of this section deals with this data issue and leads to a wish of better matching between financial reality and accounting data, which may partly be short of financial reality.

The second topic concerns the profile of Belgian bio-industry capital structure we pointed out in Section 5. The observed patterns are not always in line with financing theory. To some extent, this can be interpreted as a mismatch between entrepreneurs and capital providers' viewpoint. The second part therefore tries to shed some light on the priorities for policy makers in terms of financing policy.

## 6.1 Accounting data versus financial reality : better matching between accounting rules and relevant information

In the empirical part of this study, we analyze company accounts from their inception until their last available financial statements. Given the fact that the biotechnology sector is a young, growing sector in Belgium, this means that we have to rely partly on abbreviated versions of annual accounts for the data used. Per se, abbreviated accounts do not contain as much detail as full accounts, leading to a bias in the data collection process and in the choice of testable hypotheses. For example, we were not able to test any hypothesis involving public debt because this item only appears in the full accounts. However, there are also other data problems of a more crucial nature that are not dependent on the version of the annual accounts that is used. Rather,

they are due to the inadequate information provided by annual accounts in general, especially in relation to research and development data.

In addition to the research and development data found in the note on intangible assets in the notes on the annual accounts, we set up an original sector-based R&D database using a number of indirect sources of information, of both an accounting and non-accounting nature: the management report, the valuation rules in the notes on the annual accounts, and R&D investment tax deduction information.

One important piece of information about R&D activities that cannot be measured directly from the annual accounts is the amount of R&D that has not been capitalized in the balance sheet. This amount is included in with the operating expenses in the profit and loss account. Although Belgian accounting law stipulates that indirect information about these expenses must be provided in the management report, our research reveals that the law is not precise enough on the content of the R&D information to be mentioned in the management report. As a result, this report therefore often confines itself to reproducing quantitative information that is already available in the annual accounts. Although companies usually provide qualitative information, this information is still insufficient to give a detailed view of the company's R&D policy. This problem is exacerbated in the abbreviated annual accounts, where there is no obligation to disclose the management report. Hence, information about the R&D policy is almost never available in abbreviated annual accounts.

Information about R&D expenses can also be found in non-accounting sources. For example, we had access to information relating to R&D investment tax subsidies from the regional authorities. Other sources of information in Belgium (publicly available or not) include OSTC R&D investment surveys[14] and regional databases about investment and operating subsidies to promote R&D. R&D data is thus widely dispersed. From their external viewpoint, researchers and financial analysts cannot obtain a complete view of the R&D effort of any Belgian company, especially in biotechnology, where R&D is a central issue. A more accurate assessment of R&D activities would be desirable, and this could be achieved, for instance, by linking existing databases together.

Coming back to accounting information, although financial structure information is much better presented in annual accounts than R&D information, there are some noteworthy exceptions. First, while information

[14]Cincera (2002) uses R&D information from this source. However, this information source was not particularly suitable for use in our study because it is based on surveys and therefore does not systematically include biotechnology companies.

about equity ownership structure is available in accounting databases such as Belfirst, debt "ownership" structure is less easy to obtain, and almost impossible for some important categories of debtholders in the biotechnology sector, such as venture capitalists. To some extent, the full annual accounts compensate for the lack of debt "ownership" structure information by detailing certain classes of debt such as public debt, banking debt and lease debt. The issue is all the more crucial in abbreviated annual accounts, where long-term debt is not split between these classes. This explains why some of the hypotheses could not be tested.

In conclusion, with regard to accounting information, we do not call for an increase in the quantity of data released in the annual accounts so much as for changes to be made which would make this information more relevant to the external reader.

## 6.2 Financing reality versus theory: better matching between entrepreneurs and capital providers

The empirical results presented in Section 5 show a number of interesting patterns in the capital structure of Belgian biotechnology firms. These observed patterns allow us to draw a number of conclusions about the financing reality in this high-tech sector. These findings may question managers as well as capital suppliers.

The main issue raised in the discussion of empirical results relates to the finding that the "best" financing source for companies in case of a failure should be equity capital, while we observe that leverage is the main available instrument in this situation, during the period under consideration. In other words, the market for equity capital, either from private or public source, does not always play its role of capital provider for young and risky ventures. Belgium seems therefore to lack a suitable and well-developed equity capital culture. Moreover, while most biotechnology firms in the Anglo-Saxon world have a leverage ratio tending to zero, especially in their early stages of development – corresponding to the predictions of the trade-off theory, Belgian biotechnology companies exhibit a much more levered capital structure ratio, and increase their proportion of leverage when their situation worsens.

It is possible that the heavy recourse to debt financing corresponds to the unusually large and easy availability of cheap, long term sources of capital from financial intermediaries. This explanation is not necessarily related to a shortage of equity funds supply, but to a neglection of this source of capital by companies. The lengthening of average debt maturity partially supports this hypothesis.

A less appealing interpretation would be that total funds available from VCs are insufficient to provide required capital for companies in the sector. This is a natural way of explaining the shortage of equity capital in the biotechnology industry and the recourse to bank debt financing. Such a hypothesis reveals to be frightening as future development of the sector has to be foreseen. Huge demands for additional capital are to be expected from this blossoming sector in the near future; in Canada, where VC financing is currently sufficient to finance a tremendous amount of biotech companies, the study of future capital needs made by Bergeron et Al. (2002) indicates that a shortage of funds is to be expected under any realistic forward-looking scenario. Such a finding may prove to be all the more relevant in the case of Belgium, where initial conditions are not even satisfactory.

Anyway, the relative undercapitalization of a young and promising sector like bio-industry is all the more a crucial issue that the banking world seems more and more less willing to play the role of risky fund providers at the early stages of a company's life. We therefore speak for measures aiming a developing a stronger culture of shareholding and venture financing.

In the same vein, the sample of biotechnology firms we studied in the empirical part very rarely uses flexible hybrid financing like convertible debt. The theoretical part of the study emphasizes on the virtues of convertible debt especially in the case of high growth companies like biotechnology firms. The use of convertible debt may be a good solution to the undercapitalization problem pointed out above, in that it allows potential pessimistic shareholders to meet their desire of claims on the company when it experiences a failure, without imposing on the company the full burden of high debt costs.

On one side, the finding of the accurate use of convertibles conveys good news; on the other side, the scarcity of this instrument in Belgian bio-industries is still somewhat surprising. After all, the convertible security is a form of delayed equity financing conditional of the firm performing well. Our previous finding of shortage of equity when the moneyness of real options decreases would actually support a more accurate and elegant financing solution through much more intensive use of convertible securities.

# 7 Concluding remarks

By means of an empirical analysis of capital structure ratio with respect to the development path of Belgian biotechnology firms, the aim of this paper is to test whether biotechnology firms' financing decisions are consistent, in terms of their cost-flexibility trade-off, with their investment pattern, in terms of the evolution of its real option component.

In order to achieve this, we first set up an exploratory model to characterize the evolution of biotechnology firms along a multinomial tree capturing the development path of each company. This model is not a valuation model but rather an attempt to assess the evolution of companies along this tree and classify their evolution in terms of success, status quo or failure for a given development stage. From this classification we then derive a number of proposals about the adequate financing instruments companies should use with respect to their development path.

In the empirical part of the study, we manage to test and confirm most of our hypotheses about theoretically expected evolutions of capital structure ratios. The results can be summarized as follows. Our study reveals that Belgian biotechnology firms seem to have a good approach to the financing consequences of patenting, in that they increase the option value to wait and therefore enable for more flexible and long-term financing. Moreover, tests performed on companies that experience a success, in the sense that they follow a successful development path, show that these companies seem to make harmonious financing decisions. The behavior of companies experiencing failures along their development path is less clear. In this case, Belgian biotechnology companies seem to adapt their capital structure in a way not necessarily consistent with theoretical expectations. By using more straight debt, companies may forego the advantages of more hybrid and elaborated financing instruments like convertible debt. Financial innovation, even though it is not absent in the Belgian bio-industry, is nevertheless underused. High-tech companies like biotechnology companies, driven by innovation and technology, could therefore gain some financial strength by having a more modern and innovative approach to their financing decisions.

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