Essays on information asymmetry, disclosures and the financing of R&D

– The case of the biotechnology industry –

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Abstract

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Investments in research and development (R&D) are an important driver of innovation, productivity and economic growth. Despite the importance of R&D investments to society, it is commonly known that R&D activities are difficult to finance in a competitive marketplace. Corporate investments in intangible assets, such as R&D, create information asymmetry problems between corporate insiders and outsiders. Several additional factors contribute to information asymmetry: the relative uniqueness of R&D to the developing firm, the lack of organized markets for trading R&D assets and the scarcity of R&D information in corporate reports. As a result, Hall and Lerner (2009) suggest that the marketplace for financing R&D looks like the "lemons" market (Akerlof, 1970).

This thesis studies asymmetric information in the context of two major corporate events in the biotechnology industry: corporate financing of R&D and corporate takeovers. The two essays on corporate financing of R&D examine how biotech firm managers access capital markets to raise external financing to finance capital-intensive R&D investments and how they choose between alternative equity flotation methods. The essay on corporate takeovers investigates the role of asymmetric information in corporate takeovers between acquiring and target firms and the subsequent performance of R&D.

The results of this thesis indicate that corporate managers issue equity to a larger extent following the disclosure of R&D information, i.e. when the degree of asymmetric information is low, and when the stock is temporarily mispriced. Biotech stocks generate positive abnormal returns in the period prior to the equity issue announcement and negative abnormal returns in the period thereafter. The results also indicate that the degree of asymmetric information plays a role in the choice of equity-selling mechanisms. Biotechnology firms

issue equity publicly rather than privately following disclosures of R&D information. Finally, the empirical results show that R&D projects that are co-developed prior to the acquisition are no more likely to advance to subsequent stages of development than are R&D projects that are not preceded by alliances, which raises questions regarding the ability of R&D alliances to serve as a mechanism to mitigate information asymmetry problems.

Keywords: biotechnology, R&D, information asymmetry, disclosures, value-relevance, equity market timing, mispricing, adverse selection, monitoring, seasoned equity offerings, rights offerings, private placements, M&A, alliance

Sammanfattning

Investeringar i forskning och utveckling (FoU) är en viktig drivkraft för innovation, produktivitet och ekonomisk tillväxt. Trots betydelsen av FoU för samhället är det allmänt känt att FoU är svårt att finansiera i en konkurrensutsatt marknad. Företagens investeringar i immateriella tillgångar, såsom FoU, skapar informationsasymmetriproblem mellan företagsledningen och externa investerare. Flera andra faktorer bidrar också till informationsasymmetrin: FoU är relativt unikt för det utvecklande företaget, avsaknaden av en organiserad marknad för handel med FoU-tillgångar och den begränsade information kring FoU i företagens kvartalsrapporter och årsredovisningar. Som ett resultat av detta menar Hall och Lerner (2009) att marknaden för finansiering av FoU kan jämföras med Akerlof's (1970) "lemons market".

Denna avhandling studerar asymmetrisk information i samband med två stora och viktiga händelser för företag i bioteknikindustrin: finansiering av FoU och företagsförvärv. I företagens finansiering av FoU studeras hur bioteknikföretag söker extern finansiering via kapitalmarknaden för att finansiera kapitalintensiva FoU-investeringar och hur de väljer mellan olika finansieringsmetoder. Studien som berör företagsförvärv undersöker asymmetrisk information i företagsförvärv mellan köpande företag och målbolag och vilken effekt det har på FoU i perioden efter förvärvet.

Resultaten från denna avhandling visar att företag tenderar att söka extern finansiering i större utsträckning efter det att man släppt företagsspecifik FoU information, som i sin tur har betydande informationsinnehåll och ger investerarna värderelevant information. De söker även externt kapital vid tillfälliga felprissättningar i företagets aktie: Bioteknikaktier tenderar att ge en positiv överavkastning i perioden före tillkännagivandet av nyemissionen och negativ överavkastning under perioden därefter. Resultaten visar också att asymmetrisk information spelar en viktig roll i valet av emissionsmetod. Bioteknikföretag använder sig av företrädesemissioner i större utsträckning jämfört med riktade emissioner efter det att man släppt företagsspecifik information om FoU. Slutligen visar de empiriska resultaten att FoU-projekt som är utvecklade i en allians före förvärvet inte har större sannolikhet att lyckas jämfört med FoU-projekt som inte föregås av en allians, vilket väcker frågan om i vilken utsträckning allianser som mekanism kan överbrygga informationsasymmetrier mellan köpande företag och målbolag.

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Hans Jeppsson

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Contents

1. Introduction

It is commonly known that corporate investments in intangible assets, such as R&D, are difficult to finance in the marketplace. Schumpeter (1942) argues that R&D investments are preferably financed with internal cash flows due to agency problems and the costs associated with the disclosure of strategic information to product market rivals. R&D investments create an intangible asset, e.g., knowledge of how to cure cancer, but this knowledge is non-rivalrous in the absence of intellectual property protection, and its use by a competing firm is not prevented if the scientist leaves the firm or is fired (Hall, 2002). In such cases, firms will be reluctant to invest in R&D if the returns cannot be extracted by the firm that undertakes the investment, leading to an underinvestment in R&D in the economy.

Modigliani and Miller (1958) argue that a firm making an investment should be indifferent to its capital structure, i.e., internal and external financing sources are perfect substitutes, and the firm managers should invest if the net present value is positive. The seminal work by Modigliani and Miller (1958) has received much attention over the years and provides a useful starting point. With respect to R&D investment, several reasons have been proposed for why there may be a difference between internal and external costs of capital. Hall (2002) proposes two alternative explanations[1]: 1) asymmetric information between the inventor and the investors, and 2) moral hazard due to the separation between ownership and control.

Corporate investments in intangible assets, such as R&D, create information asymmetry problems, which refers to the fact that inventors (or corporate managers) can continually observe changes on an individual asset basis, whereas outsiders obtain only highly aggregated information at discrete points of time when R&D information is disclosed to the public. Information asymmetry is particularly evident in R&D-intensive industries, such as the high-technology sector (Himmelberg and Petersen, 1994) and especially the biotechnology industry (Lerner et al., 2003; Hall, 2002). Information asymmetry can lead to problems associated with adverse selection and moral hazard, which can have severe effects for financing R&D. According to the principal-agent theory (Jensen and Meckling, 1976), moral hazard may occur when corporate managers (agent) invest funds that may benefit them but not the existing shareholders (principal). Adverse selection can occur in markets with "hidden information", where one party is better informed than other parties. A well-known example is

[1] Hall (2002) and Auerbach (1984) also argue that tax considerations may play a role in the difference between internal and external costs of capital, although this is outside the scope of this study.

the market for used cars. According to Akerlof's (1970) lemon principle, the asymmetrically distributed information about the quality of the car between buyer and seller can result in a dramatic situation in which sellers of high-quality cars withdraw from the market and only low-quality cars become available in the market. The lemon problem is not only apparent in the market for used cars but exists in several other markets, such as the market for deals (Nanda and Williamson, 1995), the market for corporate financing (Myers and Majluf) and financing R&D (Hall and Lerner, 2009), and the market for corporate acquisitions (Hansen, 1987).

In the market for corporate financing, Myers and Majluf (1984) argue that managers of issuing firms generally have better information than the outside investors buying their securities. First, they know more about what the raised capital will be used for (e.g., financing new investments and allocation between different projects). Second, they may also be in a position to have better access to information about the true value of the company's assets in place and its future investment opportunities. Temporary mispricing of the firm's stock can impact the security issuance decisions in the following way: if the firm managers (acting in the interest of existing shareholders) believe the firm is undervalued, and if the total cost of issuing exceeds the value of the project, they will forego the investment opportunity and not issue stock, a scenario Myers and Majluf (1984) call the "underinvestment problem". Consequently, those seasoned equity offerings that are offered to the market tend to be overpriced, hence the term "adverse selection".

In the market for corporate acquisitions (Hansen, 1987), it has been argued that information asymmetry problems can be mitigated by the role of information-producing intermediaries that may help evaluate and signal to markets the quality of firms (e.g., Leland and Pyle, 1977). Nanda and Williamson (1995) argue that an alliance provides an opportunity for the acquiring firm to learn more about the quality of the asset and improve their informational disadvantage. This suggests that pre-acquisition information-gathering activities, such as alliances, may lead to more successful post-acquisition integration.

This thesis studies asymmetric information in the context of corporate financing of R&D and corporate takeovers, two major corporate events in the biotechnology industry. The biotechnology industry has made significant contributions to medicine and society. In 1982, the first biotechnology derived drug, recombinant insulin, was approved (Berg et al., 2002). Since then, more than 100 drugs have been launched that have improved the quality of life of

millions of people (Walsh, 2006). These approved drugs provide treatment for indications ranging from common diseases such as cancer and arthritis to rare genetic disorders. The biotechnology industry is one of the most innovative and important economic drivers in the United States. In 2012, biotechnology companies collectively reported more than $103 billion in revenues, spent more than $25 billion on R&D and brought in profits of more than $7.7 billion (Huggett, 2013). Between 2001 and 2006, the annual growth rate averaged 20 percent in the biotechnology industry, significantly exceeding the annual growth rate of only 6-8 percent for US pharmaceutical firms (Aggarwal, 2007).

The core business of most biotechnology firms is to engage in the research and development of therapeutic drugs. The drug development process consists of different stages that are linked to each other. These different stages are broadly classified as discovery, pre-clinical, clinical phase I, clinical phase II, clinical phase III, and regulatory review. In pre-clinical trials, the discovered drug is tested in animals before moving into clinical stages with an increasing number of human patients at each stage. The movement from one stage to the next must be built on the success of the previous stage. A key feature of the drug development process is that it is closely monitored by regulatory authorities, such as the US Food and Drug Administration (FDA), that assess and approve the transition from one stage to the next (McConomy and Xu, 2004). In addition, drug development is a very long, risky and expensive process. It is estimated to take 10 to 15 years from initial concept to product launch (Miller, 2002). Only approximately ten percent of compounds that enter clinical testing reach the market (e.g., Robbins-Roth (2001). The average cost per launched product has been estimated to be $1,318 million (DiMasi and Grabowski, 2007).

The purpose of this thesis is to address two issues. From the viewpoint of corporate managers, it examines when and how these managers seek external financing to finance investments in R&D. From the viewpoint of acquiring firm managers, it investigates whether an a prior R&D alliance with the target firm alleviates information asymmetry problems and leads to a more successful post-acquisition performance.

2. Theoretical framework

This chapter describes the theoretical framework of the essays. Section 2.1 presents the corporate financing of R&D, and Section 2.2 introduces corporate takeovers.

2.1 Corporate financing of R&D

The corporate financing of R&D is divided into the following sections. Section 2.1.1 provides an example of the challenges and underlying assumptions for an entrepreneurial firm that considers investing in a R&D project that cannot be financed with internal funds. Section 2.1.2 introduces problems that can arise in the presence of information asymmetry. Sections 2.1.2.1 and 2.1.2.2 detail two types of market imperfections due to information asymmetries: adverse selection and moral hazard. Section 2.1.3 describes R&D disclosures as a mechanism to mitigate information asymmetry problems. Section 2.1.4 presents a brief overview of capital structure and R&D, and Section 2.1.5 describes two equity-market timing theories.

2.1.1 R&D investment

Consider an entrepreneurial firm without financial slack and no assets in place that has an opportunity to invest in a risky R&D project. Let us assume that the firm's scientists have identified a key mechanism responsible for the growth of cancer tumors and have been able to develop inhibitors blocking this mechanism. Although the drug has only been tested in animal models, the results are intriguing: blocking the energy supply to the tumor not only resulted in shrinkage of the tumor but also eliminated the tumor. Finding a cure to cancer would offer a significant market opportunity. The cancer market is expected to grow to more than $40 billion. Currently approved drugs only marginally extend the life of cancer patients but offer no cure. Although the R&D project is risky, as the molecular target is non-validated, the calculated net present value of the project is positive. The only problem is that carrying out the project requires a significant amount of funding, which is estimated to be $500 million. Due to the lack of internal funds and no collateral, the firm has to raise external financing in the capital market, i.e., issue shares, to finance the investment. Due to the competitiveness in the cancer market, the investment opportunity is short-lived, i.e., it evaporates if it is not undertaken.

Managers are assumed to act in the interest of existing shareholders and will only raise equity financing if the net issue benefit is non-negative, i.e., when the net present value of the R&D project exceeds or is equal to the sum of the direct flotation costs of the issue and the expected

wealth transfer from existing to new investors. That is, when $b - [d + w(k)] \geq 0$, where b is the value of the project, d is the direct flotation cost, and $w(k)$ is the expected wealth transfer from old to new investors. The entrepreneurial firm has been listed on the stock exchange for a year, but the stock has declined significantly following the failure of a prior project based on a completely different mechanism. Investors have started to question the technology of the firm and its ability to generate promising drugs. In addition, due to the financial crisis, the investment sentiment and appetite for high risk stocks is generally low, which has driven the share price even farther down. Some of the existing large investors, unaware of the current R&D project, have indicated that they do not intend to participate in the equity issue. The managers of the firm believe the firm is substantially undervalued, especially given the current potential of the cancer R&D project. In this case, the total cost of issuing exceeds the value of the project, i.e., the dilution costs of issuing undervalued equity for existing stockholders are too high relative to the profitability of the R&D project. Therefore, the managers of the firm will forego the investment opportunity, which Myers and Majluf (1984) refer to as the underinvestment problem.[2] Although the risky R&D project was at an early stage and many years away from reaching the market by foregoing the investment opportunity would simply mean abandon a potentially life-saving discovery for millions of cancer patients.

2.1.2 Information asymmetry and R&D

Corporate investments generally create information asymmetry problems[3], which refers to the fact that corporate managers can continually observe changes in investment productivity for individual assets, whereas outsiders only have access to highly aggregated information at certain points of time when information is made public. Corporate R&D investments have several characteristics that make them different from ordinary investments. First, fifty percent or more of the amount of the R&D investment is human capital, i.e., the salaries of highly educated research scientists (Hall, 2002). In turn, they create an intangible asset, the firm's knowledge base, from which future profits will be derived. Therefore, the human capital (the

[2] In the single flotation method, as suggested by Myers and Majluf (1984), existing investors are passive and the issuing method is a direct equity sale to the public, i.e., existing shareholders do not participate in the equity issue.

[3] In well-functioning markets with perfect information, the information between sellers and prospective buyers is unbiased and symmetrical. Under such circumstances, rational buyers will choose the best products, and the market will reward sellers of the best products with higher sales. By relaxing the assumption of perfect information and well-functioning markets, the information between the two parties becomes asymmetrically distributed, i.e., one party now has more (or superior) information than another, which gives rise to information asymmetry problems.

resource base) of the firm will be equal to zero if the scientists leave the firm or are fired. Second, an important feature of R&D is the uncertainty associated with its output. In the drug development setting, for example, only approximately 10 percent of clinical candidates reach the market. Third, R&D investments are associated with long development times: it takes an average of 10-15 years to develop a new drug.

Asymmetric information problems vary across industry sectors. Himmelberg and Petersen (1994) argue that problems associated with information asymmetry are particularly evident in R&D-intensive industries, such as the high-technology sector and especially the biotechnology industry (Lerner et al., 2003; Hall, 2002). Several factors contribute to the information asymmetry in the biotechnology industry. First, managers in R&D-intensive industries generally know considerably more than outsiders do about the specification of products under development, the likelihood of success, the results of product feasibility tests, and marketing prospects (Aboody and Lev, 2000). Second, the extent of information asymmetry associated with R&D investments is larger than that associated with tangible and financial investments due to the relative uniqueness of R&D (Aboody and Lev, 2000; Titman and Wessels, 1988). R&D projects, such as the development of a new drug, are often unique to the developing firm. For example, a failure of a drug with a new mechanism of action to exhibit efficacy in humans is a unique event not shared by other biotechnology or pharmaceutical companies. Hence, investors generally derive little or no information about the firm's R&D projects by observing the R&D performance of other drugs. Third, while financial assets are traded in organized markets, where prices are observable and convey direct information about values, there are no organized markets for R&D where prices are available. Fourth, while financial assets are generally marked-to-market and reported on a quarterly basis, current accounting practice requires firms to immediately expense their significant value-enhancing investments in R&D, and therefore, it is generally not required that information be provided about the value of R&D.[4] Fifth, firms are reluctant to disclose firm-specific proprietary information about the firms' R&D activities for competitive reasons.

[4] In an international setting, the IASC implemented a standard for Intangible Assets (IAS 38) in 2001. According to IAS 38 (IFRS), research costs should be expensed when they incur, while development costs can be capitalized if certain criteria are met. One such criterion is that future economic benefits are highly probable. Even in the later stages of the clinical development process, the likelihood of success is relatively small. For example, in clinical phase III, the probability of reaching the market averages 67 percent. Consequently, most development stage biotechnology companies immediately expense the R&D investments when they occur.

In the corporate financing of R&D, several challenges arise for the asymmetrically informed agents, e.g., the corporate managers. The agents are motivated to communicate the privately owned information about the R&D project to a subset of uninformed agents (investors) but can only do so through channels or signals that benefit competing agents (Bhattacharya and Ritter, 1983). An alternative would be to communicate privately to existing investors only, who would subsequently buy and hold the entire issue. This alternative would be equivalent to having access to internal corporate funds, but this would be both difficult and illegal. Consequently, the disclosure of R&D information is of direct usefulness to competitors and, therefore, associated with a substantial cost because it serves to reduce the quality of the signal they can make about a potential project (Anton and Yao, 1998). The asymmetrically informed agent, therefore, faces a trade-off between reducing the value of its informational advantage and raising financing at better terms that reflect its innovation prospects, thus lowering the dilution suffered by its existing shareholders owning the R&D project (Bhattacharya and Ritter, 1983).[5] Spence (1974) proposes a signaling equilibrium model arising from the trade-off between increased valuation in the capital market and the lower probability of being the first to innovate. In the corporate financing of R&D, the asymmetrically distributed information between corporate insiders and outsiders can lead to problems associated with adverse selection and moral hazard.

2.1.2.1 Adverse selection

In his seminal paper, Akerlof (1970) used the market for used cars as an example of the problem when asymmetric information about quality can lead to a situation where only poor quality products ("lemons") become available in the market. Assuming that there are good cars and bad cars (lemons) in the market, prospective buyers have difficulty distinguishing between the good cars and the bad cars. Sellers know the quality of their cars but cannot convey this information credibly to buyers. To hedge for risks of buying a defective car, buyers discount the price they are willing to pay based on the expected probability that they will get a bad car. Sellers of good cars are unwilling to sell at a discounted price and withdraw from the market. As a result, only "lemons" will be for sale in the used car market. Hall and Lerner (2009) argue that a similar lemon problem exists in the market for financing R&D. Prospective buyers (e.g., outside investors) have difficulty distinguishing high-quality projects (or firms) from low-quality projects ("lemons"). High-quality firms have difficulty signaling their quality by disclosing more R&D-specific information due to the costs associated with

[5] This basically assumes that existing investors do not participate in the offering.

benefiting competitors. The lemon premium will be higher in R&D-intensive industries, especially when projects are long-term R&D investments, than when they are more short-term or low-risk projects (Leland and Pyle, 1977). In the most extreme case, the market for financing R&D projects may completely disappear if the level of information asymmetry is too high.

2.1.2.2 Moral hazard

Moral hazard problems provide another market friction in the financing of R&D. Moral hazard problems arise when there is a separation between ownership and control. The principal-agent theory (Jensen and Meckling, 1976) concerns difficulties in motivating corporate management (the agent) to act in the best interests of existing shareholders (the principal) rather than in his or her own interests. The agency theory describes the relationship as a contract under which principals engage agents to make decisions and manage the firm on their behalf. In the R&D setting, two agency cost scenarios may co-exist. First, managers may spend on activities that simply benefit them (although not the existing shareholders), such as investing in negative NPV projects. Second, risk-averse managers may be reluctant, or even avoid, investing in uncertain and high-risk R&D projects. To reduce agency costs, the amount of free cash flow available to the managers can be limited by leveraging the firm. However, the lack of collateral makes leveraging an unviable alternative. In addition, leveraging forces the firm to use the higher-cost external funds to finance R&D (Jensen and Meckling, 1976). Grossman and Hart (1980) and Shleifer and Vishny (1986) suggest that institutional ownership can lower agency costs. The higher the level of ownership concentration, the easier it is for a small group of shareholders to influence management behavior through their voting power as well as ensuring that the resources of the firm are efficiently used. In contrast, the more diverse the shareholding, the easier it is for management to expropriate their own interests or to use cash inefficiently as the level of influence by non-management shareholders decreases (Mitchell, 1983). Pension funds and venture capital funds are generally considered effective in monitoring agents (e.g., Admati and Pfleiderer, 1994; Sahlman, 1990). However, monitoring may not be effective if ownership is concentrated in the hands of passive investors.

2.1.3 Corporate disclosures

Corporate disclosures generally aim at reducing the information asymmetry between managers and investors. Firms may have incentives to make additional voluntary disclosures if these will benefit the firm (Cerbioni and Parbonetti, 2007). However, reducing information

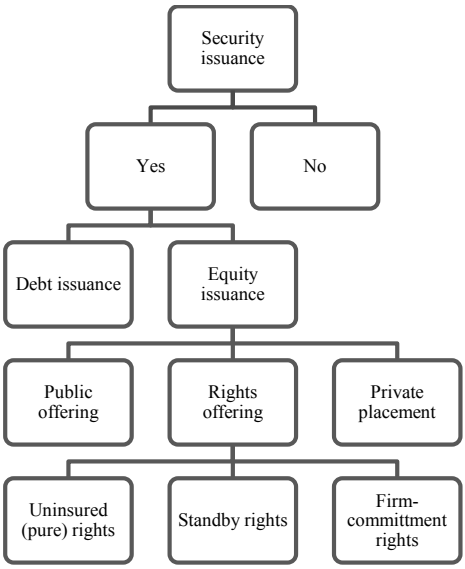
asymmetry via voluntary disclosures represents a trade-off between the benefits and costs of disclosing information. Spence (1974) proposes a signaling equilibrium model arising from the trade-off between increased valuation in the capital market and the lower probability of being the first to innovate. Prior empirical research has shown that voluntary disclosures are associated with a lower cost of equity capital (Botosan, 1997), higher stock liquidity (Diamond and Verrecchia, 1991) and an increase in information intermediation (Lang and Lundholm, 1996). In contrast, the costs of disclosures are related in terms of benefiting competitors (Guo et al., 2004) and increasing litigation exposure (e.g., Darrough and Stoughton, 1990). However, Guo et al. (2004) argue that although news about a drug's success in clinical trials might encourage competitors to develop substitute drugs, it might alternatively deter them from entering the field.

2.1.4 Capital structure and R&D

Myers and Majluf (1984) provide an early analytical framework in the context of raising external equity financing. In their model, corporate managers maximize the full-information value of existing shareholders' claims on the firm and issue equity directly to the market in a public offering with no mechanism (such as an underwriter) for communication between the issuer and outside investors and without participation in the issue of existing investors. In this setting, Myers (1984) proposed a pecking-order theory, where the cost of financing increases with the degree of asymmetric information. Corporate managers have more information about the firms' prospects than corporate outsiders, and the theory suggests a financing hierarchy, where they first prefer internal financing, then debt, and then raise external equity as a last resort. For early-stage and cash-flow negative R&D firms that invest heavily in intangible assets such as R&D, the investments generally exceed their capability of generating funds internally. Debt finance is generally not an option due to the absence of collateral (i.e., assets-in-place). Hence, equity provides the primary alternative. Blass and Yosha (2001) find that R&D-intensive US firms tend to use highly equity-based sources of financing.

The Myers and Majluf (1984) model only considers the single case, in which corporate managers issue equity directly to the market in a public offering and do not provide a rational explanation for the firm's choices of equity flotation methods, ranging from uninsured rights offerings to current shareholders to underwritten rights offerings (such as standby and firm-commitment rights) and private placements (see Figure 1).

Figure 1. The financing choices for post-IPO firms



Notes: This figure displays the most common flotation alternatives for post-IPO firms. In a public offering, securities are sold to the public, as in the Myers and Majluf (1984) model. In a rights offering (or rights issue), existing shareholders are given the pre-emptive (preferential) "rights" or option to purchase on a pro rata basis a certain number of shares at a fixed price within a specified time. A rights offering can be either uninsured (non-underwritten) or insured (underwritten). There are two variants of insured rights offerings: standby rights and firm-commitment rights offers. In a standby rights offer, an investment bank guarantees that any unsubscribed rights or shares are taken up. In a firm-commitment offer, the investment bank assumes the risk of selling the shares to the market by buying the issue from the issuer. In contrast, a private placement is a non-public offering in which securities are usually sold to a small number of chosen private institutional investors (e.g., banks, insurance companies, pension funds, mutual funds). Although several equity flotation methods exist, the preference and use tend to differ across countries. In the US, the two most commonly used equity issuance methods are public offerings and private placements. Outside the US, the two most commonly used equity issuance methods are rights offerings (uninsured rights and standby rights) and private placements. With exceptions for Japan and France, the firm-commitment underwritten offer has not yet spread outside the U.S. (Eckbo, 2008).

Eckbo and Masulis (1992) extend the Myers and Majluf (1984) model to explain the adverse selection problem by issuers with access to alternative flotation methods such as pure (uninsured) rights, standby rights and firm-commitment underwritten offerings. In addition, Eckbo and Masulis (1992) argue that the certification by an underwriter can mitigate the adverse selection problem. In their model, the adverse selection cost problem exists when the fraction of the stock issue expected to be taken up by existing shareholders (denoted k) is less than 100 percent. For a given level of current shareholder take-up (below 100 percent), the greater the undervaluation of the firm's shares, the more unlikely the firm will issue equity.

The value of k is assumed to be an exogenous factor determined by shareholder characteristics, such as wealth constraints, diversification benefits, and benefits from maintaining a shareholder's proportional ownership of the issuer's equity (Bøhren et al, 1997; Eckbo and Masulis, 1992). Although k is largely beyond managerial control, managers are assumed to have better information than the market about k, as subscription pre-commitments indicated by existing shareholders give them a good approximation of the expected take-up in the issue. If the management believes k to be high, i.e., existing shareholders are expected to buy and hold the new shares, a pure (uninsured) rights offer is the lowest-cost flotation method. In the extreme case of $k = 1$, where current shareholders purchase and hold the entire issue, there is no wealth transfer to outside investors. This is basically equivalent to having access to an internal source of funds that is not disadvantaged by asymmetric information costs. In this case, both the subscription price and the degree of undervaluation (or mispricing) are irrelevant to shareholders, as there is no wealth transfer from existing investors (no adverse selection). In theory, a deeply discounted rights offering to existing investors may help ensure the success of the offering and minimize the wealth transfer from existing to outside investors. However, the subscription price is a signal of firm quality, and a deep discount may convey negative information to outside investors about the true value of the issue (Heinkel and Schwartz, 1986; Loderer and Zimmermann, 1988). Managers may therefore be reluctant to issue rights with a deep subscription-price discount (Smith, 1977). Furthermore, it is reasonable to assume that firm managers in general are unable to commit personal wealth to the R&D project due to the significant amount of funds required to finance the R&D project, such that outside investors are incapable of deriving any signal from the corporate managers' commitment to the project.[6] Empirical studies (e.g., Eckbo and Masulis, 1992; Cronqvist and Nilsson, 2004) report an average shareholder take-up of 86-90 percent in pure (uninsured) rights offerings compared with approximately 65-81 percent for standby rights. In the current study for a sample of European biotechnology firms, the corresponding figures are 69.5 and 74.9 percent for standby rights and uninsured rights, respectively. Consequently, it is reasonable to assume that $k < 1$ in the pool of rights offerings.

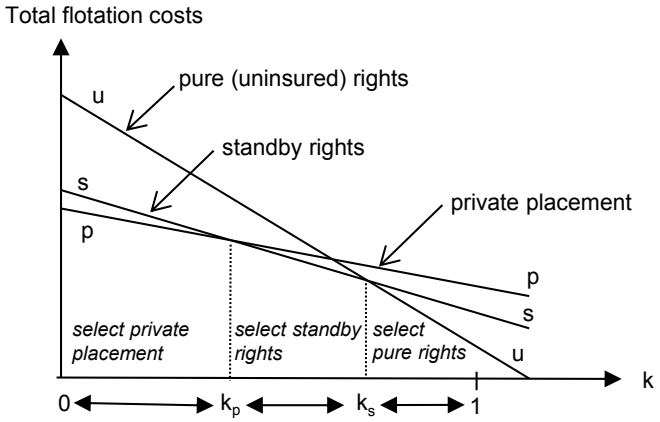
When k is expected to be less than one, some undervalued firms may find it too costly to issue new equity due to the costs to existing shareholders of selling shares to outsiders at a price

[6] Leland and Pyle (1977) consider an entrepreneur seeking external equity financing to finance a project. In contrast to outside investors, the entrepreneur knows the value of the project. However, the outside investors observe the fraction of the entrepreneur's personal wealth committed to the project and set their valuation accordingly.

below the intrinsic value. Adverse selection effects, and thus w(k), increase as k decreases. Hence, low-k issuers are likely to employ a more expensive flotation alternative (standby or firm-commitment) involving underwriter certification to narrow, although not fully remove, the information asymmetry between the firm and the market, as long as the sum of the expected certification benefit and the net project value exceeds the underwriter fee. Under Myers and Majluf's information asymmetry model for public offerings, the "underinvestment problem" can be avoided if managers are able to convey their private information to the market at no cost. Hertzel and Smith (1993) extend the Myers and Majluf (1984) model to allow the possibility that private placement investors can assess firm value through their negotiations with management and that private placements provide benefits similar to those suggested for mergers by Myers and Majluf (1984). Similarly, but for rights offerings, Eckbo and Norli (2005) expand the Eckbo and Masulis (1992) model by proposing an equity flotation pecking order (See Figure 2), in which issuing firms have access to a menu of flotation methods, including uninsured rights, standby rights and private placements, and select the cost-minimizing flotation method conditional on shareholder take-up. When k is expected to be low, in addition to hiring an underwriter (or, in the case the underwriter, declines to underwrite the offering) issuers can attempt to minimize a costly[7] market reaction to the announcement of the rights offering by choosing a private placement, in which sophisticated investors are given access to proprietary firm information. Therefore, undervalued firms can choose a private placement over a public issue (instead of not issuing and thereby potentially foregoing an investment opportunity) if it enables existing shareholders to retain a larger fraction of the firm, i.e., if the net present value of the investment opportunity exceeds the total cost of informing private investors about firm value, that is, $b \geq w(k)$, as private placements are assumed to have very low direct flotation costs. Eckbo and Norli (2005) describe the choice of the flotation method as an issuing game. High-k firms select uninsured rights, as this minimizes the potential wealth transfer to outside investors. Intermediate-k firms prefer standby rights but move to private placements if the underwriter rejects the issue. Low-k firms first select private placements but move to standby rights if they are unable to find a private placement investor. If both second choices are rejected, intermediate-k and low-k firms either select uninsured rights or abandon the issue.

[7] Eckbo (2008) documents that a stock market reaction of negative 2 percent to SEOs translates to an amount equal to 15 percent of the proceeds of the average issue, which is equivalent to more than three times the direct costs of an issue.

Figure 2. Equity flotation pecking order



Notes: This figure displays the equity flotation pecking order as suggested by Eckbo and Norli (2005). The y-axis plots the total expected flotation costs, which is the sum of the direct flotation costs and the expected wealth transfer from old to new investors. The key determinant in their model is the expected shareholder take-up by existing shareholders, denoted by *k* and shown on the x-axis. The optimal strategy at high levels of k, i.e., when k is between k_s and 1, is to select an uninsured (pure) rights offering. At intermediate levels of k, i.e., between k_p and k_s, firms first choose standby rights. Low-k firms ($k < k_p$) prefer private placements. Based on Bøhren et al. (1997) and Eckbo and Norli (2005).

2.1.5 Seasoned equity offerings and market timing

If the R&D investment opportunity evaporates if it is not undertaken, there is no room for timing an equity offering. If this assumption is relaxed, i.e., the firm's R&D investment opportunity can be postponed, undervalued firms have an incentive to postpone an equity issue until the firm's stock price is higher relative to the firm manager's belief of the firm's "true" valuation on the basis of the proprietary R&D project information. Over the years, two views on equity market timing have emerged: the mispricing and the adverse selection cost hypotheses.

2.1.5.1 The mispricing theory

Survey evidence in Graham and Harvey (2001) reveals that market timing is a primary concern of corporate executives: CFOs admit that timing considerations influence financing decisions. In a very influential study, Baker and Wurgler (2002) find that the capital structure is, by and large, a product of capital market timing. Moreover, several empirical studies have examined the stock market performance of firms around seasoned equity offerings (a stock-price run-up prior to the offering, a negative stock market reaction to the announcement of the

equity offering, and negative long-run returns). The results seem to indicate that managers time equity offerings when there is temporary mispricing (overvaluation) in the market. This is known as the mispricing ("windows-of-opportunity") hypothesis and is based on non-rational market pricing, in which investors have overly optimistic expectations about the issuing firm's future prospects. In the extreme case, where existing investors buy and hold the entire equity issue, which is similar to having access to internal corporate funds, temporary over- and undervaluation of the firm's stock is captured by existing shareholders. However, if existing investors sell some of their subscription rights in a rights issue (i.e., $k < 1$), when the firm is temporarily overvalued, outside investors will buy overpriced shares and are likely to experience a subsequent long-run underperformance when investors correct the mispricing over time.

2.1.5.2 The adverse-selection cost theory

The other equity market timing theory that has emerged is the adverse selection costs hypothesis. This hypothesis is built on the notion that the degree of asymmetric information between corporate insiders and outsiders is not fixed over time. The time-varying asymmetric information model by Korajczyk et al. (1991, 1992) suggests that immediately following an information release, few managers will have received a private signal, and the level of information asymmetry is small. As time passes, however, the information asymmetry problem becomes more severe. The model by Korajczyk et al. (1991, 1992) is based on rational market pricing and implies an association between equity issue activity and releases of firm specific information, such as the disclosure of quarterly and annual financial reports or the disclosure of R&D information. It is important to note that corporate disclosures will only reduce the information asymmetry if they contain value-relevant information. Hence, rational firm managers have incentives to raise external financing to finance R&D investments when information asymmetry between managers and investors is low, i.e., when investors are likely to understand the firm's future prospects, which typically is the case when value-relevant R&D information has been disclosed.

2.2 Corporate takeovers

Corporate takeovers are among the largest investments a firm ever will undertake. Hence, it is of great interest to examine the effect of takeovers on the wealth of bidder and target shareholders. The wealth effect of bidder and target shareholders can be investigated over a short-term event window around the acquisition announcement as well as the long-term

performance to the acquiring firm's shareholders. Most empirical research suggests that the shareholders of target firms realize significant positive abnormal returns around the acquisition announcement, while returns to acquiring firms' shareholders are close to zero (e.g., Eckbo, 2009; Huang and Walkling, 1987; Jensen and Ruback, 1983; Martynova and Renneboog, 2008). The wealth effect of merged firms in the post-merger period is inconclusive. If returns of merging firms are benchmarked to non-merging firms matched on size and the book-to-market ratio, the post-merger performance is, on average, negative (e.g., Rau and Vermaelen, 1998). However, when using asset pricing benchmarks, the abnormal performance is insignificantly different from zero.

2.2.1 Corporate takeovers and information asymmetry

Myers and Majluf (1984) argue that corporate acquisitions gives rise to adverse selection problems due to asymmetrically distributed information between parties involved in the transaction. Although corporate bidders have access to publicly available information and diligence information about the target company, they only have imperfect information about the target company's future cash flow contribution and about the prospects of a competing bid.

Several studies have suggested that information asymmetry problems may have a significant impact on the likelihood and performance implications of acquisitions (e.g., Eckbo et al, 1990; Balakrishnan and Koza, 1993; Coff, 1999). Information asymmetry further complicates the post-acquisition management of target firms with intangible assets, such as research and development (R&D), because acquirers are typically unable to verify the targets' quality prior to the acquisition. Rodriguez and Higgins (2003) find that little or no value is created for the acquiring firm's shareholders when a significant portion of the target firm's value consists of intangible assets.

2.2.2 Information intermediaries

In the market for deals, the lemon problem (Akerlof, 1970) is described such that sellers of high-quality assets withdraw from the market because they are unable to convey their information to buyers, leaving only low-quality assets left in the marketplace. In the R&D setting, Pisano (1997) finds that biotechnology firms exploit their information advantage regarding the quality of their drug candidates by out-licensing to pharmaceutical firms those

that have relatively poor prospects[8]: the real performance of out-licensed drugs have a higher likelihood of failure than projects that are developed in-house. Biotechnology firms may have access to superior information (asymmetrically distributed information) regarding adverse effects or limitations of the R&D project but have few reasons to disclose them.

Several studies discuss the role of information-producing intermediaries in various situations that may help evaluate and signal to markets the quality of firms (Leland and Pyle, 1977; Campbell and Kracaw, 1980; Chan, 1983; Chemmanur, 1993; Chemmanur and Fulghieri, 1994; Eckbo and Masulis, 1992[9]). In alliances, Leland and Pyle (1977) argue that "moral hazard problems can be alleviated if the firm gathering the information becomes an intermediary, buying and holding assets on the basis of its specialized information". Nanda and Williamson (1995) argue that an alliance provides an opportunity for the acquiring firm to learn more about the quality of the asset and improve their informational disadvantage. In the R&D setting, an alliance between a pharmaceutical firm (licensee) and a biotech firm (licensor) may mitigate information asymmetry problems if scientists of both companies work in close collaboration and exchange project-specific information.

The principal-agent relationship in an R&D alliance between the pharmaceutical and biotechnology firm is subject to moral hazard problems in several aspects. The incentives of biotechnology firm managers (agents) and alliance partners (principals) may diverge such that managers of biotechnology firms shift or extract resources from the partner project to other projects within the firm for two reasons. First, the contractual cash flow rights that are granted to the alliance partner often place a cap on the upside of the equity value of the small company (Ozmel et al, 2012). Second, risk-averse managers may extract resources to pursue similar projects (e.g., "follow-up" projects) or other projects to diversify the firms' project portfolio. Furthermore, reputational concerns, such as the ability to attract future partners, may prevent scientists at the biotechnology firm from confessing that the R&D project is unlikely to succeed and, therefore, from proposing termination.

In corporate acquisitions, several empirical studies document a positive association between having a prior alliance with the target firm and bidder returns (e.g., Chan et al., 1997; Porrini, 2004; Higgins and Rodriguez, 2006; Mantecon, 2009). For example, Higgins and Rodriguez

[8] In contrast, Nicholson et al. (2005) do not find support for a "lemons" problem in the market for know-how between biotechnology and pharmaceutical firms.

[9] In security issues, it has been argued that the role of financial intermediaries is to help mitigate, although not fully eliminate, the adverse selection problem. Eckbo and Masulis (1992) argue that certification by an underwriter can mitigate the adverse selection problem.

(2006) find, using a sample of 160 biopharmaceutical acquisitions between 1994-2011, that the overall abnormal return for acquiring firms is 3.9 percent and is positively associated with having a preceding alliance with the target firm. Thus, they conclude that "this prior contact should provide learning opportunities for the acquiring firm resulting in a more appropriate valuation being placed on the target firm". However, these studies are short-term in nature and provide no direct evidence of whether an alliance is associated with post-acquisition real performance.

3. The biotechnology industry as a research focus

The biotechnology industry has certain key features that make it an interesting study object from an academic point of view. This section describes why the disclosures of R&D information provide investors with value-relevant information, proxies for measuring information asymmetry, and what sources of R&D financing exist.

3.1 Mandatory R&D disclosures

Biotechnology firms differ from other R&D-intensive firms in the sense that the development process is closely monitored by external regulatory authorities, such as the FDA, with considerable experience of how to evaluate drugs in light of issues such as efficacy and safety. Biotechnology projects have to undergo a thorough and well-documented regulatory review process, and therefore, there are mandatory non-discretionary evaluations of the value-creation process. Publicly listed firms are subject to stock exchange regulations, which stipulate that they have an obligation to disclose "price sensitive" information as soon as possible to the public. These security laws limit the ability of firms to manage and time corporate disclosures. In addition, managers' incentives to disclose value-relevant product development information are also derived from investor demand (Guo et al, 2004; Cerbioni and Parbonetti, 2007). Consequently, disclosures of R&D information, such as clinical trial results, are generally mandatory (rather than voluntary) for small biotechnology firms. A problem with voluntary disclosures is that they are subject to a self-selection bias and, hence, the association between market reactions and disclosure might be driven by firm performance rather than disclosure per se (Healy and Palepu, 2001). Consequently, the non-discretionary nature of R&D disclosures in this industry overcomes the common criticism of endogenous events in the event study literature (Schultz, 2003; Viswanathan and Wei, 2008).

3.2 Information asymmetry and R&D disclosures

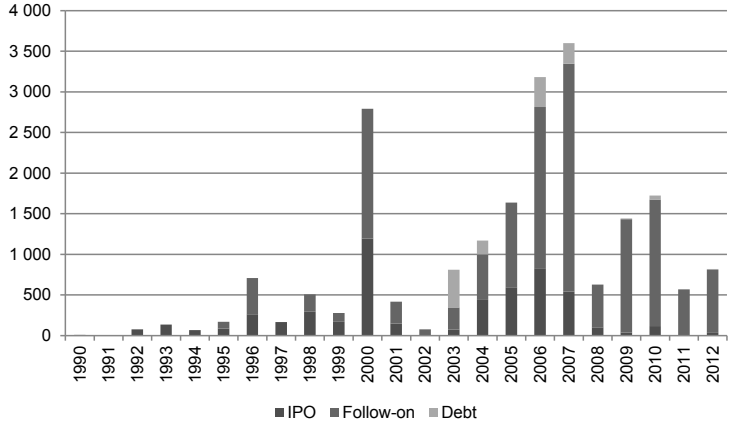
Several proxies for measuring the degree of asymmetric information are frequently employed in the academic literature, such as the number of analysts following the firm, institutional and insider ownership (e.g., Stoll, 1978; Brennan and Subrahmanyam, 1995), firm size (e.g., Vermaelen, 1981), firm age (e.g., James and Wier, 1990), trading volume (e.g., Chari et al., 1988), bid-ask spread (e.g., Glosten and Milgrom, 1985), and stock return volatility (e.g., French and Roll, 1986; Krishnaswami and Subramaniam, 1999). Aboody and Lev (2000) argue that these proxies are noisy because they reflect not only information asymmetry but also several firm and market characteristics. They suggest that the identification of firm-specific drivers of information asymmetry will provide more precise and less noisy measures of the level of information asymmetry.

Information asymmetries decrease when new value-relevant information is made public. Given that the disclosure of value-relevant information varies between firms and over time, the level of asymmetrically distributed information also varies (Dierkens, 1991; Lucas and McDonald, 1990; Choe et al., 1993). Asymmetries are low immediately following relevant news announcements because few firm managers have received a private signal, but the information advantage for managers increases with time. The adverse selection costs hypothesis tends to be tested in association with the release of earnings announcements (e.g., Korajczyk et al., 1991; 1992), dividend announcements (Loderer and Mauer, 1992) or financial forecast revisions (Lin et al., 2008). While disclosures of accounting information can be biased given the discretionary nature of accounting information, value-relevant and mandatory R&D disclosures are more likely to be a clean test of the information asymmetry hypothesis. In addition, it has been argued that accounting information for firms in R&D intensive industries such as biotechnology that invest heavily in intangibles convey less value-relevant information (e.g., Amir and Lev, 1996). Investors, therefore, are dependent on other types of information. In the biotechnology industry, a candidate drug's progress in clinical trials is a strong signal to investors that the firm creates value (e.g., Amir and Lev, 1996; McConomy and Xu, 2004). Furthermore, using an industry-specific sample provides an opportunity to use more direct and less noisy proxies of information asymmetry, which increases the power of tests for the presence of information asymmetry.

3.3 Equity financing

The biotechnology industry is different from other industries in that firms usually operate with large negative free cash flows and have significant costs associated with R&D. Most biotechnology firms are in an early life-cycle stage with no commercial product, and they invest heavily on a continuous basis in intangible assets such as R&D, but they can rarely fund these investments internally. Consequently, they are dependent on external financing. Because few biotechnology firms are profitable and investments are mainly in intangible assets, these firms cannot use debt financing and instead regularly turn to the equity market. Consequently, equity capital is a primary source of funding for publicly listed early-stage and not-yet-profitable growth firms (Bolton and Freixas, 2000; Rajan and Zingales, 1998; Ravid and Spiegel, 1997). Therefore, a sample of biotechnology firms enables a study of examining market timing theories and external financing decisions without having to think about alternative sources of external capital, such as debt financing (Guo and Mech, 2000). While debt financing is more common in the US because several larger biotechnology firms are cash-flow positive, it remains relatively uncommon in the European biotechnology industry (see Figure 3). A major advantage when examining the market timing aspects of equity issues is that one does not need to control for other sources of external capital (Guo and Mech, 2000).

Figure 3. External financing in the European biotechnology industry



Notes: This figure displays external financing in the European biotechnology industry from 1990 to 2012. Follow-on offers include rights issues and private placements. Figures are in million US dollars. Source: Annual reports and the Thomson Reuters Datastream database.

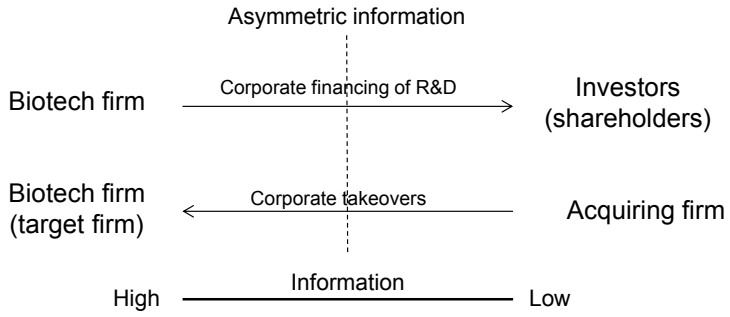
3.4 Takeovers and post-acquisition performance

A key challenge in analyzing the performance of corporate takeovers is to find appropriate measures of transaction success. Most prior studies measure the cumulative abnormal returns in the post-acquisition period. Although a positive abnormal stock market performance provides a real measure of success, a potential drawback with this measure is that it is noisy in the sense that it may reflect not only the performance of takeovers but also other firm and market characteristics that have an impact on the firm's stock. In this setting, the biopharmaceutical industry provides a unique opportunity to study the association between information asymmetry, takeovers, alliances and the post-acquisition performance of R&D projects for several reasons. First, pharmaceutical firms engage intensively in alliances as well as mergers and acquisitions of biotechnology firms to supplement their internal R&D portfolios. Second, extensive publicly data are available for both the acquiring and target firm research portfolios that are associated with information asymmetries, which provides an opportunity to directly examine the real performance of individual R&D projects regarding the project-level rather than firm-level performance in the post-acquisition period.

4. Research questions

Having the characteristics of the biotechnology industry in mind, this thesis is centered around two key events that play an important role in the biotechnology industry: 1) Corporate financing of R&D and 2) Corporate takeovers (see Figure 4). In the corporate financing of R&D, the biotechnology firm raises external financing from investors (new or existing shareholders) to finance investments in R&D. In corporate takeovers, the acquiring firm targets the biotechnology firm. In both cases, the biotechnology firm is assumed to have access to more information than investors and the acquiring firm, respectively. Table 1 provides an overview of the four essays and the research hypotheses.

Figure 4. Overview of two key events: corporate financing of R&D and corporate takeovers



Notes: This figure displays the two key events, corporate financing of R&D and corporate takeovers, and the asymmetrically distributed information between the parties.

Table 1. Overview of the essays

Essay	Research hypotheses
1. The value-relevance of accounting and non-accounting information in the European biotechnology industry	H1: Financial information is value-relevant in the European biotechnology industry H2: R&D information is value-relevant in the European biotechnology industry
2. Market timing and external financing decisions	H1: Biotechnology firms issue equity to a greater extent when equity market sentiments are strong H2: Biotechnology firms issue new equity to a greater extent after they have released disclosures of R&D
3. Information asymmetry, R&D disclosures and the choice of equity-selling mechanisms	H1: Biotechnology firms use rights offerings to a greater extent after they have released disclosures of R&D H2: Biotechnology firms use private placements to a greater extent when the level of blockholder ownership is small
4. Acquisitions, alliances and post-acquisition R&D performance	H1: Cumulative abnormal returns of acquiring firms are positively associated with prior alliances with target firm H2: An acquirer's previous alliance with a target correlates positively with post-acquisition R&D performance

Notes: This table displays the four essays and the research hypotheses.

In the corporate financing of R&D, I use R&D disclosures as the main proxy for the level of information asymmetry. Hence, the first essay examines the value-relevance of accounting (earnings and book values) and non-accounting information (R&D information). Using the well-known event study methodology (e.g., MacKinlay, 1997; Campbell et al., 1997), the market's reaction to earnings and R&D news announcements is studied.[10] How does the stock

[10] The study is directly concerned with the efficient market hypothesis developed by Fama (1970), which suggests that a market is efficient if all available information is incorporated into the market price at any time. Depending on the definition of "all available information", three forms of market efficiency can be distinguished: 1) Weak-form efficiency, 2) Semistrong-form efficiency, and, 3) Strong-form efficiency. Weak-form efficiency (tests for return predictability) assumes all historical information is already included in the

market react when quarterly earnings information or the results of clinical trials are disclosed? Is there a difference in the market's reaction between different types of R&D news announcements (e.g., pre-clinical, phase 1, phase 2, etc.), between announcements of positive and negative results, between different types of companies, and between different market sentiments? This study forms the basis for the measure of information asymmetry (R&D disclosures) used in essays two and essay three.

The second and the third essays address equity financing decisions. A schematic overview of the two essays is detailed in Figure 5. I assume that the choice to issue equity occurs at two levels. In the first level, the firm decides whether to issue equity. In the second level, firms that have decided to raise equity capital choose between raising capital via a rights offering or a private placement.

Essay two examines timing aspects of raising external financing. Are biotechnology firms able to access equity markets following a period of abnormal stock return performance? How do biotechnology stocks perform in the period after the equity issue announcement? To what degree are biotechnology firm managers able to access equity markets when there is a higher likelihood that investors understand the firm's prospects? How does the stock market respond to equity issue announcements? Is there an association between pre-issue disclosures of R&D information and the stock market reaction at the equity issue announcement?

The third essay investigates how biotechnology firm managers choose between two equity-selling mechanisms: rights offerings vs. private placements. What impact does the level of information asymmetry about firm value have on the choice between private and public equity capital? Does the risk of moral hazard play a role in the choice of equity-selling mechanisms?

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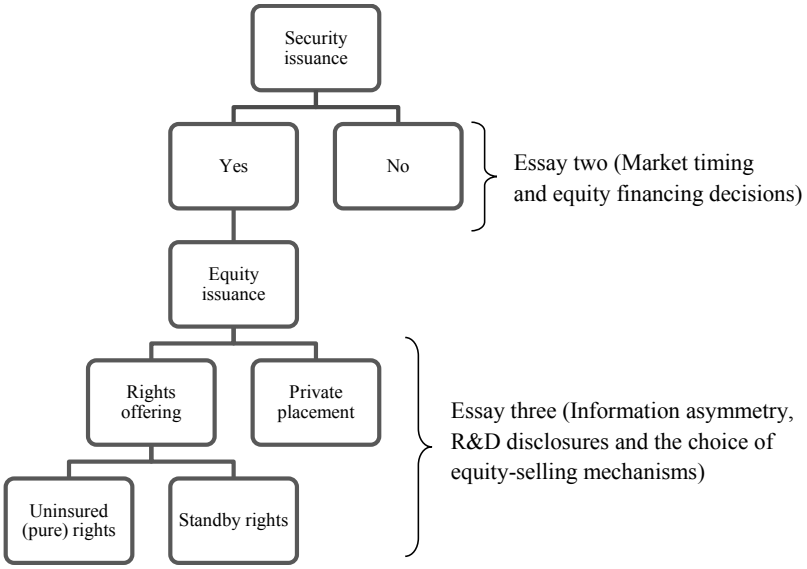
market price. According to semistrong-form efficiency, at the time public information is issued, it is immediately incorporated in the market price. In Fama (1991), this section was renamed "Event Studies". Strong-form efficiency (tests for private information) assumes that all possible information, including insider information, is included in the market price. Essay one makes the explicit assumption that the stock markets are semistrong-form efficient.

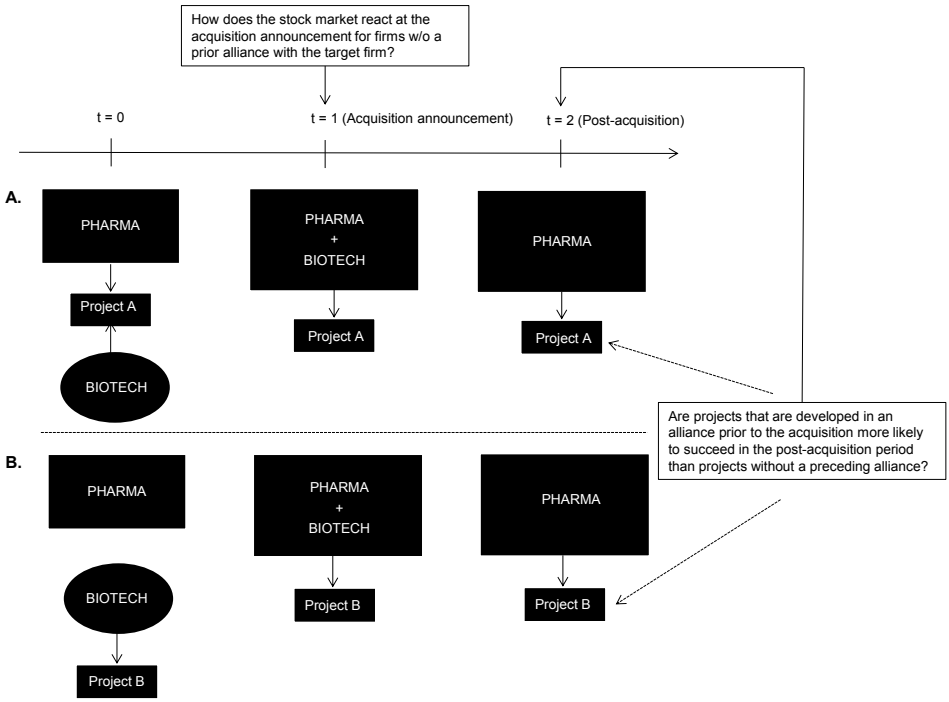
Figure 5. Financing decisions in the European biotechnology industry



Notes: This figure displays the choices public biotechnology firms have related to financing decisions. In the first level, firms choose between issuing equity versus not issuing equity. The second level refers to issuing firms and the decision to issue equity privately versus publicly.

The fourth essay examines the short-run and real long-run operating performance of acquisitions and the association with alliances. Figure 6 displays a schematic overview of essay four. Can acquiring firms mitigate the risk of buying a lemon by engaging in information-gathering activities prior to the acquisition? What is the stock market reaction (at t = 1) for an acquiring firm when they have a preceding alliance with the target firm compared with acquisitions without a prior alliance? What is the long-term performance (at t = 2) of acquired firms' R&D projects? Do pre-acquisition information-gathering activities lead to more successful post-acquisition integration, i.e., is project A more likely to succeed than project B?

Figure 6. Schematic overview of essay 4



Notes: This figure displays a schematic overview of essay four (Acquisitions, alliances and post-acquisition R&D performance) and the research hypotheses. In example A, pharma and biotech jointly develop project A, which originates from biotech (t = 0). At t = 1, pharma acquires biotech and gains full access to project A. At t = 2, the performance of project A is evaluated. In example B, the biotech company develops project B. At t = 1, pharma acquires biotech and gains full access to project B. At t = 2, the performance of project B is evaluated. The first hypothesis (H1) examines at t = 1 whether bidders' returns are positively associated with having an alliance with the target firm (Example A) compared with not having a prior alliance with the target firm (Example B). The second hypothesis (H2) investigates at t = 2 whether R&D projects are more likely to succeed if they are preceded by an alliance prior to the acquisition (Example A) versus if they are not preceded by an alliance (Example B).

5. Data

The data used in the four essays are collected from several sources. The following section describes the data collection process.

Sample firms

The sample of firms in essays one, two and three are identified from the Thomson Reuters Datastream database. Several restrictions to the sample are made. First, the company's primary listing is on a European stock exchange. Second, only firms that are engaged in the development of drugs are included. Third, to ensure a homogenous sample, pharmaceutical and generic companies are excluded as well as companies developing tools, instruments,

devices or providing technology-based services to other healthcare companies. These restrictions reduce the number of firms from 431 to 121. The distribution of the sample firms based on the year of initial public offering (IPO) or introduction and based on the country is displayed in Table 2.

Table 2. Sample of publicly listed European biotechnology firms

Year	Belgium	Denmark	France	Germany	Italy	Netherlands	Norway	Sweden	Switzerland	UK	Other	Total
1990	0	0	0	0	0	0	0	0	0	1	0	1
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	2	0	2
1993	0	0	0	0	0	0	0	0	0	2	0	2
1994	0	0	0	0	0	0	0	0	0	2	0	2
1995	0	0	0	0	0	0	0	0	0	4	0	4
1996	0	1	1	0	0	0	0	1	0	5	0	8
1997	0	0	0	0	0	0	0	1	0	3	0	4
1998	0	1	1	1	0	1	1	1	0	2	0	8
1999	0	0	1	3	0	0	0	0	0	0	0	4
2000	0	2	0	3	0	1	0	0	1	1	2	10
2001	0	0	0	0	0	0	0	1	1	1	0	3
2002	0	0	0	0	0	0	0	0	1	0	0	1
2003	0	0	0	1	0	0	0	1	0	0	0	2
2004	0	0	0	0	0	0	0	0	1	7	1	9
2005	2	1	2	2	1	0	1	1	2	7	1	20
2006	1	1	2	2	2	1	1	1	1	4	0	16
2007	2	0	2	0	1	1	1	1	2	3	1	14
2008	0	0	0	1	1	0	1	0	0	1	0	4
2009	0	0	1	1	0	0	0	0	1	0	0	3
2010	0	1	2	0	0	0	0	0	0	0	0	3
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	1	0	0	0	0	0	0	0	0	1
Total	5	7	13	14	5	4	5	8	10	45	5	121

Notes: This table displays the sample of European biotechnology firms and the year of IPO or introduction. In an IPO, shares are sold in connection with the listing. In contrast, in an introduction there are no sales of shares in connection with the listing. In total, 121 firms became publicly listed, of which 112 have made an IPO and 9 have been introduced. Source: Thomson Reuters Datastream Database.

R&D announcements

Essays one, two and three are based on a hand-collected sample of R&D announcements made by the sample of post-IPO firms. R&D announcements are primarily collected from corporate websites and the Factiva database. The final sample comprises 1,071 R&D announcements made by the sample of post-IPO firms between 1998 and 2012 and is reported in Table 3. R&D announcements are classified according to stage of development and on a good news-bad news ranking. The stages of development are briefly discussed below and a more comprehensive description is detailed in Section 6.2.

Table 3. Description and classification of R&D announcements

Announcement category	Stage	Number of announcements
Initiation		8
Results (positive)	Pre-clinical	56
Results (negative)		15
Initiation		200
Results (positive)	Phase I	123
Results (negative)		36
Initiation		214
Results (positive)	Phase II	175
Results (negative)		55
Initiation		88
Results (positive)	Phase III	66
Results (negative)		35
Total		**1,071**

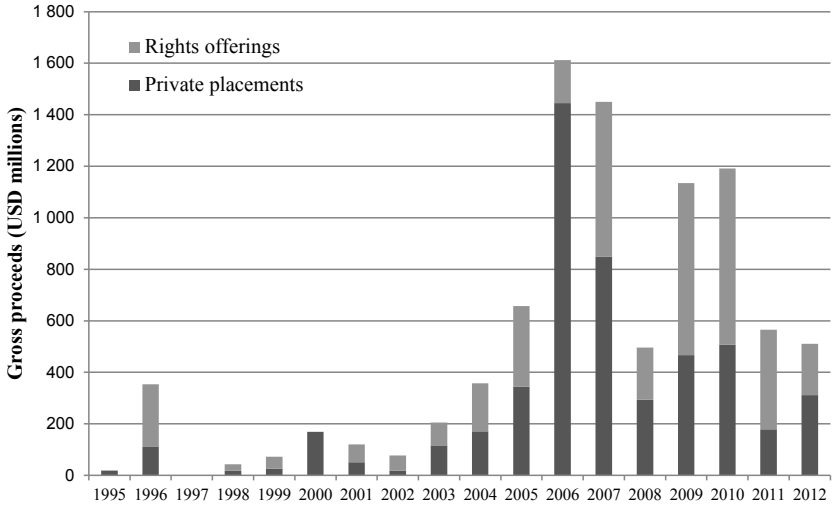
Notes: This table reports different types of announcements related to different phases (or stages) of the R&D process. These announcements are classified into three main announcement categories: initiation, results (positive), and results (negative). Four different phases are distinguished: pre-clinical, phase I, phase II and phase III. The review stage is excluded due to the low number of observations. In general, the different phases in drug development can be described as follows. At the preclinical stage, the drug is tested for safety and efficacy in animal models. Phase 1 trials examine the safety of the drug in healthy volunteers. Phase 2 examines drug efficacy in a small-scale patient group. Phase 3 examines drug efficacy in large-scale patient groups. Source: Corporate websites and the Factiva database.

Sample of equity issues

The sample of rights offerings and private placements was constructed by identifying changes in the number of shares outstanding for the sample of European public biotechnology firms using the Thomson Reuters Datastream database during 1990-2012. Several filters are imposed: (1) There must be at least a 5 percent change in the outstanding common stock of a company [11]. The 5 percent cut-off is a commonly applied standard for significant shareholdings. (2) Detailed information about the equity issue is determined using press release information from corporate webpages and the Factiva database. This collection method gives a final sample of 86 rights offerings and 226 private placements made by 91 firms over the period 1995-2012. Figure 7 displays the private placements and rights offerings in the sample.

[11] This filter automatically removes other less frequently used financing methods, such as equity credit facilities (e.g., committed equity financing facilities (CEFFs) and standby equity distribution agreements). The issue of warrants that result from stock option plans are also excluded. Five convertible bonds are excluded, as this issuance method is uncommon in Europe. In addition, nine firms report fourteen issuances of rights offerings and private placements at the same time point. These issuances are excluded, as they cannot be assigned to one of the two groups. Of the 226 private placements, 19 are to existing investors only. Of the remaining 207 private placements, 18 are to new investors only, and 189 are to both existing and new shareholders.

Figure 7. External financing of the European biotechnology industry between 1995-2012



Notes: This figure illustrates the amount raised by European biotechnology firms through private placements and rights offerings between 1995 and 2012. Source: Annual reports and the Thomson Reuters Datastream database.

Ownership data

The third essay uses a detailed hand-collected ownership dataset consisting of more than 4,000 firm-year observations for the sample firms. The ownership dataset is based on information in annual reports and proxy statements for the 121 publicly listed biotechnology firms in the sample. The classification of investors is made using several sources, including the National Venture Capital Association (NVCA), the European Private Equity and Venture Capital Association (EVCA), IPO prospectuses, the Pension Handbook, Morningstar's Mutual Fund Sourcebook and the Amadeus database.

Sample of acquisitions and alliances

In the fourth essay, the acquisition sample is collected from several sources, including the Zephyr database, the HBM Partners website and the Deloitte Recap database. Acquisition details are collected from corporate webpages and the Factiva database. Alliance data are obtained from the Deloitte Recap database. The final sample is detailed in Table 4.

Table 4. Biopharmaceutical acquisitions and alliances with the target firm by year

	Acquisitions					*Alliances*	
Year	*n*	*Fraction (%)*	*Value ($m)*	*Mean value ($m)*	*Median value ($m)*	*n*	*Fraction (%)*
1998	3	1	1,500	500	580	0	0
1999	11	5	11,598	1,054	550	2	4
2000	6	3	4,991	713	575	3	6
2001	6	3	20,937	3,490	1,060	0	0
2002	7	3	1,307	187	123	2	4
2003	9	4	6,152	684	400	3	6
2004	5	2	5,543	1,109	1,014	1	2
2005	22	10	17,786	808	289	5	10
2006	21	10	30,390	1,447	500	6	12
2007	22	10	32,234	1,465	357	5	10
2008	25	11	70,779	2,831	285	10	20
2009	20	9	14,253	713	523	2	4
2010	21	10	18,045	859	281	2	4
2011	20	9	50,840	2,542	477	2	4
2012	21	9	19,446	1,023	563	7	14
Total	219	100	305,801	1,250	505	50	100

Notes: This table provides summary statistics for the sample of 219 biopharmaceutical acquisitions and the number of alliances with the target firm in the 1998-2012 period. Source: Zephyr database, HBM Partners website, the Factiva database and the Deloitte Recap database.

6. Conclusions and further research

This section contains the major conclusions from the essays and provides some suggestions for future research.

6.1 Conclusions of the essays

The first essay, *"The value-relevance of accounting and non-accounting information in the European biotechnology industry"*, examines how the stock market reacts to the disclosure of earnings and R&D information, respectively. Using a hand-collected dataset of 1,071 R&D announcements made by publicly-listed European biotechnology firms from 1998-2012, the study shows that disclosures of positive and negative R&D information influence security prices and trading volumes and provide significant value-relevance (information content) to investors. In contrast, price and return regression models show that earnings information is not particularly value-relevant to investors. The significant stock price impact to positive, and especially negative, R&D disclosures highlights the importance of disclosure practices and stock exchange regulations. Although trading regulations require firms to disclose price-sensitive information when it appears, there seem to be some managerial discretion in the

wording of clinical trial announcements, which shed lights of the importance of a robust framework regarding the information content in press releases.

The second essay, *"Market timing and equity financing decisions"*, investigates the two views of equity market timing, mispricing and adverse selection costs, in the context of whether to issue equity. The study is based on a sample of 250 seasoned equity offerings made by publicly listed European biotechnology firms from 1998-2012. The primary motive to issue equity is due to a short-term need for cash as the average survival time at the announcement date is less than 7 months. The results of the study find support for both the adverse selection cost hypothesis and the mispricing hypothesis. They are significant explanatory factors on a stand-alone basis, and they provide incremental explanatory power beyond that of survival time. The empirical analysis shows that R&D news announcements are positively associated with issue of new equity, which lends support for the view that corporate managers access capital markets when there is relatively little asymmetric information between shareholders and management. In addition, biotechnology stocks generate positive abnormal returns in the period preceding the equity issue announcement and negative abnormal returns thereafter, which indicates that corporate managers can predict future stock returns better than investors can. During the last decade, a large body of research has focused on the idea that market timing is about opportunistic managers trying to capitalize on temporary mispricing. This study shows that the adverse selection cost theory seems to be, at least, an equally important factor in the equity issuance decision.

The third essay, *"Information asymmetry, R&D disclosures and the choice of equity-selling mechanisms"*, analyzes the impact of information asymmetry and corporate management monitoring on the choice between the two most common equity-selling mechanisms outside the US: rights offerings and private placements. The empirical study is based on 86 rights offerings and 226 private placements made by publicly listed European biotechnology firms during the 1995-2012 period. The results show that biotechnology firms tend to issue equity publicly rather than privately following the disclosures of R&D news announcements, i.e., when information asymmetry is low. However, there is no support for the monitoring hypothesis. A detailed analysis of investor identities show that confirms that monitoring does not seem to be an important determinant in the choice of equity-selling mechanisms. Several proxies, such as firm size and firm age, for measuring the degree of asymmetric information are frequently used in the literature. These proxies reflect not only information asymmetry but also several firm and market characteristics (Aboody and Lev, 2000) and do not fit well with

the time-varying asymmetric information model developed by Korajczyk et al. (1991, 1992). This paper verifies the importance of information asymmetry, using R&D disclosures as a proxy for information asymmetry, and adds to the growing literature addressing the choice between private and public financing.

The fourth essay, "*Acquisitions, alliances and post-acquisition R&D performance*", examines the short-term and real long-term performance of acquisitions and their association with alliances. The study is based on a sample of 219 biopharmaceutical acquisitions from 1998-2012. Contrary to past research, this study finds no association between having a prior alliance with target firms and bidder returns at the acquisition announcement. Using a hand-collected dataset of 383 R&D projects, the study finds that R&D projects that are co-developed prior to the acquisition are no more likely to advance to subsequent stages of development than are R&D projects that are not preceded by alliances. Even though an alliance provides an opportunity for an acquiring firm to learn more about the quality of the target firm's asset, it may not eliminate problems associated with information asymmetry. A key advantage of examining the post-acquisition R&D performance in this setting is the isolation of imperfect information, whereas the performance of out-licensed R&D projects can be either driven by imperfect information (lower-quality R&D projects that are licensed out) or perfect information (R&D projects are licensed out due to gains-from-trade). This study contributes to the acquisition literature by providing an alternative measure of analyzing transaction success in the post-acquisition period.

6.2 Future research

The empirical results from the essays have led to several interesting research questions for future research. In the corporate financing of R&D, future research can investigate questions such as: How does the private/public equity choice interact with alliance funding? What is the relation between capital requirement and the choice of equity-selling mechanism? To what extent are firms able to use both private placements and rights offerings (i.e. use a private placement to reduce information asymmetry and at the same time issue equity via a rights offering)? What is the association between the disclosure of accounting information and the choice of equity-selling mechanism in industries where accounting information provide investors with value relevant information? How are private placement investors chosen and what types of investors are likely to participate in private placements? What is the relationship between future performance of an R&D project and the choice of equity-selling mechanisms?

What is the association between future performance of an R&D project and managerial participation in the equity issue? How are firm managers working to attract long-term public investors that are willing to commit funding in the post-IPO period after venture investors liquidate their investments? Is there a potential monitoring gap problem following the departure of venture capital investors from the board before they are replaced with new blockholders?

In corporate takeovers, future research can examine when alliances are an alternative to acquisitions and when they are complementary. Additional research topics could include the determinants of significant bid premiums and whether there is a winner's curse in the biopharmaceutical industry. Further research on corporate financing of R&D and corporate takeovers seems promising.

7. The biotechnology industry

This section provides an introduction and overview of the biotechnology industry, which is the industry that the four essays address. Although reading this section is not a prerequisite before moving to the four essays, it details some of the characteristics and key features that may guide and help the reader in understanding the essays.

7.1 Definition of biotechnology

The word "biotechnology" is generally defined as the use of living systems and organisms to develop products for specific use. The term is most frequently associated with the healthcare industry/business and the use of various technologies to discover and develop new drugs for human diseases.

In this dissertation, when a "biotechnology" company is referred to, the definition common among industry practitioners is employed: "a firm that engages in the research and development of drugs and was founded after Genentech (1976)" (Nicholson et al., 2005). Therefore, companies developing tools, instruments, devices or providing technology-based services to other healthcare companies are excluded. Genentech is generally thought of as the first[12] biotechnology company that sought to produce biologics (i.e., therapeutics derived from molecules present in the human body) rather than the chemical compounds (i.e., small molecules) being developed by established pharmaceutical firms. Early definitions of

[12] In fact, Cetus Corporation was the first biotechnology company and was established in California in 1971, while Genentech was the first biotechnology company to become publicly listed (1980).

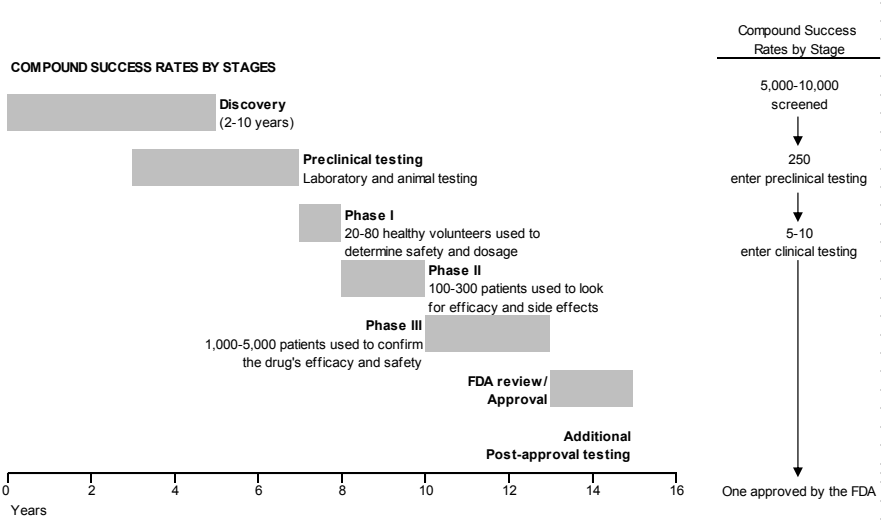
biotechnology only included companies developing injectable recombinant protein- and antibody-based drugs as opposed to the orally available small-molecule drugs historically developed by the pharmaceuticals industry. However, the distinction has become blurred, with many biotech companies developing small-molecule drugs and pharmaceutical companies developing protein-based drugs. Today, the biotech sector is a complex and fragmented market that encompasses companies with a multitude of technologies and applications. In practice, many biotechnology companies develop both biologics and chemical compounds, as do most large pharmaceutical firms.

7.2 Drug development process

Drug-development is a long, risky and costly process. It is estimated to take 10 to 15 years from initial concept to product launch. The average cost per launched product was estimated to be $1,318 million in 2006 (DiMasi and Grabowski, 2007), and only approximately 10 percent of compounds that enter clinical testing reach the market (e.g., Robbins-Roth, 2001). Because this process is central to the companies included in this thesis, it is described in more detail in this section.

Table 5. Drug development process

Panel A.



Panel B.

		Clinical trials				
	Early basic research/pre-clinical testing	**Phase I**	**Phase II**	**Phase III**	**Regulatory review process**	**Phase IV**
Purpose	Identify a drug target and a candidate drug (CD) for pre-clinical testing. Determine toxicology and pharmacology in animals	Determine safety, pharmacology and dosage in humans for the next phase	Evaluate effectiveness, look for potential toxic side effects, decide the optimal dose and form of administration	Confirm effectiveness and show statistical significance according to pre-defined endpoints, look for side effects from long-term use	Receive approval by FDA (US), EMEA (Europe) or other regulatory authority to market the drug. The regulatory decision is often preceded by a recommendation by an expert committee	Further evaluate safety in patients or evaluate the drug in additional indications with the aim of broadening its use
Time	6.5 years	6-12 months	12-18 months	12-36 months	6-12 months	6-24 months
Number of patients	Test tube and animal studies	20-80 healthy volunteers	100-300 patients	1,000-5,000 patients		50-5,000 patients
Success rate	5,000 compounds evaluated	5 compounds enter clinical trials			1 compound approved	
Probability of approval	10%	20%	30%	67%	81%	90-100%

Notes: Panels A and B display the drug development process. Source: Robbins-Roth (2001), Stewart et al. (2001), Pharmaceutical Research and Manufacturing Association

The drug development process consists of different stages that are linked to each other. These different stages are broadly classified as: discovery, pre-clinical, clinical phase I, clinical phase II, clinical phase III, and regulatory review (see Table 5). The transition from one stage to the next must be built on the success of the previous stage. In addition, regulatory authorities closely monitor the drug development process, and the transition from one stage to the next must be approved by these regulatory authorities (such as the EMA in Europe and the FDA in the US).

Drug discovery and pre-clinical development

The drug discovery process differs for small molecules and for protein therapeutic agents. In traditional drug discovery of small molecules, which historically has been employed by pharmaceutical companies, the process begins with a multitude of chemical compounds that are screened against different types of disease models. As soon as an in vitro (in the test tube) assay has been established for a selected target, researchers can begin to screen for potential hits. These screening processes are carried out in automated processes, a process referred to as high-throughput screening (HTS), in which several hundred thousand compounds can be screened during a single day. One or several compounds with the most appropriate properties are then selected and are called the lead compounds. A process called lead optimization follows, when the lead compounds are chemically modified to further improve their characteristics suited for the specific target.

The discovery process for protein therapeutics agents such as monoclonal antibodies can generally be divided into five stages: target validation, screening preparation, hit generation and lead selection, lead optimization and characterization, and candidate selection. In the first stage, evidence is collected to support the target rationale and experimentally validate the target in, e.g., an animal model. In the screening preparation stage, an assay is developed. The next stage involves generating antibody hits using a technology (such as hybridoma technology) and selecting lead compounds. In the lead optimization and characterization stage, several techniques can be employed, such as humanization and Fc engineering, along an exploratory safety study leading to the selection of a clinical candidate monoclonal antibody.

The main objectives of pre-clinical studies are to determine a candidate drug's (CD) safety profile in animals by evaluating the toxicology profile. Studies of a drug's toxicity generally include the organs targeted by the drug and whether there are any potential long-term cancer effects or toxic effects on mammalian reproduction. Typically, both in vitro and in vivo tests are performed. After the testing has been successfully completed, to legally test the drug in humans the company must first obtain an investigational new drug (IND) designation from the regulatory authorities. The regulatory authorities, such as the FDA and EMA, use a default procedure in which the sponsor can start clinical trials if the sponsor is not contacted within 30 days.

Phase I

In clinical phase I, the candidate drug is tested on a small group of healthy volunteers. The aim of this phase is to evaluate the drug's safety and side-effect profile in humans. This is performed by administering the drug in a series of escalating doses and examine how the drug is absorbed, distributed, metabolized and excreted (ADME) in the human body, and then to establish the appropriate dose and dosage interval that will have a positive effect on the disease without causing undesirable side-effects. Phase I trials generally include a small number of healthy volunteers (usually 20-80). However, in certain indications, such as HIV and cancer, the regulatory authorities allow patients with the disease to participate (in which case it is called a phase I/II). Several side effects occur at a very low frequency and, consequently, do not appear in earlier clinical trials.

Phase II

In clinical phase II, the drug is tested in a larger group of patients (usually 100-300). The purpose is to demonstrate the drug's efficacy and to confirm its safety. Phase II trials may also include comparisons with a group receiving an inactive placebo treatment or sometimes with an active comparator (i.e., an already approved drug on the market) as a control. In addition, phase II trials are sometimes studied in subgroups of patients, e.g., in patients with different solid tumors, to see if the drug is broadly efficient or only works in certain cancers. Phase II trials generally take 12-18 months to complete.

Phase III

In clinical phase III, which is sometimes referred to as confirmatory studies or pivotal trials, the drug's efficacy and safety is studied in larger patient groups (usually 1,000-5,000). The main objective is to show a statistically significant difference between patients on drugs and those on placebo (or standard treatment). The data from the clinical trial sites are collected, and the database is locked and evaluated. If the results are positive, the data is put into a file and sent to regulatory authorities requesting marketing approval.

Regulatory review

When all pre-clinical and clinical data have been collected and sent to the FDA and the EMEA, the application is called a New Drug Application (NDA) in the US if it is a small molecule/organic chemical entity and a Biological License Application (BLA) if the potential drug is a protein-based product or vaccine.

Once the NDA/BLA is submitted, the FDA has 30 days to inform the company of whether it will accept the filing. If the NDA/BLA is found insufficiently complete, which is relatively uncommon, the FDA rejects the application with the issue of a so called 'Refuse to File letter'. The review of the NDA/BLA is performed by either the Center for Drug Evaluation and Research (CDER) or the Center for Biologics Evaluation and Research (CBER). The FDA will also decide whether the NDA/BLA will receive a standard or accelerated review. A standard review implies that the FDA will complete its review within approximately 10 months, while a priority review (as a result of the FDA Modernization Act of 1997) should be completed within six months. Once the FDA has approved the NDA/BLA, the new drug can be legally marketed.

7.3 Evolution of the biotechnology industry

The biotechnology industry emerged in the US in the late 1970s and early 1980s. The basic idea was that through improved technology and a better understanding of biological processes, the R&D process would become more efficient, faster, less risky and cheaper (Pisano, 2006). The research was based on a new technology called recombinant DNA technology, which made use of genetic engineering to synthesize proteins by inserting a certain gene (which codes for a protein) into bacteria or other cell cultures to produce protein for human use. The technology used to produce certain key proteins in large quantities offered a significant market opportunity because it could displace the costly extraction from animal sources (e.g., pigs, cattle and human cadavers). In October 1982, Humulin, developed by researchers at Amgen for the treatment of insulin-dependent diabetes, became the first-ever approved genetically engineered human therapeutic. Humulin (recombinant human insulin) was synthesized by inserting the human insulin gene into bacteria (*E. coli*), which started to produce human insulin. Humulin was licensed to and developed in partnership with the insulin manufacturer Eli Lilly.

The second approved drug in the biotechnology history was Protropin (developed by Genentech), a supplementary growth hormone for children with growth hormone deficiency (so-called pituitary dwarfism). Protropin was approved by the US FDA in 1985. Before growth hormone could be produced in large quantities using recombinant DNA technology, the hormone was extracted from the pituitary glands of human cadavers, which was very costly. A standard two-year treatment with natural growth hormones required extraction from as many as fifty to a hundred human pituitaries (Elkington, 1985). Within a year after

Protropin was approved, patients were paying as much as $10,000-15,000 a year for a drug that the US government had earlier distributed for free (Hall, 2006).

While the identification and isolation of a certain gene coding for a protein could be a very time-consuming and challenging task in itself, genetic engineering presented political, social, ethical, regulatory and legal challenges (Binder, 2008; Smith Hughes, 2011). For example, questions were raised regarding the patentability of life and living organisms. Others questioned what potential harm this new technology could do to humans, and few people understood the unproven technology, which made it difficult to attract investors.

A key milestone in the biotechnology industry was the successful initial public offering (IPO) of Genentech (Genetic Engineering Technology), the first biotechnology company to become publicly listed, on October 14, 1980[13]. At the time Genentech went public, it had either sales revenues or a product on (or even near) the market. Companies at the time usually waited until they had one or more products on or very near the market and at least some sales revenues before going public. Two reforms played a key role in enhancing investment in the biotechnology industry: 1) In 1978, the US congress reduced the capital gains tax rate from 48 to 28 percent to induce investment. 2) The US Department of Labor removed the Employee Retirement Income Security Act as a barrier to venture investing, i.e., restrictions were removed on pension funds from investing in venture capital. Consequently, venture capital financing increased from less than $600 million in 1980 to $4.6 billion in 1986 (Binder, 2008).

The Genentech IPO generated $38.5 million and tripled its stock price on the first day of trading[14]. The four-year-old firm's successful IPO demonstrated to venture capitalists that an investment in biotechnology could achieve liquidity within a timetable of four to six years even if the company had no product or sales revenues. According to the prospectus, one of the VC investors, Kleiner & Perkins, owned 938,000 shares with an average price of $1.85 per share prior to the IPO. However, the early investors in many biotechnology start-ups were also corporations. For example, two of the largest investors in Amgen's first round of financing were Abbott Laboratories and Tosco Corporation of Concord. Abbott Laboratories was concerned that Amgen might intrude on its diagnostic division and therefore became a

[13] According to the prospectus of Genentech, a price range of $25-30 per share and sales of 1 million shares was expected. However, the IPO priced above the expected price range ($35), and the number of shares was increased due to strong demand (1.1 million).

[14] In the first few minutes of trading, the (GENE) shares increased from $35 to $85, which, at the time, was the largest gain in stock market history (for a newly listed company), and closed at $71 at the end of the day, valuing the company at $532 million.

major shareholder with a seat on the board (Binder, 2008)[15]. Tosco, an independent oil and energy company, invested $3.5 million with the hope that biotechnology could create bacteria capable of drawing out necessary oil-making materials (called oil shale). At that time, there was a belief that the future of the oil industry lay in hard, dark sedimentary rocks called shale, which were abundant in California.

A study by BioCentury (2002, 10:38) evaluated the performance of some of the most successful US biotechnology companies in terms of number of years from founding to IPO and number of years to 1) first product, 2) profit from founding, and 3) profit from IPO. The analysis is displayed in Table 6 and is complemented with Agouron, Celgene, Centocor and Immunex. On average, these companies went public only four years after they were founded, and it took nine years until the first product was launched. Furthermore, it took 11 years from founding and seven years from IPO to be profitable. The same analysis for more recent US biotechnology companies that have been successful in bringing a drug to the market is presented in Table 7. While the number of years from founding to IPO more or less is the same, the major difference between the two groups is the number of years to the first major product, 11 years on average for the first US biotechnology companies and 18 years for the more recent group of biotechnology companies.

Table 6. Selection of the first US biotechnology companies

Company	Founded	IPO	Years to IPO	1st (major) product launch	First major Product	Years to first product	First full-year profit	Years to profit from founded	Years to profit from IPO
Agouron	1984	1987	3	1997	Viracept	13	1998	14	11
Amgen	1980	1983	3	1989	Epogen	9	1986	6	3
Biogen	1978	1983	5	1989	IFN alpha	11	1989	11	6
Celgene	1986	1987	1	1998	Thalomid	12	2003	17	16
Centocor	1979	1982	3	1995	ReoPro	16	1984	5	2
Cephalon	1987	1991	4	1999	Provigil	12	2001	14	10
Chiron	1981	1983	2	1986	HBV vac.	5	1990	9	7
Genentech	1976	1980	4	1985	Protropin	9	1979	3	-1
Genzyme	1981	1986	5	1991	Ceredase	10	1991	10	5
Gilead	1987	1992	5	1996	Vistide	9	2002	15	10
IDEC Pharma.	1986	1991	5	1997	Rituxan	11	1998	12	7
Immunex	1981	1983	2	1991	Leukine	10	1995	14	12
MedImmune	1988	1991	3	1991	CytoGam	3	1998	10	7
Average			**3.5**			**10**		**11**	**7**
Median			**3.0**			**10**		**11**	**7**

Notes: This table displays the number of years to IPO from founding, the number of years to first product, and the number of years from founding for some of the first US biotechnology companies. Sources: BioCentury (2002, 10:38), Datastream database and annual reports.

[15] The first CEO of Amgen, George Rathmann, had previously worked at Abbott Laboratories.

Table 7. Selection of more recent US biotechnology companies

Company	Founded	IPO	Years to IPO	1st (major) product launch	First major Product	Years to first product
Alexion Pharma.	1992	1996	4	2011	Soliris	19
Amarin	1993	1993	0	2012	Vascepa	19
Amylin Pharma.	1987	1992	5	2005	Byetta	18
Arena Pharma.	1997	2000	3	2012	Belviq	15
Ariad Pharma.	1992	1994	2	2012	Iclusig	20
Dendreon	1992	2000	8	2010	Provenge	18
Human Genome Sc.	1992	1993	1	2011	Benlysta	19
Icos	1989	1991	2	2003	Cialis	14
Imclone Systems	1984	1991	7	2004	Erbitux	20
Isis Pharma.	1989	1991	2	2013	Kynamro	24
Medivation	1995	1999	4	2012	Xtandi	17
Onyx Pharma.	1992	1996	4	2005	Nexavar	13
Seattle Genetics	1998	2001	3	2011	Adcetris	13
Vertex Pharma.	1989	1991	2	2011	Incivek	22
Vivus	1991	1994	3	2012	Qsymia	21
Average			**3.3**			**18.1**
Median			**3**			**19.0**

Notes: This table displays the number of years to IPO from founding and the number of years to first product for some of the more recent successful US biotechnology companies. Sources: Annual reports and the Thomson Reuters Datastream database.

To put these figures into perspective, the same analysis is conducted for the publicly listed Nordic biotechnology companies (see Table 8). On average, the Nordic biotechnology companies went public seven years after being founded compared with three for their US counterparts. Interestingly, the number of years to first product is substantially longer compared with the first group of US biotechnology companies (see Table 6) but is equivalent to the more recent group of successful US biotechnology companies.

Table 8. Selection of Nordic biotechnology companies

Company	Founded	IPO	Years to IPO	1st product launch	Lead drug	Years to first product	Total capital raised at IPO ($m)
Active Biotech*	1991	1997	6	2013	Laquinimod	22	-
Algeta	1997	2007	10	2013	Alpharadin	16	40.1
Bavarian Nordic	1992	1998	6	2016	Smallpox vac.	24	2.3
BioInvent	1997	2001	4	2018	BI-505	21	27.2
Biotie Therapies	1992	2000	8	2013	Selincro	21	17.5
Clavis Pharma	2001	2006	5	n.a.	n.a.	n.a.	35.7
Diamyd Medical	1994	1997	3	n.a.	Diamyd	n.a.	n.a.
Genmab	1999	2000	1	2009	Arzerra	10	177.6
Karo Bio	1987	1998	11	2019	KB3305	32	17.6
Medivir	1988	1996	8	2013	Simeprevir	25	n.a.
Neurosearch	1989	1996	7	2015	Huntexil	26	48.9
Oasmia	1999	2005	6	n.a.	Paclical	n.a.	-
Orexo	1995	2005	10	n.a.	Abstral	n.a.	43.9
TopoTarget	2000	2005	5	2012	Belinostat	12	49.3
Veloxis	2002	2006	4	2014	LCP-Tacro	12	105.6
Zealand Pharma	1998	2010	12	2012	Lyxumia	14	68.8
Average			**7**			**19**	
Median			**6**			**21**	

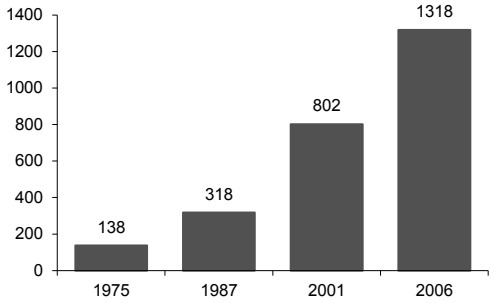
Notes: This table displays the number of years to IPO from founding and the number of years to first product for selected Nordic biotechnology companies. *Change of focus to biotech when Active Biotech acquired Pharmacia's LRC. Source: Company reports.

While the US group of companies provides a difficult comparison, as they have all been successful, the reason it takes so long may be linked to the fact that European biotechnology companies receive smaller amounts of funding compared with US companies (Bains, 2006). While there is enough capital in Europe to allow companies to bring products to the market, the greatest problem may be that Europe has a fragmented equity capital market, which limits the pool of capital accessible to individual companies (Fazeli, 2004).

7.4 R&D spending

The cost of bringing a new drug from discovery through clinical trials to approval varies depending on several factors, such as the number of required patients in clinical studies and cost per patient. DiMasi and Grabowski (2007) report that the average cost of developing a new drug has risen from an estimated $138 million in 1975 to approximately $1,318 million in 2006 (see Figure 8). It is important to note that these figures include all costs, including the cost of product failures, and is capitalized rather than discounted. The cost of developing a new drug has increased nearly tenfold over the last few decades.

Figure 8. The cost of developing a new drug ($m)



Notes: This table displays the average cost of bringing a drug to market, including the cost of product failures, Source: DiMasi and Grabowski (2007)

Although drug development costs can vary considerably, Table 9 displays an approximation of drug development costs per stage. According to these figures, the cost could, for example, range from $20 to 86 million (Bogdan and Villiger, 2007).

Table 9. Drug development costs per stage

Source: Bodgan and Villiger (2007)		Source: Stewart et al. (2001)			
Phase	**Cost ($m)**	**Number of clinical trial subjects**	**Cost per subject ($)**	**Additional costs ($m)**	**Cost ($m)**
Lead optimization	2-3				
Preclinical	2-3				
Clinical phase I	1-5	20-80	8,000-15,000	0.5	0.7-1.7
Clinical phase II	3-11	100-300	8,000-15,000	1	1.8-5.5
Clinical phase III	10-60	1,000-5,000	4,000-7,500	1.5	5.5-39
Approval	2-4			1.1-2.1	1.1-2.1
Total	**20-86**				**8.8-48.3**

Notes: This table displays estimates of drug development costs per stage. Sources: Bogdan and Villiger (2007), Stewart et al. (2001).

The large cost associated with developing a new drug has direct implications for the R&D budgets of biotechnology companies. Table 10 reviews the yearly R&D spending by the top 15 companies in the global pharmaceutical and biotechnology industry. To put these figures into perspective, I also include the R&D spending by European biotechnology companies. In total, the top 15 pharmaceutical companies invested $82.9 billion in 2012, which was nearly 7 times what the top 15 biotechnology firms invested ($12.1 billion). Four companies (Amgen, Gilead Sciences, Celgene and Biogen Idec) have R&D expenses exceeding $1 billion per year and represent 66 percent of the total spending by the top 15 companies. In contrast, the European biotechnology companies have significantly smaller R&D budgets on average.

Table 10. R&D spending in pharma and biotechnology, 2012

Top 15 global pharma ($m)		Top 15 global biotech ($m)		Top 15 European biotech ($m)	
Novartis	9,094	Amgen	3,380	Galapagos	100
Roche	9,063	Gilead Sciences	1,666	Genmab	91
Merck & Co	7,911	Celgene	1,570	Neurosearch	86
Johnson & Johnson	7,665	Biogen Idec	1,335	Biotest	67
Pfizer	7,342	Shire*	851	Basilea Pharmaceutica	63
Sanofi	6,373	Vertex Pharmaceuticals	806	Bavarian Nordic	60
Glaxosmithkline	5,416	Actelion*	487	Transgene	59
Eli Lilly	5,278	Onyx Pharmaceuticals	325	SOBI	58
Abbott Laboratories	4,180	Biomarin	302	Ablynx	58
AstraZeneca	4,138	Cubist Pharmaceuticals	278	Active Biotech	55
Bayer	3,911	Illumina	231	Morphosys	49
Bristol-Myers Squibb	3,762	Endo Health Solutions	226	GW Pharmaceuticals	43
Takeda	3,664	Alexion Pharmaceuticals	223	Orexo	31
Abbvie	2,609	Incyte	210	Bioinvent	30
Astellas Pharma	2,467	United Therapeutics	173	Medivir	30
Total	**82,874**		**12,063**		**878**

Notes: This table displays the total R&D spending for the largest pharmaceutical and biotechnology companies in 2012. Source: Thomson Reuters Datastream database, Annual Reports. * Shire and Actelion are European firms.

7.5 Sources of R&D funding

There are several potential sources of R&D funding for small entrepreneurial firms. Although not all of these sources are available for entrepreneurs at any given time, they will often become available as firms or technologies mature. In general, there are nine options available

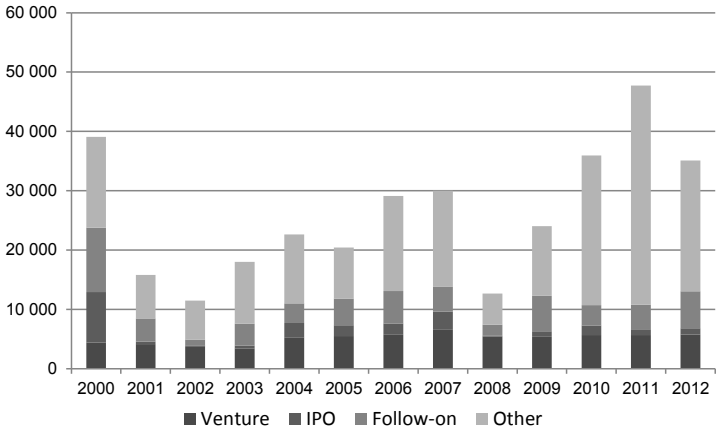
for financing: 1) friends/family, 2) "angel" investors, 3) government, 4) internal corporate funds, 5) banks, 6) venture capitalists, 7) public debt markets, 8) public equity markets, and 9) strategic alliance partners (Higgins, 2008; Metrick and Yasuda, 2010).

In the biotechnology industry, many of these options are unavailable primarily due to the characteristics of drug development. The length of the development life cycle for a successful product is usually between 10 and 15 years, the costs of developing a drug average $1,318 million (DiMasi and Grabowski, 2007) and less than 10 percent of all drugs entering clinical trials reach the market (e.g., Robbins-Roth, 2001).

Most biotechnology firms are in an early life-cycle stage and invest heavily on a continuous basis in intangible assets such as research and development (R&D), but they can rarely fund these investments internally. In other words, the financing needs of biotechnology firms typically exceed their capability of generating funds internally. In contrast, pharmaceutical firms have access to internal corporate funds that can be plowed back into R&D. The government is unlikely to provide much help in the direct financing of R&D projects, although there are other benefits associated with R&D tax credits. Although biotechnology firms hold substantial growth opportunities, banks generally do not provide bank loans (debt finance) due to the absence of collateral (i.e., assets-in-place). Another source of debt finance, namely, public debt markets, have increased as a source of financing as the industry has grown but are primarily only an option for the cash flow positive companies in the sector.

Private biotechnology companies mainly raise funding via private capital (venture capital), public equity markets (via an initial public offering) and strategic alliance partners. For public biotechnology companies, the two sources of funding are public equity markets and strategic alliance partners. Consequently, public biotechnology companies have no other choice but to regularly ask investors for (equity) finance for their research projects, and a majority of the biotechnology companies are 100 percent equity-financed. An alternative for both private and public biotechnology companies is strategic alliance partners. Small biotechnology firms without significant internal funds or that lack sufficient knowhow related to clinical development, manufacturing, regulatory expertise, marketing or sales can form a strategic alliance with a large pharmaceutical company.

Figure 9. External financing in the global biotechnology industry



Notes: This figure displays external financing in the global biotechnology industry from 2000 to 2012. Source: BioCentury

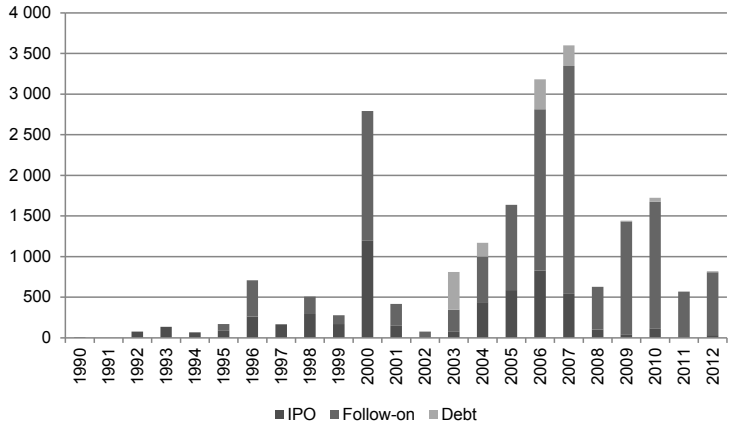
Figure 9 displays the distribution of external financing across funding sources in the global biotechnology industry but does not include alliance funding. In total, $342 billion has been raised over the past twelve years. Public debt markets (category: Other) have raised $193 billion and provided an important source of funding for some cash-flow positive companies in the US, but they remain relatively uncommon in Europe. Public equity markets (follow-on financing and IPOs) have financed approximately $82 billion, whereas $67 billion has been raised by venture capital. These figures are similar to the data (excluding debt) reported by Metrick and Yasuda (2010): public equity markets have financed approximately 60 percent of the $150 billion raised by the biotechnology industry, whereas the remaining 40 percent have been financed by venture capital.

Figure 10 displays the distribution of external financing across funding sources in the European biotechnology industry. In the European biotechnology industry, approximately $21 billion has been raised between 1990 and 2012. The total proceeds raised via IPOs are $5.4 billion (26 percent), whereas $14.3 billion (68 percent) has been raised through follow-on offerings. In contrast, only $1.3 billion (6 percent) has been raised from debt financing. [16] Consequently, a majority of the biotechnology companies are 100 percent equity-financed. From an academic point of view, this has important implications. When examining the market

[16] In Europe, there are only 14 convertible bonds issued over the entire time period, and most are made by some of the larger companies, such as Actelion, Shire and Serono. Consequently, a majority of the biotechnology companies are 100 percent equity-financed[16].

timing aspects of e.g., equity issues, one does not need to control for other sources of external capital (Guo and Mech, 2000).

Figure 10. External financing in the European biotechnology industry

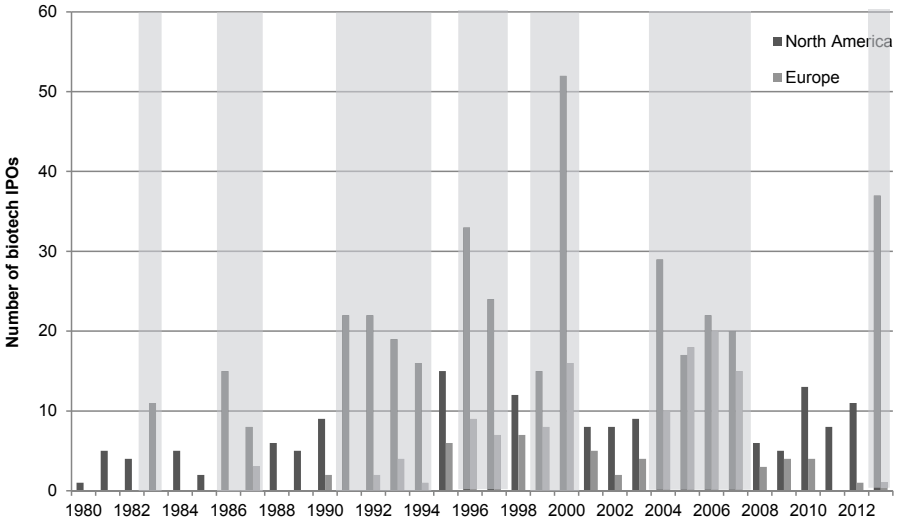


Notes: This figure displays external financing in the European biotechnology industry from 1990 to 2012. Follow-on offers include rights issues and private placements. Figures are in million US dollars. Source: Annual reports and the Thomson Reuters Datastream database.

7.6 IPO windows

Initial public offerings (IPOs) for biotechnology companies have gone through cycles ("windows") since the beginning of the 1980s, when Genentech became the first publicly listed company. In these "windows", the relative number of biotechnology IPOs has increased significantly (see Figure 11). It is generally considered that there have been six "windows", during which equity valuations were generally far better than when the window was closed. Of these six windows, three are referred to as major (1983, 1991-1994, 1999-2000) and three as minor (1986-1987, 1995, 2004-2007). There is currently an open IPO window in the US, which started at the end of 2012. From January 2013 until October 2013, there have been 38 biotechnology IPOs, the second highest number since the record year in 2000.

Figure 11. Number of biotech IPOs in North America and Europe, 1980-2012



Notes: This figure displays the number of biotechnology IPOs in North America (US and Canada) and in Europe from 1980 to 2013 (October). Firms tend to time IPOs following a period of strong stock market performance. Lerner (1994) show, using a sample of 350 venture-backed biotechnology firms between 1978 and 1992, that companies go public when equity valuations are high and use private financing when values are lower. IPO windows (major and minor) are marked in shading. Source: Thomson Reuters Datastream database

Over the past few decades, the biotechnology IPO windows have been characterized by different features. In the 1999-2000 IPO window, biotechnology companies working on discovering genes and using technologies to identify genes responsible for various diseases were sufficient to raise capital in an IPO. The burst of the so called "Genomics Bubble", which took place at the beginning of the year 2000, led to a significant drop in the NASDAQ Biotechnology index, when it became apparent that identifying the gene responsible for a disease was only the first step in developing a drug. In the 2004-2007 IPO window, the focus was shifted to companies with projects in clinical development, with preferably at least one product in clinical phase II or beyond. Companies with earlier stage drug development pipelines generally had difficulties raising external financing via an IPO. More recently, several companies have approved products (e.g., Pacira Pharmaceuticals and Horizon Pharma) or are in the regulatory stage (e.g., Supernus and Hyperion Therapeutics). Two notable exceptions are the oncology companies Verastem and Agios Pharmaceuticals, which went public in 2012 and 2013, respectively, and both of which have their lead drug in preclinical development. Other differences between past IPO windows are the average pre-money valuation as well as the IPO round sizes. It is worth noting that in April 2012, the

JOBS Act (Jumpstart Our Business Startups Act) was passed as law. The intention of the JOBS Act is to encourage the funding of small businesses in the US by easing various securities regulations, such as confidentially filing IPO documents.

In summary, IPOs are important for the biotechnology ecosystem, as they provide liquidity events[17] for early-stage venture capitalist investors (although they generally do not sell off their shares at the IPO event but after following the lock-up period) and make it possible for the companies to access public capital markets to finance R&D investments.

7.7 R&D alliances

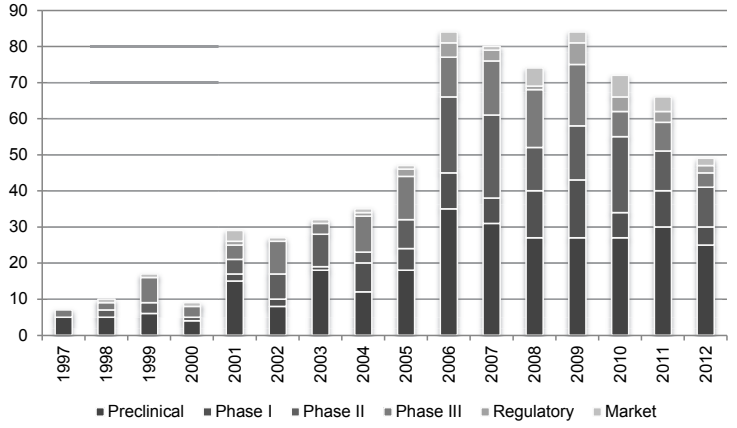
For small biotechnology firms without significant internal funds or lack of sufficient knowhow related to clinical development, manufacturing, regulatory expertise, marketing, sales or access to public markets (see prior section on IPO windows), the main alternative is to form a strategic alliance with a large drug company. The most common strategic alliance in the biotechnology industry is an R&D license agreement. In a typical R&D license agreement, the licensee (i.e., the larger company) pays the costs for the R&D project performed by a smaller company in return for receiving some rights to the technology. In addition, the licensee often pays an upfront payment at the time the license agreement is signed and makes milestone payments when certain predefined goals are reached. Once the project reaches the market, the licensor (the small company) receives a fraction of sales in terms of royalty revenues. Entering an R&D license agreement may have several implications. First, the contractual cash flow rights that are granted to the alliance partner often place a cap on the upside of the equity value of the small company (Ozmel et al, 2012) in exchange for early and certain upfront and milestone payments. Second, the risk is shared between the licensor and the licensee.

Ozmel et al. (2012) is one of the few studies that examines, using a sample of private US biotechnology firms, how the interplay between alternative funding sources, such as project-level alliance funding and firm-level venture capital funding, affects exit decisions from the private capital market. They find that strategic alliances and venture capital funding both raise the hazard that a start-up company will go public as well as the hazard of being acquired. Nicholson et al. (2005) document that strategic alliance partners provide an important source

[17] Burrill (2013) argues, on the basis of more recent IPOs, that these are actually financing events, as venture-backed biotechnology companies go public with substantial participation by their existing venture investors and insiders.

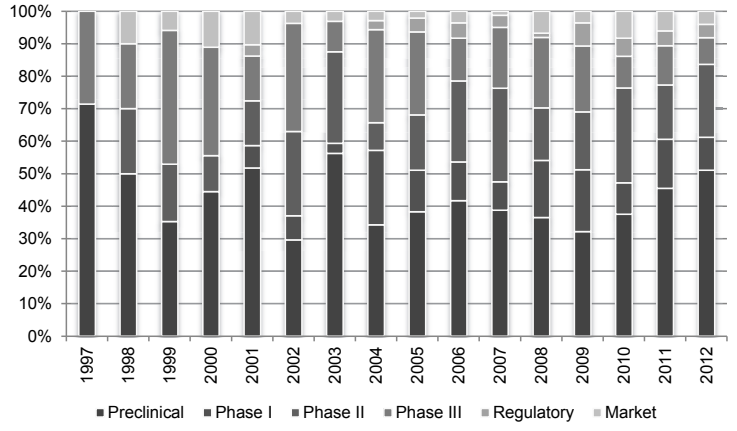
of R&D financing in addition to private and public equity and that the proportion of biotechnology financing raised through alliances varies with the state of equity markets.

Figure 12. Number of pharmaceutical-biotech deals (>$100 m), 1997-2012



Notes: This figure shows the number of deals per year between pharmaceutical and biotech firms exceeding $100 m in total deal value between 1997 and 2012. Source: Deloitte Recap.

Figure 13. Distribution of pharmaceutical-biotech deals (>$100 m) across phases, 1997-2012



Notes: This figure shows the distribution of deals across different phases per year between pharmaceutical and biotech firms exceeding $100 m in total deal value between 1997 and 2012. Source: Deloitte Recap.

Over the past 15 years, the number of alliances between pharmaceutical and biotechnology firms with total deal valuations exceeding $100 million has increased more than five-fold. In

1997-2000, the average number of deals was 15 per year, whereas the average number of deals was 81 between 2006 and 2012 (see Figure 12). Figure 13 shows that a large proportion of deals exceeding $100 million are attributed to early-stage preclinical projects.

7.8 Mergers and acquisitions (M&A)

Over the past two decades, more than 300 biotechnology companies have been acquired by larger pharmaceutical companies. Corporate takeovers have become increasingly important vehicles to accessing new drugs and/or technologies and supplementing internal R&D pipelines for pharmaceutical firms. The key driver of M&A in the industry has been the need for replacement to fill gaps in a company's pipeline following patent expiration of major commercial products (e.g., Higgins and Rodriguez, 2006; Danzon et al., 2007). Of the top 10 leading biotechnology firms by sales in 2005, seven (Genentech, Serono, Genzyme, MedImmune, Chiron, Millennium Pharmaceuticals and ImClone) have been acquired by larger pharmaceutical companies. Today, only Amgen, Biogen Idec and Gilead Sciences remain. Table 11 shows some of the largest biotechnology acquisitions.

It is notable that many biotechnology companies have been acquired at significant premiums (see Table 12). For example, Roche's acquisition in 2011 of the hepatitis C-developer Anadys, in a deal valued at $230 million, representing a bid premium of 256 percent, and Bristol-Myers Squibb's acquisition of Inhibitex (also within hepatitis C) in 2012, in a deal valued at $2.5 billion, representing a bid premium of 163 percent, clearly show the pharmaceutical industry's belief in biotechnology products.

Table 11. Selection of some of the largest biotechnology acquisitions

Acquiring company	Target company	Deal size ($m)	Year	Lead drug	Stage	Stock /Cash	Premium
Roche	Genentech	46,800	2008	Herceptin and others	Market	Cash	9%
Sanofi	Genzyme	20,100	2011	Cerezyme and others	Market	Cash	48%
Amgen	Immunex	16,000	2001	Enbrel and Leukine	Market	Cash/Stock	31%
AstraZeneca	MedImmune	16,000	2007	Synagis and others	Market	Cash	53%
Merck KGaA	Serono	13,200	2006	Rebif and others	Market	Cash	20%
Gilead Sciences	Pharmasset	11,200	2011	PSI-7977	Phase 2	Cash	89%
Takeda	Millennium	8,800	2008	Velcade (bortezomib)	Market	Cash	53%
Teva	Cephalon	6,800	2011	Nuvigil and others	Market	Cash	6%
Eli Lilly	ImClone Systems	6,621	2008	Erbitux	Market	Cash	51%
Novartis	Chiron	5,316	2005	TOBI and others	Market	Cash	32%
J&J	Centocor	4,900	1999	Remicade and ReoPro	Market	Stock	23%
Astellas Pharma	OSI Pharma.	4,000	2010	Tarceva (erlotinib)	Market	Cash	55%
Eisai	MGI Pharma	3,900	2007	Aloxi and others	Market	Cash	39%
Abbott	Kos Pharma.	3,770	2006	Niaspan and Advicor	Market	Cash	56%
Glaxosmithkline	HGS	3,600	2012	Benlysta	Market	Cash	99%

Notes: This table displays a selection of some of the largest biotechnology acquisitions. * The total deal value excludes a contingent value right, which, if fully realized, could add an extra $3.8 billion. Source: Zephyr database and annual reports

The acquisition of Pharmasset by Gilead stands out in terms of deal size ($11,200 million) and the stage of the lead drug (PSI-7977 was in Phase II). Bid premiums in the biopharmaceutical industry tend to be significantly higher compared with those in other industries, which typically are in the range of 20-40 percent. In essay four (Acquisitions, alliances and post-acquisition R&D performance), I document bid premiums averaging 65.4 percent for a sample of 219 biopharmaceutical acquisitions (of which 124 target firms are publicly listed) between 1998 and 2012. To show that the results of the cross-sectional regression analysis are not driven by omitted variables, I control for bid premium (Travlos, 1987) and bid premium squared for the sub-sample of 124 public target firms.

Table 12. Selection of biotechnology acquisitions with high bid premiums

Acquiring company	Target company	Deal size ($m)	Year	Motive	Lead drug	Stage	Indication	Premium
GSK	Genelabs Tech.	57	2008	Product	HEV Vac.	Phase II	Hepatitis E	465%
Roche	Anadys	230	2011	Product	Setrobuvir	Phase II	Hepatitis C	256%
Genzyme	AnorMED	580	2006	Product	Mozobil	Phase III	Stem cell tr.	168%
Pfizer	Coley	164	2007	Techn.	N/A	N/A	N/A	167%
BMS	Inhibitex	2,500	2012	Product	INX-189	Phase II	Hepatitis C	163%
Eli Lilly	SGX Pharm.	64	2008	Techn.	N/A	N/A	Cancer	119%
Novartis	NeuTec	569	2006	Product	Mycograb/	NDA	MRSA	109%
ViroPharma	Lev Pharm.	618	2008	Product	Cinryze	NDA	HAE	103%
Merck	Sirna Therap.	1,100	2006	Both	Sirna-027	Phase II	AMD	102%
Novartis	Speedel	880	2008	Product	Tekturna	Market	Hypertension	94%
BMS	Medarex	2 400	2009	Both	Ipilimumab	Phase III	M. melanoma	90%
Gilead	Pharmasset	11,200	2011	Product	PSI-7977	Phase II	Hepatitis C	89%
Dendreon	Corvas	73	2003	Product	rNAPc2	Phase II	ACS	86%
Pfizer	Vicuron Pharm.	1,900	2005	Product	Anidulafun.	NDA	Infections	84%
BMS	Zymogenetics	885	2010	Product	Peg-INF λ	Phase IIb	Hepatitis C	84%

Notes: This table displays a selection of biotechnology acquisitions with high bid premiums. Source: Zephyr database and annual reports

7.9 The biotechnology industry from an industry perspective

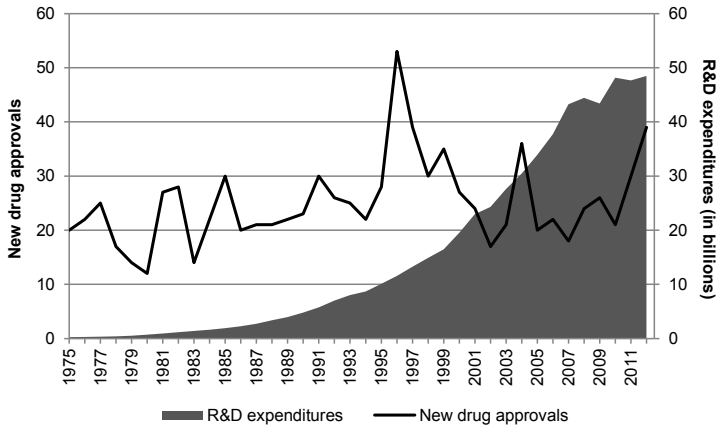
The following section examines biotechnology from an industry perspective, i.e., how many drugs have been approved over the years. Before turning to productivity in the biotechnology industry, I examine the R&D productivity in the pharmaceutical industry.

R&D productivity

Over the past few decades, advances in molecular biology and an increasing understanding of the underlying mechanisms of diseases have expanded the number of potential therapeutic targets for the development of new drugs. Nevertheless, the pharmaceutical industry has experienced a decline in productivity (e.g., DiMasi et al, 2003; Cockburn, 2006, Pammolli et al., 2011): R&D spending has increased substantially, but the number of new drug approvals has remained relatively constant (see Figure 14). In the period 1975-1985, the number of new

drugs approved by the US FDA per billion US dollars spent averaged 37. In comparison, the same ratio for the sub-periods 1986-1997, 1998-2004, and, 2005-2012 were 4.8, 1.3, and, 0.6, respectively. This trend is due to significantly higher costs for developing new drugs (DiMasi et al., 1991, 2003; DiMasi and Grabowski, 2007) accompanied by higher attrition rates in drug development.

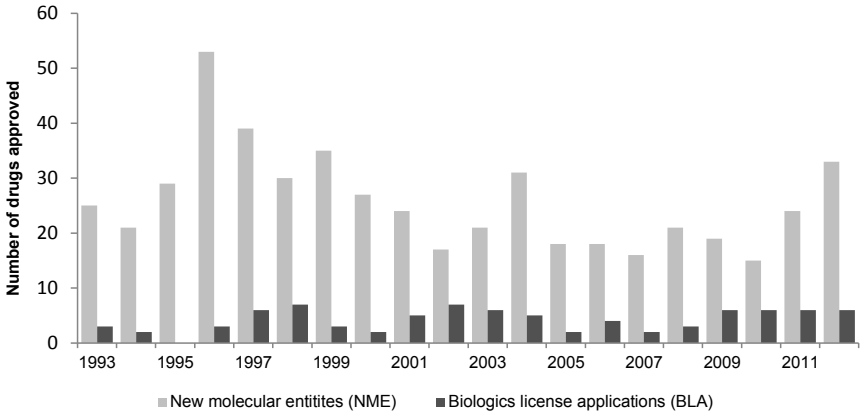
Figure 14. R&D productivity in the pharmaceutical industry



Notes: This figure displays new drug approvals (left axis) by the US Food and Drug Administration (FDA) and R&D expenditures (right axis) for pharmaceutical companies in the United States from 1975 to 2012. New drug approvals represent new chemical entities (NMEs). R&D expenditures are inflation-adjusted to 2012-year values using CPI data from the Bureau of Labor Statistics. Data on new drug approvals are collected from FDA.gov, and R&D expenditure data are obtained from the Pharmaceutical Research and Manufacturers of America webpage.

New drug approvals can be separated into two main classes: new chemical entities (NCEs) and biologics license applications (BLAs). These two classes are shown in Figure 15. Historically, pharmaceutical companies have generally engaged in the research and development of small molecules, whereas biotechnology companies have adopted engineering technologies to produce, e.g., monoclonal antibodies and proteins. In practice, however, many biotechnology companies develop both biologics and chemical compounds, as do most large pharmaceutical firms. Although the figure neither displays whether the origin is a pharmaceutical or a biotechnology firm nor the level of innovation, DiMasi (2000) reported that 38 percent of the 691 NCEs approved by the US FDA between 1963 and 1999 were in-licensed.

Figure 15. FDA drug approvals since 1993 (NMEs and BLAs)



Notes: This figure displays the number of FDA drug approvals between 1993 and 2012. New drug approvals are separated into new chemical entities (NCEs) and biologics license applications (BLAs). Source: FDA.gov

7.10 The biotechnology industry from an investor perspective

This section aims to gain an understanding of the biotechnology sector from an investor perspective. This section contains a brief description of how biotech stocks typically behave when positive and negative clinical trial results are disclosed. Next, this section examines the returns that have been generated and the risks of the industry.

Stock price reaction to clinical trial results

Table 13 displays the stock market's reaction to a selection of positive and negative clinical trial results. As evident in the table, clinical trial results have a significant share price reaction. For example, the failure of the phase III study of Talactoferrin in lung cancer resulted in a share price reaction for Agennix at the day of the announcement of -72 percent. It is therefore reasonable to assume that these events provide corporate managers and investors with value-relevant information.

Table 13. Selection of stock market reactions to clinical trial results

Company	Stage	Project	Indication	Date	Share price reaction
Panel A. Negative news					
Actelion	Phase III	Veletri™ (Tezosentan)	Acute heart failure (AHF)	2001-04-20	-62%
Agennix	Phase III	Talactoferrin	Non-small cell lung cancer	2012-08-06	-72%
Alizyme	Phase III	Renzapride	Irritable Bowel Syndrome	2008-04-23	-26%
Antisoma	Phase III	ASA404	Non-small cell lung cancer	2010-03-29	-75%
BioInvent	Phase II	BI-204	Atherosclerosis	2012-07-11	-67%
Diamyd Medical	Phase II	NP2 Enkephalin	Severe intractable cancer pain	2012-07-03	-30%
Evolutec	Phase IIb	rEV131	Allergic rhinitis	2006-12-04	-72%
Genmab	Phase II	HuMax™-CD4	Rheumatoid Arthritis	2002-09-24	-61%
Karo Bio	Phase III	Eprotirome	HeFH	2012-02-14	-68%
Medivir	Phase IIa	Alovudine (MIV-310)	AIDS	2005-03-15	-24%
Neurosearch	Phase II	Tesofensine (NS2330)	Alzheimer's Disease (Dementia)	2005-08-10	-46%
Newron	Phase IIb/III	Ralfinamide	Neuropathic Low Back Pain	2010-05-06	-59%
Paion	Phase III	Desmoteplase	Acute ischemic stroke; Stroke	2007-05-31	-66%
Renovo	Phase II	Juvista®	Wound Healing	2008-03-03	-51%
Silence Therapeutics	Phase III	SRL172	Non-small cell lung cancer	2001-04-11	-77%
Sygnis Pharma	Phase II	AX200	Acute ischemic stroke	2011-12-15	-54%
Topotarget	Phase II	Belinostat	Cancer of unknown primary	2012-06-29	-60%
Wilex	Phase III	Rencarex	Renal cell carcinoma	2012-10-16	-63%
Panel B. Positive news					
4sc	Phase II	Resminostat	Liver cancer	2012-01-19	46%
AB Science	Phase II	Masitinib	Gastrointestinal stromal tumors	2012-02-01	72%
Active Biotech	Phase III	Laquinimod	Multiple sclerosis	2010-12-09	33%
Addex Therapeutics	Phase IIa	Dipraglurant	Parkinson's disease	2012-03-21	85%
Algeta	Phase III	Alpharadin	Prostate cancer	2011-06-06	37%
Galapagos	Phase II	GLPG0634	Rheumatoid arthritis	2011-11-22	22%
Morphosys	Phase Ib/IIa	MOR103	Rheumatoid arthritis	2012-09-20	15%
NicOx	Phase IIb	BOL-303259-X	Glaucoma	2012-03-12	45%
SOBI	Phase III	rFIXFc	Hemophilia B	2012-09-26	44%
Topotarget	Phase II	Belinostat	Peripheral T-cell lymphoma	2012-09-21	145%

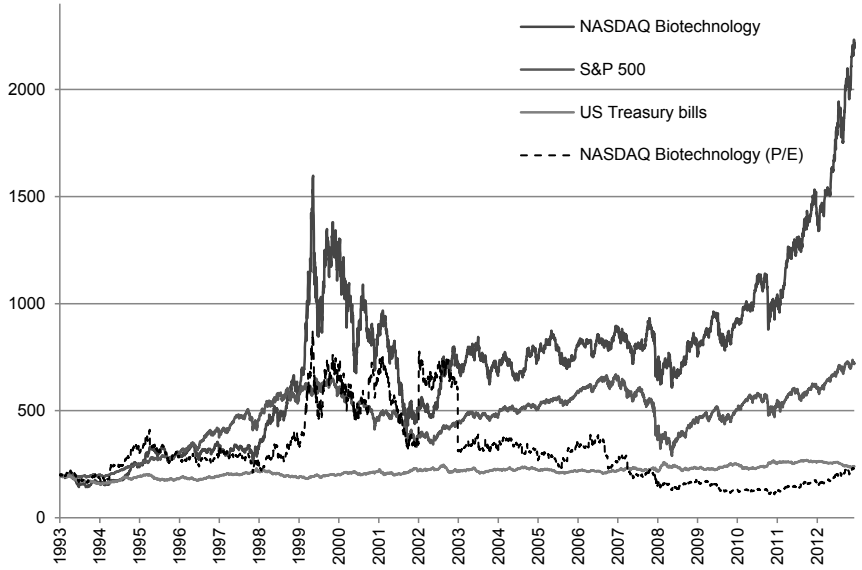
Notes: This table displays the stock market's reaction to the disclosure of positive and negative clinical trial results. Source: Corporate webpages

Financial performance of the biotechnology industry

To evaluate the performance of the biotechnology industry, I first look at US publicly listed companies incorporated in the NASDAQ Biotechnology index[18] that have been involved in biotech research over the past twenty years. Figure 16 shows the performance of the NASDAQ Biotechnology index, the S&P 500 and US Treasury bills over the period 1993 to 2012.

[18] The NASDAQ Biotechnology index constitutes NASDAQ listed US biotechnology firms with approximately 20 years of history (1993-10-29-today). As of October 2013, the index included 120 firms.

Figure 16. Performance of NASDAQ Biotechnology, S&P 500 and US Treasury bills from 1993 to 2012



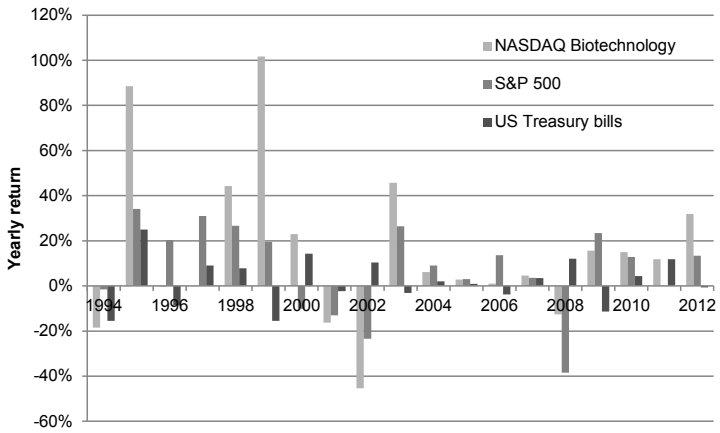
Notes: This graph displays the performance of the NASDAQ Biotechnology index, S&P 500, and US Treasury bills over the period 1993-10-29 to 2013-10-08. Source: Thomson Reuters Datastream database

During the 1990s, the NASDAQ Biotechnology index underperformed the S&P 500 index, and it was not until August 1999 that the level of the NASDAQ Biotechnology index exceeded that of the S&P 500. The rise in the NASDAQ Biotechnology index started at the end of 1997 and experienced a significant increase at the end of 1999. It then reached a peak in March 2000 and traded close to 1,600. In the following period, the index traded down and reached a bottom level of 404 in July 2002. Since then, the index has steadily increased and passed 2,000 in July 2013. A much-discussed topic among industry observers is whether the industry is in a "bubble". I include the NASDAQ Biotechnology price-to-earnings (P/E) ratio as defined by the Thomson Reuters Datastream database[19]. It is notable that the biotechnology industry P/E multiple was relatively high during the Genomics bubble in early 2000, when the NASDAQ Biotechnology index peaked. However, the industry P/E ratio is significantly lower today compared with early 2000, although the NASDAQ biotechnology index has reached all-time high levels.

[19] The NASDAQ Biotechnology price-to-earnings ratio (calculated by Thomson Reuters Datastream) is derived by dividing the total market value of the NASDAQ Biotechnology index by the total earnings, thus providing an earnings-weighted average of the price-to-earnings ratios of the constituents.

From an investor perspective, it is also of interest to look at yearly returns. Figure 17 displays the yearly return for the three indices. In years with positive market performance, the NASDAQ biotechnology index has performed exceptionally well, especially in 1995 (+88.5 percent), 1998 (+44.3 percent), 1999 (+101.6 percent), and 2003 (+45.7 percent). It is notable that in 2008, when the S&P 500 was down 38.5 percent, the NASDAQ Biotechnology index was only down by 12.6 percent.

Figure 17. Annual returns of NASDAQ Biotechnology, S&P 500 and US Treasury bills from 1993 to 2012



Notes: This graph displays the annual returns for NASDAQ Biotechnology, S&P 500 and US Treasury bills. Source: Thomson Reuters Datastream database

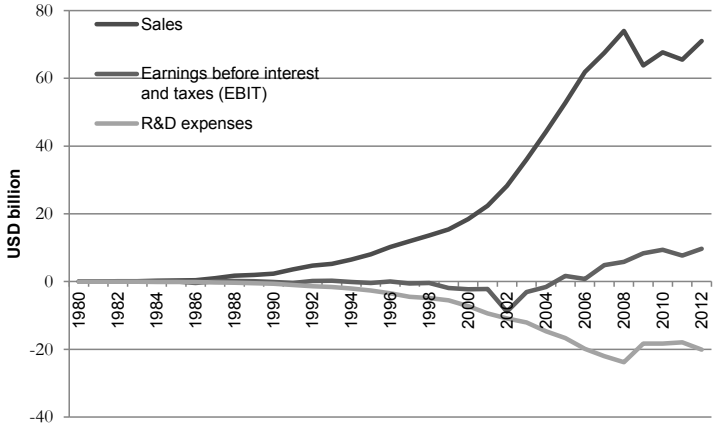
An investment in a diversified biotech portfolio, i.e., the NASDAQ Biotechnology index, generated over the period 1993-2012 a 6.6-fold return, or an annual return of approximately 11.9 percent. To put these figures into perspective, I compare them to the returns of a more risk-averse investor who invested in US Treasury bills over the same time period, who had a 0.3-fold return (1.5 percent annual rate of return). The same investment in the S&P 500 index generated a 2.1-fold return (6.5 percent annual rate of return). While the biotechnology industry carries substantially more risk as an asset class compared with the broad S&P index, I calculate the risk-adjusted performance. I employ the Sharpe ratio[20] for the NASDAQ Biotechnology index and the S&P 500, and I use the risk-free rate as the benchmark asset. The Sharpe ratios for the NASDAQ Biotechnology index and the S&P 500 are 1.53 and 2.15,

[20] The Sharpe ratio is defined as the excess return (asset return minus the return of the benchmark asset) divided by the standard deviation of the expected excess return.

respectively. A simple linear regression using the single Capital Asset Pricing Model (CAPM) generates a beta value of 1.97 ($p < 0.001$).

A widely held perception is that the biotech industry has not performed as an asset class and has failed to deliver on the high promises of the underlying technologies. While the comparison made in this section illustrates that even the NASDAQ Biotechnology index has failed to outperform the S&P 500 on a risk-adjusted basis, it has generated an annual return of nearly 12 percent on an absolute basis.

Figure 18. Biotechnology revenues, profitability and R&D expenses, 1980-2012

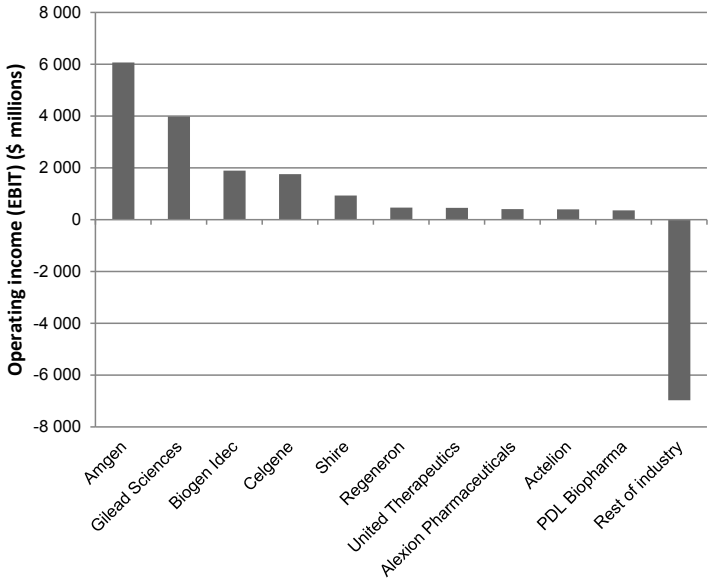


Notes: This figure displays the economic performance for a sample of 584 publicly listed biotechnology firms in the US and Europe between 1980 and 2012. Source: Thomson Reuters Datastream database

Another alternative way to look at the performance of the biotechnology industry is to look at economic performance. Similar to Pisano (2006), I create a yearly aggregate income statement for the entire industry, i.e., I combine the income statements of every company year by year since 1980 into one industry-level statement until 2012. The data are based on a sample of 584 publicly listed biotechnology firms in the US and Europe. I focus on sales, earnings before interest and taxes (EBIT) and R&D expenses. Figure 18 illustrates the yearly development of the total sector from 1980 to 2011. Pisano (2006) uses data on US publicly listed biotechnology companies over the time period 1975 to 2004. Interestingly, as Pisano notes, revenues have increased significantly, while earnings have remained flat. However, in 2004 onward, where Pisano's analysis ends, the industry has showed some signs of profitability.

The profitability of the biotechnology industry has, however, been driven by the performance of a few successful companies. In 2004, the top 15 biotechnology firms accounted for 93 percent of total sales, of which two companies (Amgen and Genentech) represented 53 percent of total sales in the US sector (Pisano, 2006). In 2012, Amgen and Gilead Sciences accounted for 24.3 percent and 13.7 percent, respectively, of the total sales in the entire industry (see Figure 19). In the same year, the top 15 firms accounted for 78.5 percent of total sales.

Figure 19. Biotechnology economic performance by firm, 2012



Notes: This figure displays the operating income for publicly listed biotechnology firms in 2012. Source: Thomson Reuters Datastream database

Indeed, the vast majority of biotech firms are still young and at the developmental stage. In 2012, 58 public biotechnology firms in the US and Europe reported a positive operating income, while 267 companies reported a loss. This has implications for access to different sources of financing, such as public debt and equity markets.

7.11 Industry summary

This analysis of the performance of the biotechnology industry highlights several important findings. The industry analysis by Pisano (2006) ended where the industry turned profitable on an aggregate level. Although the industry is profitable on an aggregate level, it is mainly driven by a few large and profitable biotechnology companies that were also among the

earliest entrants in the industry. More than 33 years since the IPO of Genentech, the first biotechnology company to go public, or approximately two product life cycles, a majority of the public (and private) biotech universe is loss-making R&D firms with no products on the market. The current industry analysis also sheds light on the long time it takes to bring a new drug to the market: the average number of years from company founding to the launch of the first major product for a sample of more recent successful US biotechnology companies is 18 years. While this group of companies on average went public only three years after founding, this means that public capital markets have provided the R&D capital needed for a majority of the period.

Although the NASDAQ biotechnology industry index has underperformed the S&P 500 index on a risk-adjusted basis over the period 1993-2013, there have been periods when returns have been excessively high and have generated significant profits for public investors. The underlying driving factors of the industry, such as big pharma's need to replace the major blockbusters due to patent expiration, and the significant bid premiums in M&As and the returns generated over certain periods in the sector will certainly play an important role in the industry's ability to attract R&D funding in the future.

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I

The value-relevance of accounting and non-accounting information in the European biotechnology industry

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Abstract

This paper examines the value-relevance of accounting and non-accounting information in the biotechnology industry. The study is based on hand-collected R&D data of publicly listed companies in the European biotechnology industry from 1998 to 2012. Consistent with expectations, information regarding the progress of individual research projects is value-relevant, whereas earnings information is not particularly value-relevant. The study shows that a stock market reacts more strongly to late-stage announcements than to early-stage announcements. These findings are consistent for both positive and negative R&D announcements. In addition, market reactions are explained using project- and firm-specific variables. Furthermore, the study documents a large asymmetry in the stock market's reaction to positive and negative R&D announcements. Importantly, there are significantly more positive than negative R&D news announcements. The findings of this study raise two important issues. First, firms may be reluctant to disclose negative information given the huge stock price impact of adverse news announcements. Second, given the large information asymmetries in the biotechnology industry and the large capital requirements, managers may use the value-relevant, mandatory and non-discretionary R&D news announcements as an instrument in the decision to raise external financing when there is a chance that investors will understand the firm's prospects better.

JEL-classification: G14
Keywords: Value-relevance; Accounting information; Non-accounting information; Disclosures; R&D; Biotechnology

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1. Introduction

Traditionally, accounting information, such as earnings and book value of equity, has been considered value-relevant to investors (e.g. Easton and Harris, 1991; Collins et al., 1997; Francis and Schipper, 1999). However, it has been argued that accounting information for firms in R&D intensive industries, such as the biotechnology industry, that invest heavily in intangibles convey less value-relevant information (e.g. Amir and Lev, 1996). Large investments in intangibles, such as research and development (R&D), that are immediately expensed and less frequently capitalized, has two main consequences. First, current performance measures are excessively low (often negative), even though one can expect that the more negative the current performance, the more positive future performance will be. Second, the measure of the current resources, equity, becomes excessively low because few investments are booked as assets.

Instead of relying on accounting information investors have to rely on voluntary and mandatory disclosures of information about the status of the firm's investment projects. Empirical accounting research verifies that voluntary disclosures improve stock liquidity (Diamond and Verrecchia, 1991), reduce the cost of equity capital (Botosan, 1997) and increase information intermediation (Lang and Lundholm, 1996). A problem is that voluntary disclosures are subject to a self-selection bias and, hence, the association between market reactions and disclosure might be driven by firm performance rather than disclosure per se (Healy and Palepu, 2001: 431). In this setting the biotechnology industry is studied in which investors make little use of accounting information and disclosures of R&D information is generally unbiased and mandatory[1] (rather than voluntary), and hence, problems associated with self-selection bias are less prominent. In addition, the drug development process is heavily regulated and monitored by regulatory authorities. As a result, the non-discretionary nature of disclosures in this industry overcomes the common criticism of endogenous event in the event study literature (Schultz, 2003; Viswanathan and Wei, 2008).

This study provides three contributions to the accounting and finance literature. First, it documents how the market reacts in aggregate to the disclosure of non-discretionary information. It shows the extent to which different accounting and non-accounting information is relevant to investors (in the sense that it influences security prices). This knowledge is important to investors who are evaluating firms within a given industry.

[1] For a review of disclosure issues for biotechnology and pharmaceutical firms, see Fisher (2002).

Second, while numerous studies have used information from the US stock exchanges (Ely et al., 2003; McConomy and Xu, 2004), this study uses a unique hand-collected dataset of publicly listed firms in the European biotechnology industry from 1998–2012. It has been argued that the US biotechnology sector differs from the European biotechnology sector in terms of maturity, size and the availability of funding (Dedman et al., 2008). Hence, this study provides the largest analysis by far of the European biotechnology industry, covering 87 firms from eleven countries over thirteen years.

Third, the study provides evidence of the differences in market reactions according to predictions. In particular, there are differences in stock price and in trading volume between projects in different phases, as well as between positive and negative outcomes. The study also documented how market reactions are explained, using project- and firm-specific variables.

The remainder of the paper is organized as follows. Section 2 contains a literature review and describes the hypotheses. Section 3 introduces the methodology, and section 4 explains the data sample. Section 5 presents the empirical results, and Section 6 concludes.

2. Theory and research hypotheses

2.1 Value-relevance of accounting information

It is known that value-relevant information changes stock prices because it causes investors to revise their expectations of the firms' future cash flows (Francis and Schipper, 1999). To determine expected future cash flows investors use the information they find value-relevant (Holthausen and Watts, 2001; Barth et al, 2001). Accounting information, such as earnings and book value of equity, has generally been considered to provide investors with value-relevant information (Easton and Harris, 1991; Francis and Schipper, 1999). However, it has been questioned to what extent accounting information plays a role for firms in high-tech industries that invest heavily in intangible assets, such as R&D, that are less frequently capitalized. Most research suggests that accounting information plays a less prominent role for these firms (e.g. Amir and Lev, 1996).

Amir and Lev (1996) examined the value-relevance of financial and non-financial information for a sample of US cellular firms. They find that accounting information (such as earnings, changes in earnings, book values and cash flows) on a stand-alone basis is not particularly

value-relevant. Amir and Lev (1996) argue that biotechnology firms suffer from the same inadequacies as do cellular firms. Using a sample of 44 US biotechnology firms, where earnings are predominantly negative, they find that book values and changes in earnings are positively related to market values, while earnings are negatively related to market values. Similarly, Ely et al. (2003) provide evidence, using a sample of 83 US biotechnology firms with no marketable products, that the market value of equity is associated to book value, but not significantly related to earnings (before R&D). Furthermore, Dedman et al. (2008) find, for a sample of UK biotechnology and pharmaceutical firms between 1990 and 1998 that book value of equity is positively associated with market value of equity, while earnings showed no significant association with market value of equity. Overall, past empirical research find mixed evidence that accounting information is value-relevant. Prior studies have primarily used information from the US stock exchanges.[2] US biotechnology sector differs from the European biotechnology sector in terms of maturity, size and the availability of funding (Dedman et al., 2008). Hence, whether accounting information for European biotechnology firms is value-relevant to investors is an open empirical question. This leads to the first hypothesis:

H_1: Financial information is value-relevant in the European biotechnology industry.

2.2 Value-relevance of non-accounting information

In industries where accounting information convey less value-relevant information it is essential to identify important non-accounting performance indicators. In the cellular industry, Amir and Lev (1996) show that non-accounting information, such as the population size of areas in which service licenses are held, potential growth in customers and market penetration, are highly value-relevant. Behn and Riley (1999) provide evidence that non-

[2] Generally accepted accounting principles (GAAP) in the US requires firms to immediately expense their significant value enhancing investments in internally developed intangible assets, and therefore, large investments in intangibles have two main consequences. First, current performance measures, such as earnings, are excessively low (often negative), even though one can expect that the more negative the current performance, the more positive future performance will be. Second, the measure of the current resources, equity, becomes excessively low because few investments are booked as assets. In an international setting the IASC implemented a standard on Intangible Assets (IAS 38) in 2001 which declares that development expenditures, fulfilling certain critera, shall be capitalized and amortized over its useful life (maximum five years). Lev and Sougiannis (1996)

accounting disclosures, such as several proxies for customer satisfaction, enhance traditional accounting information in the US airline industry. McConomy and Xu (2004) suggest industry-specific non-accounting disclosures of information, such as load factors in airlines, web traffic and customer experience in internet-based firms that may be value-relevant factors.

Several studies have examined the value-relevance of non-accounting information in the biotechnology industry that are engaged in the research and development of drugs.[3] For example, Yang (2008) finds that non-financial patent information is associated with biotechnology firms' financial performance as well as provides incremental value-relevance over traditional accounting information to the market value of equity. Ely et al. (2003) examine the value-relevance of product development information in the US biotechnology sector. They find that the significant positive association of market value with R&D costs is a function of portfolio potential as measured by the number of a firm's in-process drugs weighted by their development status. Measuring the stock market's reaction to phase initiations and status updates of R&D projects, they find the most significant reaction to phase II initiations and phase II status update announcements. However, they find no significant stock market reaction to news concerning later stages of development, such as phase III and FDA submissions, which interpret their findings as evidence that phase II is the stage at which investors begin to consider R&D projects as value-relevant[4]. Dedman et al. (2008) investigate the stock market reaction to research progress information. They find that the stock market reacts positive to phase III results (2.35 percent) and final success (1.87 percent), but not significantly positive to phase I and Phase II results[5].

Overall, it appears that there is a lack of general consensus on the value-relevance of non-accounting R&D information in the biotechnology industry. In addition, prior studies on

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and Oswald and Zarowin (2007) find that capitalization of R&D expenditures is associated with more informative stock prices, relative to expensing R&D.

[3] The drug development process consists of different stages that are linked to each other. These different stages are broadly classified as: discovery, pre-clinical, clinical phase I, clinical phase II, clinical phase III, and regulatory. The transition from one stage to the next must be built on the success of the previous stage. In addition, regulatory authorities closely monitor the drug development process, and the transition from one stage to the next must be approved by these regulatory authorities (such as the EMA in Europe and the FDA in the US).

[4] Joos (2003) provide several explanations to the event study findings by Ely et al. (2003) that Phase III and FDA submissions are not considered value-relevant. First, there may be wrong event dates. Second, phase initiations are not always good news as firm may initate the next clinical trial for a more limited set of indications than the market initially expected. Similarly, although the FDA may approve a drug, it may not always be good news as the drug may be approved in a sub-population or include unfavorable black-box labels.

biotechnology firms have only studied the stock market reaction to positive news, due to small sample sizes (Ely et al., 2003; Dedman et al., 2008)[6]. Hence, the second hypothesis is:

H_2: R&D information is value-relevant in the European biotechnology industry.

3. Methodology

This section describes the research methodologies used in the paper. First, the price regression model to explain the value-relevance of accounting variables is described. Second, the event study methodology is described that is used to assess the stock market's price and trading volume reaction to announcements of earnings- and R&D information. Third, the cross-sectional regression model that is employed to investigate the link between project- and firm-specific variables, as well as accounting variables, on stock market returns, is presented.

3.1 Price regression model

To examine if accounting information provides investors with value-relevant information, I follow Amir and Lev (1996) and estimate the following price regression model from panel data of quarterly financial information for a sample of European biotechnology firms:

$$P_{i,t} = \alpha_0 + \alpha_1 EPS_{i,t} + \alpha_2 \Delta EPS_{i,t} + \alpha_3 BV_{i,t} + u_{i,t} \quad (1)$$

$P_{i,t}$ is the stock price of firm i at the end of the second month following quarter t. The independent variables, $EPS_{i,t}$ and $BV_{i,t}$, are quarterly earnings per share and book value per share, respectively, of firm i at the end of quarter t. $\Delta EPS_{i,t}$ is measured as the change in earnings per share from the same quarter in the year before. Since the panel data set includes the same companies in successive quarters, I include a dummy variable for each firm to control for firm-fixed effects.

[5] A potential explanation to the findings by Dedman et al. (2008) is that 54 percent of the positive R&D announcements were released by three pharmaceutical firms during the test period.

[6] McConomy and Xu (2004) find that phase III results (positive/negative) exhibits the strongest market reaction of the different stages, but do not comment on differences between market reactions between positive and negative news across phases.

3.2 Event study methodology

To investigate the stock market's price reaction to earnings- and R&D announcements, the standard methodology for a short run event study, as suggested by MacKinlay (1997) and Campbell et al. (1997), is followed. For robustness reasons, I also examine trading volumes surrounding R&D announcements.

3.2.1 Price reaction

To estimate abnormal returns, I first employ OLS regression methods to estimate predicted returns in the following market model[7]:

$$R_{i,t} = \alpha_i + \beta_{i,m} R_{m,t} + \varepsilon_{i,t} \quad (2)$$

where $R_{i,t}$ is the daily market return on the acquiring firm *i* over day *t*, $R_{m,t}$ is the return on the value-weighted market portfolio over day *t*, α_i and β_i are the parameters of the market model, and $\varepsilon_{i,t}$ is the zero mean disturbance term. As a proxy for the market portfolio, the equal-weighted dividend- and split-adjusted stock return for all other firms that were included in the sample is used.[8] Predicted returns are estimated using ordinary least squares (OLS) regression over an estimation period of 221 days (the time period starting 250 days prior to the announcement and ending 30 days prior to the event). The abnormal return is the difference between a firm's predicted and actual stock price for any given day, derived from the market model:

$$AR_{i,t} = R_{i,t} - \left(\hat{\alpha}_i + \hat{\beta}_{i,m} R_{m,t}\right) \quad (3)$$

where $\hat{\alpha}_i$ and $\hat{\beta}_{i,m}$ are estimates of the regression parameters. The cumulative abnormal return (CAR) is calculated by aggregating the abnormal returns across two dimensions; firms and time. First, the cumulative abnormal return is calculated over the event window for each event in the sample. I use an event window of three days, which includes the day of the announcement as well as the day before and after.

[7] For robustness reasons, I also estimate predicted returns using the Fama-French three factor model. The three factor model yield similar results.
[8] Biotech- (and pharmaceutical) stocks are non-cyclical. Hence, this study uses an industry index rather than a market index.

$$CAR_i = \sum_{t=t_1}^{t_2} AR_{i,t} \tag{4}$$

Second, the cumulative average abnormal return across all the events, *N*, in the sample is calculated.

$$CAR = \frac{1}{N}\sum_{i=1}^{N} CAR_i \tag{5}$$

To eliminate the effect of confounding events and a possible dependence between abnormal returns, overlapping events were excluded (using a three-day period centered on the announcement date). Day 0 is designated as the day when the firm makes the earnings or R&D announcement.[9] If the information is disclosed during a weekend or any other time when the markets are closed, the next trading day becomes the event day. As a check of robustness, the cumulative abnormal returns (CAR) for a three-day event window (from day −1 to day +1), a five-day event window (from day −2 to day +2), and a twelve-day event window (from day −2 to day +10) are calculated. In addition to Student's *t* test, the non-parametric Wilcoxon signed ranks test is used, which does not require that the population be normally distributed.

3.2.2 Trading volume

Trading volumes may provide a better measure of information content than do price reactions (Beaver, 1968; Bamber, 1986). While price reactions reflect an average revision in investor beliefs, trading volume reactions reflect idiosyncratic belief revisions (Karpoff, 1986; Kim and Verrecchia, 1991a and 1991b). To calculate abnormal trading volume, I follow the procedure adopted by Roni and Jean-Luc (1996) and Lin et al. (2008). [10]

[9] Most US studies use the announcement dates in the *Wall Street Journal* as the event dates. Newspapers normally have one or two days of delay in their announcements. Business intelligence databases use newspapers as sources of information. Hence, relying on the dates from newspapers or databases might bias the event date. Therefore, as a check of robustness, different event windows are used, although the longer event windows tend to be noisier.

[10] As a robustness check, I also calculate abnormal trading volume following Ajinkya and Jain (1989). Abnormal trading volume is the difference between the actual and predicted trading volume. Equivalent to the estimation of predicted returns, the single-index market model with an estimation window of 180 days (day −200 to day −21) is used. A firm's actual trading volume is the number of shares traded on day *t* scaled to the total number of shares outstanding. The market proxy is the number of shares traded for all other firms (that were included in the sample), scaled by these firms' total number of shares outstanding. The model yield similar results.

I first calculate the average trading volume (ATV) during the observation period, which is defined as the average daily turnover rate during the period of days -45 to -4 and +4 to +45 relative to the issue announcement. That is:

$$ATV_i = \frac{\sum t\epsilon[-45,-4] \cup [+4,+45] TV_{i,t}}{T} \quad (6)$$

where $TV_{i,t}$ denotes the trading volume of stock *i* on date *t* and T represents the trading days during the observation period. Daily abnormal trading volume (ATV) during the event period is defined as:

$$ATV_{i,t} = \frac{TV_{i,t}}{ATV_i} - 1 \quad (7)$$

Summing up daily abnormal trading volume during the event period yields cumulative abnormal trading volume (CATV):

$$CATV_i = \sum_{t=t_1}^{t_2} ATV_{i,t} \quad (8)$$

3.3 Cross-sectional regression

Kothari and Zimmerman (1995) argue that the use of both return and price models has the potential to yield more convincing evidence. Following Kothari and Zimmerman (1995) and Amir and Lev (1996), I estimate the following return model:

$$CAR_{i,t} = \beta_0 + \beta_1 EPS_{i,t} + \beta_2 \Delta EPS_{i,t} + v_{i,t} \quad (9)$$

$CAR_{i,t}$ is the cumulative abnormal return of firm *i* over a three day event window around quarter *t* earnings announcement (centered on the quarterly earnings announcement day). The estimation of $CAR_{i,t}$ is detailed in the previous section. The independent variable, $EPS_{i,t}$, is defined as quarterly earnings per share of firm *i* at the end of quarter *t*. $\Delta EPS_{i,t}$ is measured as the change in earnings per share from the same quarter in the year before.

I also employ a regression model to explain the cross-sectional variations in cumulative abnormal return (Kale et al., 2002) of R&D announcements, using firm- and project-specific information:

$$CAR_{i,t} = \alpha_0 + \alpha_1 COMPLEXITY_{i,t} + \alpha_2 RISK\_SHARING_{i,t} + \alpha_3 INVESTMENT_{i,t} + \alpha_4 DIVERSIFICATION_{i,t} + \alpha_5 MTB_{i,t} + \sum_{j=1}^{3} \beta_j REGION_{i,t} + e_{i,t} \quad (10)$$

$CAR_{i,t}$ is the cumulative abnormal return of firm i over a three day event window around quarter t earnings announcement (centered on the R&D announcement day). The regression is run for three models with the following dependent variables: (1) all positive R&D announcements, (2) positive phase I announcements, and (3) positive phase II announcements.[11] The independent variables are described below.

Complexity

The therapy area of a project is a proxy for the complexity of the research project (*COMPLEXITY*). Projects within therapy areas that tend to have low success rates, such as the central nervous system, are expected to have a larger stock market reaction following positive news on clinical trials. Historical success rates per therapy area are based on DiMasi (2001).[12]

Risk-sharing

Biotech firms generally seek to collaborate with experienced partners in the costly late-stage clinical trials to share the risk.[13] A dummy variable (*RISK_SHARING*) is given a value of one when a project is developed with a partner; otherwise, it is zero.

Investment

The number of patients varies; not only between the different stages of drug development, but also between firms. The size of clinical trials (i.e., the number of patients included in the study) is a function of the size of the investment made by the firm and may provide investors with a more credible signal of the firms' belief in the project. The variable (*INVESTMENT*) is the logarithmic value of the number of patients.

[11] The few number of R&D announcements in other categories restricted the cross-sectional analysis to these categories.

[12] The success rates by DiMasi (2001) are based on pharmaceutical firms and may not directly apply to biotechnology firms. However, the success rates are not inflated by the R&D announcements in this sample. Hence, they are considered to be independent.

[13] For example, Paion's business strategy is to partner clinical products after the first major value driving milestone (after phase II), in order to share the risk of later clinical development (Paion, Annual Report, 2008).

Project diversification

A firm with many projects is less dependent on the success of each single project, compared to a firm with only one project. Project diversification (*DIVERSIFICATION*) is measured as the logarithmic market value of equity (measured as the average market value from day −21 to day −2, relative to the R&D announcement).

Other independent variables

Other control variables are market-to-book (*MTB*) and region dummies. Following La Porta et al. (1998), region dummies are included to control for the institutional characteristics between countries. The Anglo-Saxon region is used as a benchmark relative to the other three regions (Germanic, French, and Scandinavian).

3.4 Hypothesis testing

Two tests are performed. First, the value-relevance of accounting information is examined (H1). To examine if accounting information (earnings and book value of equity) provides investors with value-relevant information I perform a price regression on accounting variables (equation 1). To test for hypothesis 1, I ascribe the results from the price regression model. Following Kothari and Zimmerman (1995) and Amir and Lev (1996), I also estimate a cross-sectional return model (equation 9). To shed additional light, I examine the price and trading volume reaction around earnings announcements following the event-study methodology.

Second, the value-relevance of non-accounting information is investigated (H2). To examine if non-accounting information (R&D announcements) provides investors with value-relevant information I examine the stock market's reaction (with respect to price and volume) to R&D announcements. To test for hypothesis 2, price and trading volume reactions for R&D announcements are assumed to be significantly different from zero, i.e. no price and trading volume reaction.

4. Data and sample selection

4.1 Sample selection

This study examines R&D announcements of 87 publicly listed European biotechnology firms between 1998 and 2012[14]. The sample of firms is primarily identified from the Thomson Datastream database. Three restrictions to the sample are made. First, the company's primary quotation is on a European stock exchange. Second, only firms that are engaged in the development of drugs are included.[15] Third, to ensure a homogenous sample, pharmaceutical and generic companies are excluded. Prior research has used US data (Amir and Lev, 1996; Ely et al., 2003), whereas Dedman et al. (2008) use a mix of UK biotechnology and pharmaceutical firms. Even though the drug development process is essentially identical for biotechnology and pharmaceutical companies, the key difference is that pharmaceutical companies are generally much larger and hold a much more diversified project pipeline than biotech companies. Furthermore, pharmaceutical companies have revenue-generating products, and therefore, failures (and successes) of early-stage projects might be considered to be, relatively speaking, less value-relevant information. In addition, disclosure of early-stage R&D information may not be subject to mandatory disclosures, but rather voluntary disclosures. Consequently, voluntary disclosures of the clinical trial results of pharmaceutical firms may suffer from potential self-selection bias, meaning that the results cannot be generalized to biotechnology firms. These restrictions reduce the number of firms from 431 to 87. These firms are listed on 11 stock exchanges across Europe. [16]

Financial and accounting information, such as the dividend- and split-adjusted stock prices and trading volumes, as well as quarterly earnings, the number of shares outstanding and the book value of equity, are gathered from the Thomson Datastream.

[14] Ely et al. (2003) use a sample of 83 US biotech firms with no marketable products between 1988 and 1998. Dedman et al. (2008) use a sample of 22 UK firms, comprising a mixture of both biotechnology and pharmaceutical companies. The final sample consists of 151 positive announcements made between 1990 and 1998, of which 81 are made by three pharmaceutical firms.

[15] The biotechnology companies can be broadly classified to the fields of medical devices, diagnostics, information technology, tools and equipment, and drug development.

[16] The stock exchanges are the following: Vienna Stock Exchange (Austria), Copenhagen Stock Exchange (Denmark), Helsinki Stock Exchange (Finland), Euronext Paris (France), Frankfurt Stock Exchange (Germany), Milano Stock Exchange (Italy), Euronext Amsterdam (the Netherlands), Oslo Stock Exchange (Norway), OMX Stockholm (Sweden), Swiss Stock Exchange (Switzerland), and London Stock Exchange/Alternative Investment Market (United Kingdom).

4.2 R&D announcements

This study uses a complete sample of 1,071 R&D announcements made by all public biotechnology firms between 1998 and 2012. For active firms, the information related to R&D announcements is collected from corporate websites and is cross-checked (with a focus on event dates) with the Factiva database. For inactive firms, I primarily use the Factiva database and in some cases annual reports.[17] In general, the different phases in drug development can be described as follows. At the preclinical stage, the drugs is tested for safety and efficacy in animal models. Phase 1 trials examine safety of the drug in healthy volunteers. Phase 2 examines drug efficacy in a small-scale patient group. Phase 3 examines drug efficacy in large-scale patient groups. Clinical trial results are subject to a good news-bad news ranking (Guo et al., 2004).

The biotechnology industry has two key features that make studies of market reactions to the disclosure of R&D information of special interest. First, disclosures of R&D information is generally mandatory (rather than voluntary), and hence, problems associated with self-selection bias are less prominent. Second, the drug development process is heavily regulated and monitored by regulatory authorities, and consequently, the non-discretionary nature of disclosures in this industry overcomes the common criticism of endogenous event in the event study literature (Schultz, 2003; Viswanathan and Wei, 2008). In addition, managers' incentives to disclose value-relevant product development information are also derived from investor demand (Guo et al, 2004; Cerbioni and Parbonetti, 2007). Public firms are subject to stock exchange regulations[18], which not only require the information disclosed by a company to be correct, relevant, clear, and not misleading, but also require the information to be comprehensive enough to provide adequate guidance to assess the effect on the price of its securities. Firms must have a headline indicating the substance of the announcement and they must also clearly present the most important information at the beginning of the announcement. Hence, wording in the heading such as "positive results," "successful completion" or "primary endpoint was met" are classified as positive news. Similarly, press

[17] Joos (2003) argue that clinical trial results may also become available through alternative information sources, such as medical journals, conference abstracts and analyst meetings, and consequently, some news may suffer from potential biases. However, stock exchange regulations require public firms to have their own website on which "price-sensitive" information shall be made available as soon as possible after the information has been disclosed. According to these rules, firms are not allowed to provide price sensitive information at general meetings or analyst presentations without also disclosing the information elsewhere.

[18] Publicly-listed firms are subject to certain requirements about trading rules and regulations. Following general disclosure rules, firms have an obligation to disclose "price sensitive" information as soon as possible to the public.

releases including adverse notifications such as "negative results," "failure" or "primary endpoint was not met" are coded as negative news.

4.3 Descriptive statistics

Table 1 reports the distribution of positive and negative R&D announcements per development stage. In total, there are 1,071 R&D news announcements, of which 561 announcements are related to positive and negative R&D results. There are more positive R&D announcements than negative R&D announcements: 75 percent [420/(420+141)] of the R&D announcements are positive. These findings are consistent with those of Dedman et al. (2008) and Ely et al. (2003), who also find that firms disclose relatively few negative announcements in relation to positive announcements.

Table 1. Description and classification of R&D announcements

Announcement category	*Stage*	*Number of announcements*
Initiation		8
Results (positive)	Pre-clinical	56
Results (negative)		15
Initiation		200
Results (positive)	Phase I	123
Results (negative)		36
Initiation		214
Results (positive)	Phase II	175
Results (negative)		55
Initiation		88
Results (positive)	Phase III	66
Results (negative)		35
Total		1,071

Note: This table reports different types of announcements related to different phases (or stages) of the R&D process. These announcements are classified to three main announcement categories: initiation, results (positive), and, results (negative). Four different phases are distinguished between, i.e. pre-clinical, phase I, phase II and phase III. The review stage is excluded due to few observations.

The cumulative success rate from pre-clinical to clinical phase III is 30 percent, which reflects the low success of drug development.[19,20] Interestingly, the main attrition occurs in late-stage, rather than in early-stage, as 35 percent of the projects fail in phase III, and only 23 percent fail in phase I.[21] The results contrast those in DiMasi (2001), where the main attrition of pharmaceutical companies occurred in phases I and II (87 percent). There are also more announcements of phase II than of phase I because firms often expand a candidate drug's number of indications during later clinical stages. Fewer announcements concern the initiation

[19] The success rate is the probability that a project entering a phase reaches the next phase. Attrition, or failure, is equal to one minus the success rate.
[20] Not tabulated. [15/(56+15)]* [36/(123+36)]* [55/(175+55)]* [35/(66+35)] = 0.303
[21] [35/(66+35)]

of projects at the pre-clinical stage, compared with the initiation of projects in the clinical stages. Preclinical results are often published in scientific journals and companies only sporadically disclose this information in annual reports and company announcements (Joos, 2003). [22] In summary, this study primarily focuses on the three stages of drug development: clinical phase I, phase II and phase III, and there is good reason to believe that disclosures during these stages constitute the most value-relevant disclosures about the firms' projects.

5. Empirical results

5.1 Value-relevance of accounting information

In this section, I examine if accounting information (earnings and book value of equity) provide investors with value-relevant information. I follow Amir and Lev (1996) and regress stock prices on reported financial accounting variables. Table 2 presents coefficient estimates from the price regressions.

In Table 2, the coefficient on earnings (*EPS*) is statistically insignificant across models 1-4. In addition, the results of models 2-4 indicate that changes in the level of earnings (*ΔEPS*) are not value-relevant. In contrast, the coefficient on book value of equity (*BV*) is positive and statistically significant (1 percent level). Similar to the findings in this study, Ely et al. (2003) and Dedman et al. (2008) find that book value is significantly positively related to firm value, while earnings have no significant association with the market value of equity. The results contrasts the findings in Amir and Lev (1996), who finds that neither earnings nor book value are relevant in explaining the market value of cellular companies. Ohlson (1995) argues that book value is expected to be the dominant valuation variable when earnings are not informative. To control for impact of regulatory changes, following the adoption of IFRS in the European Union in 2005[23], I include a dummy variable (*Time*) taking the value of one for years in the period 2005-2012, and zero for periods prior to 2005. In model 4, the interaction variable between *EPS* and *Time* is statistically insignificant, which indicates that there is no

[22] A firm has no reason to file an Investigational New Drug (IND) with regulatory authorities if they find that the drug has adverse effects in animal studies. As a result, an announcement related to this stage may suffer from a self-reporting bias problem.

[23] In March 2002, the European Parliament passed a resolution requiring all firms listed on stock exchanges of European member states to apply International Financial Reporting Standards (IFRS) when preparing their financial statements for fiscal years beginning on or after January 1, 2005. According to IAS 38 (IFRS), research costs should be expensed when they incur, while development costs can be capitalized if certain criteria are met. One such criterion is that future economic benefits are highly probable.

Table 2. Value-relevance of accounting information

	Predicted Sign	(1)	(2)	(3)	(4)
Intercept		-2.312** (0.025)	-2.395*** (0.005)	-7.644*** (0.000)	-7.268*** (0.000)
EPS	+	-0.487 (0.748)	-1.089 (0.476)	-1.131 (0.451)	-0.200 (0.914)
ΔEPS	+		-0.723 (0.359)	-0.703 (0.359)	-0.661 (0.399)
BV	+	3.904*** (0.000)	3.878*** (0.000)	3.884*** (0.000)	3.876*** (0.000)
Time				6.123*** (0.000)	5.737*** (0.000)
EPS x Time	+				-1.093 (0.648)
Firm-fixed effects		Yes	Yes	Yes	Yes
Number of observations		1734	1599	1599	1599
Adj R^2		0.889	0.887	0.888	0.888
F-value		386.26	260.65	204.53	168.18
(p-value)		(0.000)	(0.000)	(0.000)	(0.000)

Notes: This table shows the regressions results of market value of equity on accounting variables. The sample consists of 87 biotechnology firms in the years 1998-2012. The dependent variable is the share price (price per share) of firm *i* at the end of the second month following quarter *t*. EPS and BV are, respectively, earnings per share and book value of equity for firm i at the end of period *t*. ΔEPS is the change in earnings per share for firm *i* for period *t*. Time is a dummy taking the value of 1 for years 2005-2012, zero otherwise. For robustness reasons, all *t*-tests are double-sided and computed using the Huber-White-Sandwich estimator of variance that produces consistent standard errors. *p*-values are displayed in parentheses. *, **, and *** denote the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively.

difference in the value-relevance of earnings prior to and after the adoption of IFRS. In untabulated tests, I separate between positive and negative earnings. However, the earnings coefficients are not statistically significant.

Following Amir and Lev (1996) and Ely et al. (2003) I also perform regressions including earnings before R&D expenses. However, the coefficient is statistically insignificant. A potential explanation is that a majority of the firms are at a development stage with no regular revenues. Ely et al. (2003) find that earnings before R&D is significantly positively related to market value of equity only for biotechnology firms with marketable approved drugs. Another potential reason is that due to the relatively low likelihood of reaching the market (even in phase III the probability of reaching the market averages 67 percent) firms not believe that future economic benefits are highly probable according to one of the criteria in IAS 38, and therefore do not capitalize investments in R&D. In summary, the results indicate that earnings

are not value-relevant, whereas book value of equity is value-relevant. This indicates that the null hypothesis cannot be rejected.

5.2 Value-relevance of non-accounting information

In this section, I examine the value-relevance of accounting and non-accounting information by examining the stock market's reaction to earnings- and R&D announcements. Table 3 presents the short-run stock price and volume reaction to earnings- and R&D announcements (related to the stages of drug development).

The stock market reaction at day zero to earnings announcements is -0.79 percent and statistically significant (1 percent level). However, the magnitude of the coefficient is small. The abnormal volume at day zero and around earnings announcements (days −1 to +1 relative to the announcement day) is statistically insignificant, which indicates that earnings announcements provide limited information content.

Next, the stock market's reactions to R&D announcements are examined. The stock market reacts positively (negatively) to all positive (negative) R&D announcements on day zero.[24,25] The day zero mean abnormal return is 1.99 percent (−12.25 percent) for clinical phase I results, 6.37 percent (−15.78 percent) for clinical phase II results and 7.53 percent (−31.77 percent) for clinical phase III results. The strong stock market reaction to negative news announcements, especially to clinical phase III, suggests that they were largely unanticipated by investors. In the most extreme case, the market value decreased by 75 percent during one day on a single negative phase III news announcement (not tabulated).

Column two of Table 3 documents the stock market's reaction over a three-day event window (days −1 to +1 relative to the announcement day). Positive R&D announcements are not different when using a one- or three-day event window. In contrast, negative R&D announcements exhibit a larger negative reaction when using the three-day event window. For example, the three-day cumulative abnormal return to negative phase II results is −24.18

[24] All of the reactions are statistically significant at the 1% level, but reactions to positive phase I announcements were significant at the 5% level.
[25] Non-parametric tests confirm the results.

Table 3. Stock market reaction to earnings- and R&D announcements

Event		Abnormal return (%)			Abnormal volume (%)		
		n	$\overline{AR}_0$ (t value)	$\overline{CAR}_{-1,+1}$ (t value)	n	$\overline{AV}_0$ (t value)	$\overline{CAV}_{-1,+1}$ (t value)
Earnings	All	2018	-0.79*** (-6.32)	-0.45*** (-4.32)	1982	0.86 (0.74)	0.92 (0.75)
	Negative	1554	-0.99*** (-6.77)	-0.59*** (-4.88)	1511	0.89 (0.87)	0.86 (1.20)
	Positive	456	-0.08 (-0.37)	-0.06 (-0.32)	442	0.12 (1.13)	0.17 (1.09)
Phase I	Initiation	200	1.55*** (3.07)	1.22* (1.77)	190	0.30 (1.47)	0.37 (1.28)
	Results (positive)	120	1.99*** (3.67)	1.68** (2.32)	118	0.54*** (2.81)	0.73*** (2.62)
	Results (negative)	34	-12.25*** (-3.94)	-15.20*** (-5.04)	32	3.00* (1.93)	3.52* (-1.91)
Phase II	Initiation	202	1.23** (2.46)	0.95* (1.71)	180	0.23*** (3.16)	0.30** (1.99)
	Results (positive)	174	6.37*** (4.21)	7.13*** (4.43)	172	0.93*** (4.96)	1.66*** (4.90)
	Results (negative)	55	-15.78*** (-4.24)	-24.18*** (-4.25)	54	2.58** (2.01)	4.94*** (2.67)
Phase III	Initiation	88	2.28 (1.31)	2.57 (1.53)	78	0.26 (1.22)	0.29 (0.85)
	Results (positive)	66	7.53*** (8.02)	6.44*** (4.45)	65	0.90** (2.55)	1.23*** (2.83)
	Results (negative)	34	-31.77*** (-4.45)	-38.80*** (-5.35)	32	7.82*** (2.59)	11.55*** (3.13)

Note: This table reports mean abnormal return and mean abnormal volume for day zero and for the event window (-1 to +1 day relative to the announcement day). The t values are based on robust standard errors and are displayed in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

percent (t-statistic −4.25), while the day zero mean abnormal return is −15.78 percent (t-statistic −4.24). If negative announcements are largely unanticipated, one would expect that the larger stock market reaction to negative news for the three-day event window occurs on

day zero and on the following day, rather than before the event date.[26] Not tabulated data shows that the mean cumulative abnormal return prior to the event (i.e., day −10 to day −1) is −8.31 percent for negative phase I news announcements (*t*-statistic −3.02). However, the market's reactions prior to the event for negative phase II and phase III news announcements are insignificant; hence, investors do not seem to anticipate negative phase II and III results.

Table 4. Robustness – Event windows

Stage of R&D process	Event	Abnormal return			Abnormal volume		
		n	$\overline{CAR}_{-2,+2}$ (*t* value)	$\overline{CAR}_{-2,+10}$ (*t* value)	n	$\overline{CAV}_{-2,+2}$ (*t* value)	$\overline{CAV}_{-2,+10}$ (*t* value)
Phase I	Initiation	200	1.47*	1.34	190	0.43	0.40
			(1.93)	(1.15)		(1.26)	(0.65)
	Results (positive)	120	1.33*	-1.28	118	0.75**	0.75
			(1.71)	(-0.93)		(2.42)	(1.37)
	Results (negative)	34	-17.25***	-19.31***	32	3.58*	2.73
			(-5.82)	(-3.91)		(1.84)	(1.31)
Phase II	Initiation	202	0.45	-0.41	180	0.38*	0.69
			(0.64)	(-0.31)		(1.70)	(1.19)
	Results (positive)	174	7.33***	6.43***	172	2.08***	3.18***
			(4.17)	(2.86)		(4.55)	(4.04)
	Results (negative)	55	-24.74***	-27.78***	54	6.33***	9.12***
			(-4.49)	(-3.88)		(3.08)	(3.49)
Phase III	Initiation	88	1.84	4.62	78	0.25	-0.20
			(0.95)	(1.46)		(0.64)	(-0.28)
	Results (positive)	66	5.34***	6.69*	65	1.53***	2.48***
			(2.94)	(1.68)		(2.69)	(3.58)
	Results (negative)	34	-38.60***	-38.55***	32	13.32***	14.63**
			(-5.73)	(-5.16)		(2.91)	(2.55)

Note: This table reports mean abnormal return and mean abnormal volume for two different event windows (-2 to +2 day, and -2 to +10 day relative to the announcement day, respectively). The *t* values are based on robust standard errors and are displayed in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Columns 3 and 4 of Table 3 present the results of the day zero mean abnormal volume and the three-day mean cumulative abnormal volume for R&D announcements, respectively. The stock market reacts to all positive (negative) R&D announcements on day zero. For example,

[26] It is important to note that only events with no announcements that occurred simultaneously or during a three-day period centered on the event date are included in the sample, and, hence, the impact of other events should not explain the difference between the day-zero and the three-day event window.

the mean abnormal volume on day zero for negative phase III results is 7.82 percent (*t*-statistic 2.59) compared to 3.00 percent (*t*-statistic 1.93) for negative phase I results. The mean cumulative abnormal volume over the three-day window documents that the trading volume increases significantly for negative phase II and III results, compared to day zero (11.55 percent > 7.82 percent, and 4.94 percent > 2.58 percent, respectively). In contrast, the trading volumes (in regards to the positive and negative phase I results) only exhibit small differences between the one- and three-day event windows. In summary, the results of Table 3 indicate that H2 cannot be rejected.

Table 3 also reports that the stock market reacts positively to news about the initiations of clinical phase I (1.55 percent, *t*-statistic 3.07) and clinical phase II (1.23 percent, *t*-statistic 2.46), but that there is no significant reaction to initiations of clinical phase III. There are two explanations for this result for clinical phase III. First, phase initiations are not always good news because firms may start a clinical trial for fewer indications than were being investigated in the prior stage (Joos, 2003). Second, following positive clinical phase II results, the initiation of clinical phase III trials may already be anticipated by investors.

For robustness reasons, I examine if the findings are consistent using different alternative event windows. Table 4 presents the mean cumulative abnormal return (volume) for R&D announcements for two different event windows: days −2 to +2, and days −2 to +10, respectively. Overall, the results reveal that the price and volume-reactions to phase II and phase III results are persistent over longer event windows, while only price-reactions to negative phase I results are persistent.

5.3 Cross-sectional regression results

One key feature in the biotechnology industry is that firms disclose quite detailed information and, quite possibly, there is no other industry in which such detailed information about ongoing projects is disposed. Corporate disclosures concerning clinical trial results in general contain information, such as type of compound, indication and therapy area, stage of development, number of patients, comments made by CEO and/or medical director et cetera. In addition, disclosures contain information about if the primary and/or secondary endpoint/s of the study was met (such as safety, efficacy, or tolerability of the drug), which is based upon

pre-defined measures.[27] Hence, clinical trial results are subject to a good news-bad news ranking (Guo et al, 2004).

If the stock market responds differently to similar type of information, the results may be driven by key features of the sample. For example, a firm with a single project in phase II has a considerably different risk profile than a firm with five projects in clinical trials of which one is phase II. Joos (2003) proposes that collecting a richer set of data on micro level might provide additional insight into the value creation process and how R&D contributes to the value of a biotech firm. While important to investors, reliable measures of these differences are scarce in the literature.

To examine the association between the magnitude of the three-day cumulative abnormal return and the project- and firm-specific variables, a cross-sectional regression model is used. Table 5, panel A, presents summary statistics of the independent variables. The mean success rate (*COMPLEXITY*) per therapy area is 0.56. The average clinical trial (INVESTMENT) enrolls 176 patients (or health volunteers). 24.5 percent of the projects are developed in collaboration with a partner (*RISK_SHARING*). However, there is a large variation in the size. The largest clinical trial involves 3,000 patients and the smallest has only 10 patients enrolled (not tabulated). The average market capitalization (*DIVERSIFICATION*) is €369 million. Most of the firms are quite small, though a few firms are substantially larger than the average (not tabulated). Panel B of Table 5 contains a pair-wide correlation matrix and documents a low correlation overall between the independent variables.

Table 6 presents the results of the cross-sectional regression model. The dependent variables are the day zero abnormal returns for (i) all positive R&D announcements, (ii) positive phase I announcements, and (iii) positive phase II announcements. In general, these tests confirm our expectations. Model (i) documents negative and significant effects of *COMPLEXITY* (*t*-statistic −2.00) and *DIVERSIFICATION* (*t*-statistic −2.21), as well as a positive and significant effect of *INVESTMENT* (*t*-statistic 1.99). In model (ii) and model (iii), positive R&D announcements of phase I and II are tested separately. Both models suggest that *COMPLEXITY*, *INVESTMENT* and *DIVERSIFICATION* are statistically significant.

[27] Stock exchange regulations not only require information disclosed by the company to be correct, relevant, clear, and not misleading. It also requires information to be comprehensive enough to provide adequate guidance

Table 5. Descriptive statistics

Panel A. Summary statistics

	Number of observations	*Mean*	*Q1*	*Median*	*Q3*	*St. dev*
COMPLEXITY	483	0.555	0.446	0.512	0.646	0.122
RISK_SHARING	483	0.245				
INVESTMENT	483	176.1	33	66	186	318.9
DIVERSIFICATION	483	369.2	87.0	155.0	312.0	713.0
MTB	483	2.145	0.697	1.047	2.017	3.153

Notes: This table reports descriptive statistics of the independent variables. COMPLEXITY, RISK_SHARING, and, INVESTMENT are project-specific variables. DIVERSIFICATION and MTB are firm-specific variables. COMPLEXITY is the historical success rate per therapy area. RISK_SHARING equals 1 if the project is developed in collaboration with a partner company, zero otherwise. INVESTMENT represents size of the clinical trial, i.e. the number of patients. DIVERSIFICATION is measured as the average market value of equity 20 days prior to the R&D news announcement (measured between day -24 to day -5). MTB represents market-to-book value of equity and is measured as the market value of equity divided by the book value of equity preceding the R&D announcement (scaled by the median market-to-book value).

Panel B. Correlation matrix

	COMPLEXITY	RISK_SHARING	INVESTMENT	DIVERSIFICATION	MTB
COMPLEXITY					
RISK_SHARING	0.117*				
INVESTMENT	-0.066	0.160**			
DIVERSIFICATION	-0.028	-0.026	0.071		
MTB	0.167	-0.038	0.075	0.310***	

Notes: This table reports pair-wise correlations. ***, **, and *, denote two-tail 1%, 5% and 10% significance, respectively. The variables are detailed in Table 5, panel A.

In summary, three project-specific variables can explain the cross-sectional variation in positive R&D news: (1) when there is low probability of a success but a success occurs, the market reaction is large (*COMPLEXITY*); (2) the smaller and less diversified the firm is, the larger the market reaction (*DIVERSIFICATION*); and (3) the more capital that has been invested in the clinical trial, the larger the market reaction (*INVESTMENT*). The models do not lend support to the idea that *RISK_SHARING* could explain the cross-sectional variation in abnormal returns.

to render possible assessment of the effect of the price of its securities.

Table 6. Cross-sectional regression models

Panel A. Earnings announcements

	Predicted Sign	(1)	(2)
Intercept		-0.004*** (0.000)	-0.004*** (0.000)
EPS	+	0.002*** (0.000)	0.002** (0.025)
ΔEPS	+		-0.001 (0.600)
Firm-fixed effects		Yes	Yes
Number of observations		1845	1665
Adj R^2		0.007	0.004
F-value		14.78	3.97
(p-value)		(0.000)	(0.019)

Notes: This table shows the cross-sectional regressions results of cumulative abnormal return on accounting variables. The sample consists of 87 biotechnology firms in the years 1998-2012. The dependent variable is the cumulative abnormal return of firm *i* over a three day event window around quarter *t* earnings announcement (centered on the quarterly earnings announcement day). EPS are earnings per share for firm i at the end of period t. ΔEPS is the change in earnings per share for firm i for period t. For robustness reasons, all t-tests are double-sided and computed using the Huber-White-Sandwich estimator of variance that produces consistent standard errors. p-values are displayed in parentheses. *, **, and *** denote the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively.

Panel B. R&D announcements

	Predicted Sign	(1) All positive R&D announcements (n=360)	(2) Positive phase I announcements (n=120)	(3) Positive phase II announcements (n=174)
Intercept		0.191*** (2.69)	0.186 (1.40)	0.216 (1.20)
Complexity	-	-0.158** (-2.00)	-0.264* (-1.68)	-0.150* (-1.66)
Risk sharing	-	0.031 (0.92)	0.013 (0.81)	0.089 (0.89)
Investment	+	0.039** (1.99)	0.055* (1.80)	0.047* (1.69)
Diversification	-	-0.050** (-2.21)	-0.025* (-1.82)	-0.089** (-2.45)
MTB	+/-	0.002 (0.41)	0.001 (0.51)	0.021 (1.18)
Dummies for regions		Yes	Yes	Yes

Notes: This table provides the estimates from the linear regressions. The sample consists of 87 biotechnology firms in the years 1998-2012. The dependent variable is the three-day cumulative abnormal return for (1) all positive R&D announcements, (2) positive phase I announcements, and, (3) positive phase II announcements.. COMPLEXITY, RISK_SHARING, and, INVESTMENT are project-specific variables. DIVERSIFICATION and MTB are firm-specific variables. COMPLEXITY is the historical success rate per therapy area. RISK_SHARING equals 1 if the project is developed in collaboration with a partner company, zero otherwise. INVESTMENT represents size of the clinical trial, i.e. the number of patients. DIVERSIFICATION is measured as the average market value of equity 20 days prior to the R&D news announcement (measured between day -24

to day -5). MTB represents market-to-book value of equity and is measured as the market value of equity divided by the book value of equity preceding the R&D announcement (scaled by the median market-to-book value). For robustness reasons, all *t*-tests are double-sided and computed using the Huber-White-Sandwich estimator of variance that produces consistent standard errors. *p*-values are displayed in parentheses. *, **, and *** denote the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively.

6. Conclusion

This paper investigates the stock market's reaction to disclosures of accounting and non-accounting information in the biotechnology industry. The interest in the value-relevance of non-accounting information stems from the concern that accounting information is not particularly relevant for firms in R&D intensive industries which invest heavily in intangibles that are immediately expensed and less frequently capitalized. The biotechnology industry has two features that make studies of market reactions to the disclosure of non-accounting information of special interest. First, disclosures are generally mandatory (rather than voluntary), and hence, self-selection biases are less prominent. Second, the drug development process is heavily regulated and monitored by regulatory authorities. As a result, the non-discretionary nature of disclosures in this industry overcomes the common criticism of endogenous event in the event study literature.

The empirical study is based on a unique hand-collected dataset of all publicly-listed firms in the European biotech industry from 1998–2012. While prior studies have used data from the US stock exchanges, this study provides the largest analysis by far of the European biotech industry, covering 87 firms from 11 countries over 15 years. Using price and return regression models, as well as examining the price and trading volume reactions, earnings are not considered value-relevant to investors. In contrast, the study shows the extent to which different non-accounting information, such as positive and negative news announcements concerning R&D projects, are value-relevant to investors and can influence security prices and trading volumes. The study provides evidence of differences in market reactions according to predictions. In particular, there are differences in stock price and trading volume differences between projects in different phases, as well as between positive and negative outcomes. The study also documents how market reactions are explained using project- and firm-specific variables.

The findings highlight two important issues. First, the large stock market reaction to clinical trial events is of great concern to both investors and management of biotechnology companies. Firm managers may be reluctant to disclose negative R&D news; this reluctance

highlights the importance of stock exchange regulations and the disclosure of price-sensitive information. At the same time, the disclosure of information has to be credible and reliable to investors and other market participants. This is of crucial importance in an industry where capital markets provide the only funding alternative. Although trading regulations require firms to disclose price-sensitive information when it appears, there seem to be at least some managerial discretion in the wording of clinical trial announcements. Regulators should provide a robust framework regarding the information content in press releases. Second, the firm's managers may use the value-relevant R&D news as an instrument to access the capital markets when information asymmetries are low and when there is a chance that investors will understand the firm's prospects better.

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II

Market Timing and Equity Financing Decisions[1]

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Abstract

Equity market timing is a much-discussed topic in the capital structure literature. We study two views of equity market timing, mispricing and adverse selection costs, using a sample of 250 seasoned equity offerings (SEOs) made by publicly listed European biotechnology firms between 1998 and 2012. To a large extent, the primary motive to issue equity is to sustain operations, and the average survival time at the announcement date is less than 7 months. We can neither reject the adverse selection cost hypothesis nor the mispricing hypothesis. The analysis shows that R&D news announcements are positively associated with issues of new equity. We also find that biotechnology stocks generate positive abnormal returns prior to the equity issue announcement and negative abnormal returns after the equity issue announcement. After controlling for anticipation, our results indicate that R&D disclosures are unassociated with the stock price reaction at equity issue announcements.

JEL-classification: G32
Keywords: Market timing; Mispricing; Adverse selection; Equity financing; R&D disclosures; Seasoned equity offerings (SEOs); R&D; Biotechnology

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1. Introduction

Growing enterprises usually require external capital to fund their operations. Accessing capital markets is a balancing act that depends on both firm- and market-specific factors. Somewhat surprisingly, academic research is still puzzled by management's decisions over when and why to seek external equity financing. Over the years, two main theories have emerged: the mispricing and the adverse selection cost theories. According to the mispricing theory, managers seek external financing when it is easily available at favorable prices (Ritter, 1991; Loughran and Ritter, 1995; Baker and Wurgler, 2002). For the same reason, they repurchase shares when prices are excessively low (Ikenberry et al., 1995). The mispricing theory suggests that managers believe the firm is not always correctly priced and that managers want to capitalize on the mispricing. In contrast, the adverse selection cost theory is built on a dynamic framework of the Myers and Majluf (1984) model, where time-varying asymmetric information plays a major role. The rationale goes that firms issue equity when adverse selection costs are low, that is, following credible information releases (Korajczyk et al., 1991). Consequently, the adverse selection cost theory suggests there are moments when it is more favorable for managers to issue equity without necessarily acting solely in their own interest.

Past empirical research has verified the importance of both theories; but the emphasis has been on the mispricing theory. As accounting information provides credible signals of how an economic entity performs, the adverse selection cost theory tends to be tested in association with the release of accounting information (e.g. Korajczyk et al., 1991; 1992). However, an issue of new equity might be made after accounting information has been disclosed because management believes that the firm's prospects are mispriced. In particular, accounting information is discretionary and an issue of new equity is likely to influence accounting choices and perhaps even provoke earnings management. While it is likely that the disclosure of accounting information reduces information asymmetry, it is unlikely that accounting information provides a clean test of the adverse selection cost hypothesis.

With these issues in mind, we study an industry; biotechnology, that has some attractive characteristics. Equity capital is a primary source of funding for publicly listed early-stage and not yet profitable growth firms (Bolton and Freixas, 2000; Rajan and Zingales, 1998; Ravid and Spiegel, 1997). Typically, biotechnology firms are in an early life-cycle stage with no commercial products and, hence, their investments cannot be internally funded. Because

investments are mainly in unrecognized intangible assets they cannot use debt financing either, and instead they issue new equity on a regular basis. The biotechnology industry, therefore, permits a study of equity market timing without having to think about alternative sources of external capital. Because biotechnology firms are in the early life-cycle stage and invest heavily in R&D, accounting information is a poor indicator of value creation (Dedman et al., 2008; McConomy and Xu, 2004). However, indirectly, regulatory authorities, such as the US Food & Drug Administration (FDA), make independent assessments of the research projects. These R&D disclosures are mandatory, non-discretionary and value-relevant (e.g. Fisher, 2002).

In this setting, we study equity market timing and assess the mispricing and adverse selection cost arguments. Similar to Loughran and Ritter (1995, 1997), Baker et al. (2003), Huang and Ritter (2009), DeAngelo et al. (2010), mispricing is measured using stock returns (*pre-abnormal return* and *post-abnormal return*). We expect the prior (future) stock abnormal return to be positively (negatively) associated with the probability that a firm conducts an SEO. The adverse selection cost hypothesis is tested using the mandatory non-discretionary information that biotechnology firms have to release about their research projects' progress. We expect firms to issue new equity when the degree of asymmetric information is lower, i.e., following announcements of the research projects' current status.

The primary motive for seeking external financing is a need to sustain operations. Therefore, we expect market timing (either because of mispricing or adverse selection costs) to provide incremental explanatory power to the biotechnology firm's survival time.[2] The sample consists of 87 European biotechnology firms that have been publicly listed sometime between 1998 and 2012. In total, these firms have made 250 equity offerings and 561 public announcements concerning their research projects' progress as compared with regulatory authorities' assessment criteria.

The empirical data confirms that new equity, to a large extent, is issued to sustain operations; the average survival time at the announcement date is 7 months. This is consistent with DeAngelo et al. (2010). In addition to the survival time, there is support for both the adverse selection cost hypothesis and the mispricing hypothesis, and both have incremental effects.

[2] An example of market timing is exemplified by the following paragraph from a press release on March 23, 2010, for the French biotechnology firm Transgene, which went public in 1998: "In light of its net cash position at December 31, 2009, of €64.7 million, the Company is able to determine the timing of the fund raising and its announcement when it deems the conditions most appropriate".

We find that biotechnology stocks generate positive abnormal returns prior to the equity issue announcement and negative abnormal returns after the equity issue announcement. However, the mispricing measure is sensitive to the length of the selected time period prior to and after the equity issue announcement. We also find that R&D news announcements are positively associated with issues of new equity. Although R&D news announcements are helpful to investors to anticipate equity issues our results indicate that they are unable to reduce the information asymmetry at the equity issue announcement. Controlling for anticipation using the conditional event study methodology (Acharya, 1988) we do not find that R&D disclosures are associated with the stock price reaction at the equity issue announcement.

The remainder of the paper is outlined in the following way. Section two provides a theoretical framework, an overview of prior studies and a presentation of the two research hypotheses. Section three discusses methodological issues related to the study. Section four contains the empirical results. Section five includes additional tests and, finally, section six concludes.

2. Theory and research hypotheses

2.1 Market timing and capital structure

The capital structure decision has puzzled finance researchers for decades (Lintner, 1965; Myers, 1984), and two main capital structure theories dominate research: the "static trade-off" and the "pecking-order" theories. According to the static trade-off theory, firms have a target capital structure, determined by advantages and disadvantages of debt financing (Jensen and Meckling, 1976; Myers, 1977). Although agency costs are important in this setting, the capital structure decision depends on a rational analysis of relevant factors, and there is little room for managerial opportunism or for the timing of capital markets.

According to the pecking-order theory, firms follow a financing hierarchy, in which they prefer to finance their investments with internal funds, then with external debt, and with issues of new equity as a last resort (Myers and Majluf, 1984; Myers, 1984). The pecking-order theory considers that agents make the decision, and that information is asymmetrically distributed between the firm's management and shareholders. In a similar vein, it is suggested that a firm's capital structure is an effect of management's ability to seek external financing

when easily accessible at a low cost (Baker and Wurgler, 2002). Two views on equity market timing have emerged: the mispricing and the adverse selection cost hypotheses[3].

2.2 The mispricing theory

The standard finance model, in which rational investors ensure that stock prices equal the present value of expected future cash flows, has considerable problems explaining many stock market events (Shiller, 2000; Baker and Wurgler, 2007). Empirical research has come across several factors, such as size and the book-to-market ratio, which seems to be associated with stock returns without necessarily being measures of systematic risk. It is, therefore, not surprising that corporate finance decisions (e.g., initial public offerings, mergers, acquisitions and issues of equity and debt) are non-random. Just like investors, managers make use of capital markets as if they are predictable. The seemingly systematic variations in the association between stock price and fundamentals form the basis for the mispricing hypothesis of equity issuance.

There are many reasons for taking a privately owned firm public, including investment needs and public attention. However, a most important reason is that owners of the private firm believe they get a good price. Initial public offerings (IPOs) occur in cycles (Ibbotson and Jaffe, 1975; Ritter, 1984; Ibbotson et al., 1988, 1994) that seem to follow stock market sentiments; when prices are high, there are more IPOs (Pástor and Veronesi, 2005). In a similar vein, Alti, (2006) shows that market sentiments increase not only the number of IPOs but also their size and the proportion of the firm that is sold.

Research on mergers and acquisitions also reveal patterns, usually referred to as merger waves (Rhodes-Kropf et al., 2005; Harford, 2005; Martynova and Renneboog, 2008). While merger waves are more complicated to pinpoint – as dependent on prices of both acquiring and target firms and the method of payment – they stem from the idea of predictable stock prices. Harford (2005) explain merger waves as the outcome of market timing, where industries respond to shocks and reorganize through mergers and acquisitions, creating a clustering of merger activity, in which liquidity plays an important role.

A clustering of seasoned equity offerings (SEOs) in "hot issue" markets is well known in the finance literature (Hickman, 1953; Choe et al., 1993; Bayless and Chaplinsky, 1996). Starting with Taggart (1977), many studies also show how firms make more SEOs when market

[3] The mispricing hypothesis is built on the notion of market inefficiency, whereas the adverse selection costs hypothesis assumes market efficiency.

valuations are high relative to book values or historical market values. Survey evidence in Graham and Harvey (2001) reveals that market timing is a primary concern of corporate executives: CFOs admit that timing considerations influence financing decisions. In a very influential study, Baker and Wurgler (2002) find that the capital structure is, by and large, a product of capital market timing. Several empirical studies have examined the stock market performance of firms conducting equity issues. For example, Loughran and Ritter (1995) find that firms issuing stock, either through IPOs or SEOs, experience low returns in subsequent years. In summary, there is ample evidence that firms take advantage of temporary mispricing in financial markets and thus issue equity when it is perceived as being overvalued.

The mispricing hypothesis suggests that managers issue new shares when market prices are high (Ritter, 1991; Loughran and Ritter, 1995, 1997), and repurchase shares when market prices are low (Ikenberry et al., 1995). There are two possible reasons for this behavior. First, managers have access to private information and might know better than investors what the firm's true performance is. Essentially, managers make use of asymmetrically distributed information. Second, equity markets, in general, are "hot", in the sense that investors temporarily seem to be more optimistic about expected growth rates, profit margins, etc. Thus, managers make use of market sentiments, rather than asymmetric information, and the firm's operating performance is unassociated with the decision to issue new equity (Alti, 2006). We refer our measure of market sentiments to the mispricing theory, which suggests that prior (future) stock abnormal return is positively (negatively) associated with the probability of issuing equity (e.g. Baker and Wurgler, 2007; DeAngelo et al., 2010). While the asymmetric information argument is interesting in itself, our first hypothesis relies on the latter aspect of mispricing:

H_1: Biotechnology firms issue new equity to a greater extent when equity market sentiments are strong.

2.3 The adverse selection cost theory

In the presence of information asymmetry, the information asymmetry model by Myers and Majluf (1984) for public offerings suggests that equity issues to outside investors are associated with an adverse selection problem as managers will issue equity only when they

believe the firm is overvalued. Their model assumes managers act only in the interest of existing investors, managers have superior information and existing investors do not participate in the equity issue. Eckbo and Masulis (1992) extend the information asymmetry framework by Myers and Majluf (1984) and show that rights offerings to existing investors are associated with a similar adverse selection problem when the anticipated current shareholder participation is less than 100 percent.

Information asymmetries decrease when new value-relevant information is made public. Given that the disclosure of value-relevant information varies between firms and over time, the level of asymmetrically distributed information also varies (Dierkens, 1991; Lucas and McDonald, 1990; Choe et al., 1993). Immediately following relevant news announcements, asymmetries are low, but the information advantage of management increases with time. Korajczyk et al. (1991, 1992) suggest that the perceived change in information asymmetry raise the adverse selection costs of equity investments. There is thus a rational expectation that corporate financial decisions, such as issues of new equity, are influenced by information asymmetry and the release of new credible information. We refer to this as the adverse selection cost hypothesis of equity issuance, which suggests that firms issue equity when the market is comparatively better informed.

Empirical research tends to use mandated accounting information as a measure of credible value-relevant information. Korajzcyk et al. (1991; 1992) find that firms issue more equity following the disclosure of financial reports, when the asymmetry of information is small. In addition, the price drop at the announcement of a new equity issue increases with the time since credible information has been disclosed. All in all, they suggest that adverse selection costs influence equity issuances negatively and that mandatorily reported accounting information reduces these costs.

Investors react to different types of information in the equity issuance setting. Korajczyk et al. (1991) find that accounting earnings have a significant effect on the market's reaction to the issuance of new equity. This is supported by Denis and Sarin (2001) who find earnings announcements from four quarters prior to the offer significantly associated with the market's reaction. Therefore, equity issues tend to follow informative earnings releases. Information of a more discretionary character seems less informative. Loderer and Mauer (1992) find that dividend announcements do not reduce valuation uncertainty. Lin et al. (2008) get similar price reactions, although dividends appear to be associated with volume reactions. Most non-

accounting disclosures are discretionary and firms tend to make more such disclosures prior to issues of new equity (Cooper and Grinder, 1996; Lang and Lundholm, 2000). In summary, the association between disclosure and issuances of new equity supports the adverse selection cost hypothesis, and the association improves with the disclosed information's credibility.

Healy and Palepu (1990) document that firms perform better than usual when they issue new equity; however, after the issue, their profitability decreases (Loughran and Ritter, 1997). Quite the same, IPO firms are more profitable than similar firms already listed (Pagano et al., 1998) and more profitable than they are subsequent to the public listing (Jain and Kini, 1994; Mikkelson et al., 1997). The excess performance around the time of the issue of new equity can be a function of equity market timing, but a number of studies suggest that information disclosures are used opportunistically around the time of the SEO (Rangan, 1998; Shivakumar, 2000), and the IPO (Teoh et al., 1998a; Teoh et al., 1998b; Roosenboom et al., 2003). Although accounting information is informative and reduces adverse selection costs surrounding issuances of equity, it is still manipulable. Other type of announcements, such as information about major investments, product launches, and collaborations, are even more discretionary. When tests of the adverse selection cost hypothesis are based on discretionary information, it is impossible to avoid biases from manipulated information and thus mispricing issues.

Studying firms in the biotechnology sector is particularly interesting given the problems highlighted above. Biotechnology firms are in early life-cycle stages, and, with their future performance being considerably uncertain, the adverse selection cost problems are likely to be substantial. Because biotechnology firms tend to be unprofitable and are unable to capitalize their investments as assets, accounting information is less value-relevant (Amir and Lev, 1996; Dedman et al., 2008; McConomy and Xu, 2004). However, regulatory authorities have to assess biotechnology firms' investment projects whenever they are in critical stages; therefore, there are mandatory non-discretionary evaluations of the value-creation process. Disclosure of how clinical trials progress is known to impact security prices and volumes (McConomy and Xu, 2004). On the basis of the above-mentioned discussion, we expect the following:

H_2: Biotechnology firms issue new equity to a greater extent after they have released disclosures of R&D

3. Methodology

3.1 Research setting

The study is based on firms operating in the biotechnology industry, as it offers unique opportunities to study the decision to issue new equity. Biotechnology firms invest heavily on a continuous basis, but they can rarely fund these investments internally. Consequently, they regularly turn to the equity market for new capital.

Two issues make the biotechnology setting interesting. First, investors are unable to use accounting information in any meaningful way when assessing the biotechnology firm's future prospects. If a loss is indicative of future performance, then the firm has no value (Hayn, 1995). In this case, investments are expensed immediately and, hence, both the income statement and the balance sheet contain little information useful to forecast future cash flows. Investors are, therefore, fully dependent on other type of information. Second, biotechnology firms differ from other research-intensive firms in the sense that the development process is closely monitored by regulatory authorities with considerable experience of how to evaluate drugs on issues such as efficacy and safety. Biotechnology firms usually cooperates with regulatory authorities in early phases of research as a failure to comply with recommendations might ultimately prolong the development process, inhibit a future drug approval, and even lead to private lawsuits and enforcement actions by agencies such as the Securities and Exchange Commission (SEC). Although accounting information has a low association to the value of biotechnology firms (Dedman et al., 2008; McConomy and Xu, 2004), investors can rely on information that is verified by regulatory authorities acting independently. A candidate drug's progress in clinical trials is a strong signal to investors that the firm creates value (e.g., Amir and Lev, 1996; McConomy and Xu, 2004).

The equity announcement

Because biotech firms invest substantial amounts in research projects and tend to have few projects with positive operating cash flows, they need to issue new equity on a regular basis. From an economic perspective, the main motive for issuing new equity is that projects with a positive net present value exist and need to be funded. Therefore, when future investment cash flows cannot be covered by existing funds, the firm seeks external funding to sustain its survival.[4] A negative aspect of issuing new equity is that pre-issue shareholders have to split

[4] There might be other options available for the biotech firm. One option is to cancel, or delay, investments. A considerable portion of the biotech firm's resources consist of human capital, and while a temporary reduction of

the value of future cash flows with others. Pre-issue shareholders lose rights to future cash flows unless they subscribe for their part of the new issue.

If a new issue of equity is used to finance previously unconsidered operating activities, the market's reactions to the new issue of equity can be positive. However, if the capital is used to finance ongoing activities, there may be a share price decline following the announcement of a new issue. Although we make no distinction between different forms of equity issuances in the empirical study, we acknowledge that there are some notable differences between them. Eckbo and Masulis (1992) extend the Myers and Majluf (1984) model to explain the adverse selection problem by issuers with access to alternative flotation methods, such as pure(uninsured) rights, standby rights and firm-commitment underwritten offerings.

3.2 Research design

R&D disclosures prior to seasoned equity offerings in this study refer to managers' mandatory disclosures[5]. Let v_i represent public information and managers' private information regarding the effects of equity issues on the value of firm i, then:

$$v_i = u_i + \eta_i \tag{1}$$

where u_i represents the public's prior expectation of v_i, and η_i is the managers' private information, which outside investors cannot obtain or predict via publicly available information. Managers are assumed to maximize the interests of existing shareholders and only issue equity when $v_i \geq 0$. Accordingly, when $\eta_i \geq - u_i$, the managers will choose to issue equity and when $\eta_i < - u_i$, the managers will decide not to issue equity. Managers' private information is assumed to be independently and normally distributed with mean zero and variance σ^2. Although managers' private information, η_i, is unobservable, at the time an equity issue is publicly announced, outside investors recognize both managers' incentives and

personnel expenses reduces overall costs, it is in reality difficult not to make it a permanent reduction. From a strategic point of view, it might be undesirable and an absolute last resort. Another option is to sell valuable resources, should there be any, to another biotech firm. This alternative has two drawbacks; resources are often difficult to disentangle, and, if so, they often carry a lower value when disentangled. In addition, the choice to sell assets only exists if there is excess cash in the biotech industry and this tends to be positively correlated with market sentiments. In other words, it might be just as difficult to sell assets as it is to issue new equity. A final option is to enter a partnership with another firm on a candidate drug and thereby achieve an upfront cash payment.

[5] Publicly-listed firms are subject to certain requirements about trading rules and regulations. Following general disclosure rules, firms have an obligation to disclose all information material to stock prices as soon as news comes into possession. For small biotechnology firms, all results that relate to clinical projects are considered as price-sensitive information. For a review of disclosure issues for biotechnology and pharmaceutical firms, see Fisher (2002).

the preference of equity-selling mechanism[6]. In the additional tests section, we will refer back to this model when we examine the association between R&D disclosures and the stock market reaction at the equity issue announcement, using the conditional event study methodology, and control for expectations.

To estimate the probability of equity issues requires issuing and non-issuing observations. Our sample of issuing firms is constructed from the Thomson Reuters Datastream database by identifying changes in the number of shares outstanding for the sample firms. We use corporate websites, annual reports and the Factiva database to identify equity issue announcement dates and equity issue data. Firms can issue new shares (i.e., primary shares), or they can sell existing shares held by insiders or stockholders (i.e., secondary shares). We only consider SEOs in which the firm received cash because only the issuance of primary shares leads to a capital inflow to the firm, which can be used to finance investments. We exclude IPOs because we have no historical stock market data. The sample firms primary raise funds to finance existing and new drug development projects. We exclude issues that are made to finance acquisitions of other companies.

Table 1. Descriptive statistics – Equity issues by year

	Sample of equity issues		Sample of no equity issues	
Year	*n*	*Fraction (%)*	*n*	*Fraction (%)*
1998	3	1.2	6	1.5
1999	4	1.6	13	3.3
2000	9	3.6	11	2.8
2001	6	2.4	28	7.1
2002	4	1.6	25	6.3
2003	9	3.6	27	6.8
2004	13	5.2	26	6.5
2005	21	8.4	21	5.3
2006	31	12.4	16	4.0
2007	27	10.8	37	9.3
2008	16	6.4	56	14.1
2009	34	13.6	29	7.3
2010	33	13.2	42	10.6
2011	18	7.2	46	11.6
2012	22	8.8	14	3.5
Total	250	100%	397	100%

Notes: This table contains the number of equity issues and the fraction of equity issues per year for the issuing and non-issuing sample of firms.

[6] In this study, we make no distinction between different type of equity-selling mechanisms.

Following Guo and Mech (2000), the sample of non-issuing firms is built using a random number generator (without replacement) to randomly select 400 security-days from the sample of firms from 1998 to 2012. We restrict the non-issuing sample and exclude observations for which there was an equity issue in the subsequent 150 trading days. Three observations are deleted due to incomplete data. The final sample contains 250 observations for issuing firms and 397 observations for non-issuing firms. In the probit model, issuing observations take the value 1, whereas non-issuing observations take the value 0. Table 1 displays the distribution of the number of equity issues per year and the fraction of equity issues for the sample of issuing and non-issuing firms.

3.3 Research model

We use a probit regression model and differentiate between issuing and non-issuing firms. We expect both mispricing (*pre-abnormal return* and *post-abnormal return*) and adverse selection costs (*R&D news*) to have incremental effects beyond those of *survival time*. This is consistent with the view of DeAngelo et al. (2010), who find that the primary motive for firms to issue equity is to meet a short-term need for cash[7].

We employ the following model:

$$\begin{aligned} Prob(Equity\ issue_i) \\ = \alpha + \beta_1 Survival\ time_i + \beta_2 Pre\_abnormal\ return_i \\ + \beta_3 Post\_abnormal\ return_i + \beta_4 R\&D\ news_i + Controls + \eta i \end{aligned} \quad (2)$$

Survival time

Financial distress has a well-known effect on capital structure decisions (Miller and Modigliani, 1966), and analyses of the decision to issue equity often employ the level of debt as a proxy of it (e.g., Mackie-Mason, 1990). Biotechnology firms tend not to hold debt, but given that their cash flows are almost always negative (large continuous investments and little revenue) costs associated with financial distress are captured using the firm's expected "survival time"; the time that the firm can sustain its operations without seeking additional financing or cutting back on its research activities (Lerner et al., 2003).

Following Lerner et al. (2003) *survival time* is measured for each quarter as the firm's beginning-of-period cash balance scaled by net income. Net income is used as a proxy for

[7] DeAngelo et al. (2010) find that 63 percent of issures would run out of cash and 81 percent would operate on subnormal cash levels without the offer proceeds.

cash flows because biotechnology firms tend to expense most investments immediately and, in addition, these firms rarely gain revenue from continuous operations. In the regression models, we use the inverse of the firms' survival time. There is no association between positive earnings and survival time (i.e., when earnings are positive, the survival time is infinite); therefore, the measure is set to zero for profitable firms (Lerner et al., 2003). In summary, because shorter survival time increases the probability of encountering financial distress costs, we expect the probability of issuing new equity to decrease with survival time.

Mispricing

The mispricing hypothesis suggests that managers can predict stock returns more precisely than investors can. Since biotechnology firms expense most of their investments immediately, the market-to-book ratio to be likely to be a biased measure of mispricing.[8] Instead, we use historic and realized future abnormal stock returns as indicators of mispricing[9] (Baker and Wurgler, 2007; DeAngelo et al., 2010). Our use of realized future stock abnormal returns as a proxy for managers' expectations of the firm's share price performance is similar to Spiess and Affleck-Graves (1995), Baker et al. (2003), Huang and Ritter (2009), and DeAngelo et al. (2010). For each firm in the sample, we use the following measures:

Absolute firm stock return: the dividend- and split-adjusted stock return in the 6 months (120 trading days) before and after the equity issue announcement date.

Index stock return: the equal-weighted dividend- and split-adjusted stock return of all other biotechnology firms (included in the sample) in the 6 months before and after the equity issue announcement date.

Abnormal stock return: the difference between the absolute and index stock returns. We assume unsystematic risk is similar across the industry (DeAngelo et al., 2010).

In the empirical analysis, we test for differences in abnormal stock returns between our sample of issuing and non-issuing firms. We expect the prior (future) stock abnormal return to be positively (negatively) associated with the probability that a firm conducts an SEO.

[8] Indeed, all measures involving accounting information are likely to suffer from biases.

[9] Our sample of issuing and non-issuing observations are predominantly made by growth-stage firms. Carlson et al. (2006) argue that the stock price run-up prior to the seasoned equity offering (SEO) is a reflection of an increase in the value of growth options, with a subsequent need for capital to exercise them and the exercise explains the negative returns post the SEO.

Adverse selection costs

We expect the issue of new equity to be positively associated with announcements of the progress of the biotechnology firm's candidate drugs in clinical trial. Credible announcements of the status of research projects reduce adverse selection costs, and, as a result, managers make use of investors' better understanding of the firm's prospects and issue equity shortly after public news announcements about their R&D projects.

Our main variable for measuring adverse selection costs, *R&D news*, is a dummy variable taking the value 1 if a disclosure of R&D is made in days t_{-40} to t_0 preceding the equity issue announcement date, otherwise 0. We also distinguish between positive and negative news announcements. Both provide information to investors that reduces adverse selection costs, but their propensity to do so, as well as their association to other variables might differ. Although negative news announcements do not carry a subsequent capital requirement, they generally have a significant negative share price reaction. Dittmar and Thakor (2007) argue that firms will issue equity when stock prices are high, but only if a high stock price coincides with low adverse selection. Consequently, we expect to see firms to issue equity only following positive R&D news[10][11]. We make no distinction between R&D disclosures that relate to separate phases in the drug development[12]. We also include the variable *R&D* $news_{day}$, which represents the number of days between a R&D disclosure and an issue announcement. We use the inverse of the number of days between the R&D disclosure and the equity issue announcement. This variable is used in the additional tests section.

Control variables

To ensure that results are not driven by omitted correlated variables, we include a number of control variables. Table 2 provides variable definitions control variables as well as experimental variables.

[10] In this study, no equity issues for issuing firms are preceded by a negative R&D news announcement, whereas 22 equity issues for the non- issuing firms are preceded by negative R&D news announcements.

[11] Often, a larger firm is less dependent on individual news announcements; therefore, the control variable *firm size* also reduces scaling problems associated with news announcements.

[12] Although the information asymmetry may vary between R&D announcements across firms and also concering R&D announcements for different projects within the same firm, we argue that the disclosure of R&D information convey a strong signal as the average firm only have around 3-4 clinical projects in different clinical phases and each phase takes between 1 to 4 years to complete.

Table 2. Variable definitions

Variable	Definition/description
Survival time	The cash balance (including marketable securities) scaled by net income from the preceding quarterly report. The inverse of the survival time is used in the regressions.
Pre-firm return	The firm return over the 6 months (120 trading days) preceding the equity issue announcement date.
Pre-index return	The equal-weighted dividend- and split-adjusted stock return of all other biotechnology firms (included in the sample) over the 6 months preceding the equity issue announcement date.
Pre-abnormal return	The difference between the pre-firm return and the pre-index return.
Post-firm return	The firm return over the 24 months after the equity issue announcement date.
Post-index return	The equal-weighted dividend- and split-adjusted stock return of all other biotechnology firms (included in the sample) over the 24 months after the equity issue announcement date.
Post-abnormal return	The difference between post-firm return and the post-index return
R&D news	Dummy taking the value 1 if a disclosure of R&D is made in days t_{-40} to t_0 preceding the equity issue announcement date. Otherwise 0.
R&D $news_{day}$	The number of days between a R&D disclosure and an issue announcement
Bid-ask spread	The mean daily bid-ask spread over a six-month period preceding the equity issue announcement date.
Stock return volatility	The standard deviation of daily stock returns over a six-month period prior to the equity issue.
MTB	The market value of equity divided by book value of equity for the quarter closest in time, but prior to the SEO. Values greater are truncated at 15, i.e. values that are greater than 15 are set equal to 15.
Firm age	Number of years since the firm was incorporated.
Public firm age	Number of years since the firm went public.
Firm size	The log of the average market value of equity over a six-month period prior to the equity issue announcement date.
Region dummy	Regions classified according to La Porta et al. (1998): Anglo-Saxon, Germanic, French and Scandinavian legal origins. Anglo-Saxon legal system is used as the reference.

Notes: This table provides variable definitions of experimental and control variables.

Most shareholders are outsiders and rely on public information alone. They have to rely on information given to them by management and on insider owners acting in the interest of all shareholders. The extent to which the biotech firm has been publicly listed and thus upholds a track record is likely to be an indicator of how well investors know the firm. We measure this as the number of months that the firm has been publicly listed (*public firm age*). A firm's size (*firm size*) and market-to-book ratio (*MTB*) are used to control for several concerns, including risk and growth opportunities. We also include region dummies to control for potential differences across institutional settings (La Porta et al., 1998). The four region dummies are: Anglo-Saxon, Germanic, French and Scandinavian legal origins. We use the Anglo-Saxon legal system as the reference.

The Pearson correlation matrix for the dependent and independent variables is presented in Table 3. We note, in particular, that the equity issue decision is positively associated with *survival time*, *pre-firm return*, *pre-index return*, *pre-abnormal return*, *R&D news*, *firm age* and *public firm age*, and negatively associated with *post-abnormal return* and *firm size*. As expected, the two variables *pre-firm return* and *pre-index return* are highly correlated with *pre-abnormal return*. However, these variables are not included in the same multivariate regressions. None of the other bivariate correlations between independent variables exceeds a value of 0.31.

3.4 Interaction effects

We also examine interaction effects between *survival time*, *pre-abnormal return*, *post-abnormal return*, and *R&D news*. In contrast to interaction effects in linear models, the interaction effect in non-linear models is conditional on the independent variables (e.g. Ai and Norton, 2003; Powers, 2005). We follow the methodology developed by Norton et al. (2004) to calculate the correct marginal effect of the interaction variables. Norton et al. (2004) show that the interaction effect may have different signs for different values of covariates. Therefore, we display the graphs of the distribution of marginal effects and the associated *z*-statistics over the entire range of predicted probabilities.

3.5 Conditional event study

In the additional tests section, we examine the association between pre-issue disclosures of R&D information and the stock market reaction at equity issue announcements. We employ the conditional event-study methodology (Acharya, 1988), but allow the variance of the managers' private information to vary across firms (Guo and Mech, 2000). By incorporating investor's expectations, the cumulative abnormal return (CAR_i), can be expressed as:

$$E(CAR_i|Equity\ issue) = E(v_i|\eta_i \geq -u_i) = u_i + E(v_i|v_i \geq -u_i) = u_i + \sigma\frac{n(Z_i)}{N(Z_i)} \qquad (3)$$

where $Z_i = u_i/\sigma$, and $n(Z_i)$ and $N(Z_i)$ represent the standard normal density and distribution functions, respectively. We employ a two-stage procedure, as suggested by Acharya (1988) and Prabhala (1997). In the first stage, we estimate $n(Z_i)/N(Z_i)$. We employ the probit regression model (see equation 2) to estimate $N(Z_i)$ and calculate $n(Z_i)$ from this estimate. In the second stage, we incorporate $n(Z_i)/N(Z_i)$ in the regression model to control for investor's expectations.

Table 3. Pearson correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Equity issue															
2. Survival time	0.213*** (0.000)														
3. Pre-firm return	0.183*** (0.000)	-0.021 (0.635)													
4. Pre-index return	0.176*** (0.000)	-0.005 (0.912)	0.347*** (0.000)												
5. Pre-abnormal return	0.151*** (0.000)	-0.033 (0.446)	0.980*** (0.000)	0.266*** (0.000)											
6. Post-firm return	-0.108** (0.011)	-0.013 (0.793)	0.046 (0.287)	-0.146*** (0.001)	0.061 (0.160)										
7. Post-index return	-0.029 (0.501)	0.021 (0.664)	0.080* (0.067)	-0.125*** (0.003)	0.081* (0.063)	0.387*** (0.000)									
8. Post-abnormal return	-0.112*** (0.009)	-0.012 (0.799)	0.029 (0.505)	-0.161*** (0.000)	0.045 (0.298)	0.982*** (0.000)	0.280*** (0.000)								
9. R&D news	0.238*** (0.000)	0.103** (0.024)	0.083* (0.053)	0.001 (0.980)	0.088** (0.040)	-0.054 (0.240)	0.019 (0.678)	-0.089 (0.201)							
10. Bid-ask spread	0.031 (0.443)	0.002 (0.958)	0.030 (0.468)	-0.024 (0.546)	0.022 (0.593)	-0.057 (0.186)	0.050 (0.252)	-0.080* (0.064)	0.066 (0.125)						
11. Stock return volatility	0.052 (0.187)	0.075* (0.085)	0.180*** (0.000)	-0.197*** (0.000)	0.209*** (0.000)	0.240*** (0.000)	0.159*** (0.000)	0.240*** (0.000)	0.029 (0.488)	0.006 (0.882)					
12. MTB	0.121*** (0.003)	-0.037 (0.423)	0.026 (0.530)	0.055 (0.182)	0.009 (0.824)	-0.180*** (0.000)	-0.190*** (0.000)	-0.173*** (0.000)	0.005 (0.903)	0.152*** (0.000)	-0.108*** (0.008)				
13. Firm age	0.095** (0.015)	0.008 (0.853)	-0.017 (0.664)	-0.011 (0.786)	-0.019 (0.632)	-0.027 (0.519)	0.009 (0.826)	-0.040 (0.343)	0.087** (0.039)	-0.049 (0.222)	-0.058 (0.139)	-0.031 (0.452)			
14. Public firm age	0.151*** (0.000)	0.057 (0.188)	0.064 (0.112)	-0.003 (0.949)	0.048 (0.232)	-0.032 (0.447)	-0.048 (0.259)	-0.046 (0.277)	0.093** (0.028)	-0.080** (0.046)	-0.070* (0.074)	0.115*** (0.005)	0.543*** (0.000)		
15. Firm size	-0.101*** (0.010)	-0.121*** (0.005)	0.083** (0.039)	0.077* (0.050)	0.072* (0.070)	-0.238*** (0.000)	-0.185*** (0.000)	-0.242*** (0.000)	0.070* (0.096)	0.275*** (0.000)	-0.371*** (0.000)	0.371*** (0.000)	0.150*** (0.000)	0.177*** (0.000)	

Notes: This table shows pair-wise correlations for the experimental and control variables in the regression equations. The variables are described in Table 2. The numbers listed horizontally across the top row correspond to the numbers and variables listed vertically on the table. *, **, and *** denote the pair-wise correlations are significantly different from zero at the 10%, 5%, and 1% levels, respectively. *p*-values are in brackets.

We use the event study methodology (Brown and Warner, 1985; Campbell et al., 1997) to compute the cumulative abnormal returns around the time of the issue announcement. Predicted returns are calculated using the market model with a value weighted market index (MSCI Europe) over an estimation period of 221 days (t-$_{250}$ to t-$_{30}$, where t is the equity issue announcement date). We use an event window of three days, which includes the day of the announcement as well as the day before and after. We use the following model:

$$CAR_i = \alpha + \beta_1 R\&D\ news_i + \beta_1 R\&D\ news_{day,i} + Controls + \sigma \frac{n(Z_i)}{N(Z_i)} + \varepsilon_i \qquad (4)$$

R&D news is a dummy variable taking the value 1 if a disclosure of R&D is made in days t_{-40} to t_0 preceding the equity issue announcement date, otherwise 0. The $R\&D\ news_{day}$ variable measures the number of days between the equity issue announcement and the R&D announcement. In the regression models, we use the inverse of the number of days between the equity issue announcement and the disclosure of R&D. The term $n(Z_i)/N(Z_i)$ is the Heckman's (1979) inverse Mills' ratio. The control variables are described in Table 2.

3.6 R&D announcements

This study employs a hand-collected dataset of R&D announcements made by 87 publicly listed biotechnology firms between 1998 and 2012. In total, these firms have made 561 public announcements on clinical trial results. These announcements are classified on a good news-bad news ranking as suggested by Guo et al. (2004). The details of this classification are discussed in McConomy and Xu (2004). There are some discretionary elements in the disclosure of news announcements concerning, in particular, research projects in their early stages. Before initiation, regulatory authorities approve the design of a study, including primary and secondary endpoints, but they often do not scrutinize the clinical results before the biotechnology firm initiates the next phase. Opportunistic interpretations of results would, however, lead to serious discontent from both investors and regulatory authorities.

Table 4 reports the distribution of positive and negative R&D announcements related to different stages. There are more news announcements concerning phase II projects than there are concerning phase I projects (and more news announcements concerning phase I projects than pre-clinical projects). Positive news announcements are more common than negative

news announcements. Failure rates are the highest, at 35%, for phase III projects [35 / (66+35)], but the overall failure rate is 70%.[13]

Table 4. Description and classification of R&D announcements

Announcement category	*Phase*	*Number of announcements*
Results (positive)	Pre-clinical	56
Results (negative)		15
Results (positive)	Phase I	123
Results (negative)		36
Results (positive)	Phase II	175
Results (negative)		55
Results (positive)	Phase III	66
Results (negative)		35
Total		561

Note: This table reports different types of announcements related to different phases (or stages) of the R&D process.

For the sample of issuing and non-issuing firms, we use the data set of R&D announcements and construct the adverse selection costs variable, *R&D news*, which is a dummy variable taking the value 1 if a disclosure of R&D is made in days t_{-40} to t_0 preceding the equity issue announcement date, otherwise 0. We also include the variable $R\&D\ news_{day}$, which represents the (inverse) number of days between a R&D disclosure and an issue announcement.

4. Empirical results

4.1 Market timing of new equity issues

Mean-comparison test of the adverse selection cost hypothesis

Table 5 presents mean-comparison tests regarding R&D news announcements prior to the issue of new equity for issuing and non-issuing firms. *R&D news*, is a dummy variable taking the value 1 if a disclosure of R&D is made in days t_{-40} to t_0 preceding the equity issue announcement date, otherwise 0. In this study, no equity issues for issuing firms are preceded by a negative R&D news announcement, whereas 22 equity issues for the non- issuing firms are preceded by negative R&D news announcements. For robustness reasons, we include the category "*All R&D news announcements*", which include both positive and negative R&D news announcements. Although both provide information to investors that reduce adverse selection costs, negative news announcements are generally associated with a significant negative share price reaction. Dittmar and Thakor (2007) argue that firms will issue equity

[13] Not tabulated. [15/(56+15)]* [36/(123+36)]* [55/(175+55)]* [35/(66+35)] = 0.303

when stock prices are high, but only if a high stock price coincides with low adverse selection. In the probit regressions, we display results only of those with positive R&D news announcements[14].

Table 5. R&D Announcements prior to the issue of equity

		40 trading days before issue		30 days before issue	
	Number	*Mean*	*Difference*	*Mean*	*Difference*
All R&D news announcements					
Issuers of equity	253	0.3123	**0.1351*****	0.2951	**0.1429*****
Non-issuers of equity	311	0.1771	(0.000)	0.1522	(0.000)
Positive R&D news announcements					
Issuers of equity	253	0.3123	**0.1932*****	0.2951	**0.1842*****
Non-issuers of equity	311	0.1190	(0.000)	0.1109	(0.000)

Notes: R&D news is a dummy variable that equals one if a R&D news announcement occurs within the 40 (30) trading days prior to the equity issue announcement date and zero otherwise. All R&D news announcements include positive and negative news. Reported p-values are the results of *t* test used to examine if there is a significant difference in the mean of the two samples (sample of issuers of equity and sample of non-issuers of equity). Significance assessed using Games-Howell test, which does not assume balance samples or equality of variance. ***, **, and *, denote two-tail 1%, 5% and 10% significance, respectively.

We test for differences between issuers (253 observations) and non-issuers (311 observations). Mean-comparison tests between issuers and non-issuers in Table 5 displays that the R&D news announcement is statistically significant ($p < 0.01$) for both measures. For robustness reasons, we also examine whether the results are consistent for a shorter time period (30 days prior to the equity issue announcement) or a time period of 60 days (untabulated results). The different time windows generate similar results, although the statistical power is weaker for longer time periods. The data suggests that biotechnology firms issue equity following the disclosure of R&D news announcements[15]. The results are consistent with other studies using accounting information (e.g. Lin et al., 2008) and provide support for the adverse selection cost hypothesis of equity market timing.

Mean-comparison test of the mispricing hypothesis

The mispricing version of equity market timing is tested using two measures of mispricing; historic and realized future abnormal stock returns. We expect the prior (future) stock abnormal return to be positively (negatively) associated with the probability that a firm

[14] We also perform regressions using all R&D news announcements. The results are similar to that of positive R&D news announcements.

[15] In general, positive announcements implicitly lead to higher capital requirement in order to initiate the next phase, i.e., firms need to make substantial investments to continue with their drug development. This does, however, not always hold if the project is partnered with another firm (often a pharmaceutical firm), which is responsible for the development costs. We do at this stage not for control for this.

conducts an SEO. Table 6 tabulates a mean-comparison analysis of market sentiments around the issue of equity using different time windows. The means for the 249 issuing and 379 non-issuing firms are reported separately and *t*-statistics for differences across these groups are presented.[16] Panel A, B, and C report stock market returns over three different time periods prior to and after the equity issue announcement; 6, 12 and 24 months, respectively.

In panel A of Table 6, issuers of equity have a higher absolute stock return prior to an equity issue than non-issuing firms. This is consistent with Asquith and Mullins (1986), Masulis and Korwar (1986), Lucas and McDonald (1990) and Guo and Mech (2000), who show that firms tend to issue equity following large stock price run-ups. The result is robust to an event window of 12 months (Panel B), but becomes statistically insignificant for 24 months (panel C). Prior index returns are positive and statistically significant across all time periods preceding the equity issue announcement. Turning over to prior abnormal returns, issuing firms tend to have experienced high abnormal stock returns over the most recent 6-month period (0.1511, $p < 0.000$, panel A), and the relation is even stronger when we extend the time period to 12 months (0.1917, $p < 0.000$, panel B). However, prior abnormal return becomes insignificant ($p > 0.10$) when extending the time period to 24 months (panel C). Post abnormal returns are negative across all three time periods, but only statistically significant for the 12-month ($p < 0.10$) and 24-month window ($p < 0.01$). One potential reason why the shorter window do not generate statistically significant results may be due to the timing of new equity issues occurs in the beginning or the middle of a financing window. Although this analysis indicates that the mispricing measure is sensitive to the length of the selected time period, our results from the mean- are largely consistent with Baker et al. (2003), Baker and Wurgler (2007), DeAngelo et al. (2010) and other studies.

[16] The reason for the sample size of issuing and non-issuing rims differ across Panel A, B, and, C in Table 6 is due to lack of historical data when the event window is expanded from 6 months in Panel A to 24 months in Panel C. Therefore, the abnormal stock return cannot be calculated. For the same reason, in the multiple regressions in Table 6, there are slightly fewer observations in those quarters when *post-abnormal return* is used as an explanatory variable. These differences in sample size have no material effects on the empirical results. To have a representative sample, we use samples that are as large as possible.

Table 6. Market sentiments around the issue of equity

Panel A. Market sentiments 6 months before and after the equity issue announcement

		6 months before issue		6 months after issue	
	Number	*Mean*	*Difference*	*Mean*	*Difference*
Absolute firm stock return					
Issuers of equity	249	0.1803	**0.1925*****	0.0033	**0.0022**
Non-issuers of equity	379	-0.0122	(0.000)	0.0010	(0.956)
Equal-weight index return					
Issuers of equity	253	0.0578	**0.0589*****	0.0155	**0.0334****
Non-issuers of equity	399	-0.0011	(0.000)	-0.0179	(0.011)
Abnormal stock return					
Issuers of equity	249	0.1414	**0.1511*****	-0.0218	**-0.0248**
Non-issuers of equity	379	-0.0097	(0.000)	0.0029	(0.521)

Panel B. Market sentiments 12 months before and after the equity issue announcement

		12 months before issue		12 months after issue	
	Number	*Mean*	*Difference*	*Mean*	*Difference*
Absolute firm stock return					
Issuers of equity	241	0.2981	**0.2427*****	0.0013	**-0.0827**
Non-issuers of equity	357	0.0554	(0.002)	0.0840	(0.203)
Equal-weight index return					
Issuers of equity	253	0.0932	**0.0770*****	0.0388	**0.0491*****
Non-issuers of equity	399	0.0161	(0.000)	-0.0103	(0.008)
Abnormal stock return					
Issuers of equity	241	0.2387	**0.1917*****	-0.0322	**-0.1037***
Non-issuers of equity	357	0.0470	(0.009)	0.0715	(0.097)

Panel C. Market sentiments 24 months before and after the equity issue announcement

		24 months before issue		24 months after issue	
	Number	*Mean*	*Difference*	*Mean*	*Difference*
Absolute firm stock return					
Issuers of equity	224	0.3556	**0.0561**	-0.0145	**-0.2737*****
Non-issuers of equity	314	0.2995	(0.678)	0.2592	(0.008)
Equal-weight index return					
Issuers of equity	253	0.1280	**0.0595****	0.0137	**-0.0192**
Non-issuers of equity	399	0.0685	(0.023)	0.0329	(0.506)
Abnormal stock return					
Issuers of equity	224	0.2564	**-0.0317**	-0.0282	**-0.2545*****
Non-issuers of equity	314	0.2881	(0.809)	0.2263	(0.009)

Notes: This table reports mean-comparison test results of market sentiments before and after the issue of equity. We use three measures (a) absolute firm stock return, (b) equal-weight index return, and, (c) abnormal stock return. We measure the stock returns in three ways (a) as the dividend- and split-adjusted stock return of the firm prior to/ after the issue of new equity (b) as the dividend- and split-adjusted stock return of all other biotechnology firms (included in our sample) prior to/ after the issue of new equity (c) as the difference (which

we call pre- and post-abnormal return) between the dividend- and split-adjusted stock return of the prior to/ after the issue of new equity and the dividend- and split-adjusted stock return of all other biotechnology firms (included in our sample) prior to/ after the issue of new equity. Panel A, B, and C, report market sentiments across different time periods prior to/after the equity issue announcement: 6 months (Panel A), 12 months (Panel B), and, 24 months (Panel C). Similar to DeAngelo et al (2010), we do not risk-adjust for firm-specific risk. Similar to prior studies (e.g. Baker et al, 2003; DeAngelo et al., 2010), pre- and post-abnormal stock return refer to our measure of mispricing. Reported p-values are the results of *t* test used to examine if there is a significant difference in the mean of the two samples (sample of issuers of equity and sample of non-issuers of equity). Significance assessed using Games-Howell test, which does not assume balance samples or equality of variance. ***, **, and *, denote two-tail 1%, 5% and 10% significance, respectively.

4.2 Determinants of the decision to issue new equity

In this section, we examine whether the probability that biotechnology firms issue new equity is positively related to the survival time and the market-timing measures, mispricing and adverse selection costs. Similar to Loughran and Ritter (1995, 1997), Baker et al. (2003), Huang and Ritter (2009), DeAngelo et al. (2010), mispricing is measured using stock returns (*pre-abnormal return* and *post-abnormal return*). Conversely, we follow Korajczyk et al. (1991), Guo and Mech (2000) and Lin et al. (2008) to study the probability of equity issues to adverse selection costs. However, R&D announcements (*R&D news*) are used, rather than earnings and dividend announcements, as our proxy for adverse selection. Market timing is expected to have incremental effects beyond those of *survival time*.

Table 7. Sample statistics

	Sample of equity issues				Sample of no equity issues				*t*-Statistic for the difference in mean
	n	Mean	Median	Stdev	n	Mean	Median	Stdev	
Survival time	213	0.456	0.39	0.342	318	0.124	0.13	0.928	5.83***
Pre-firm return	249	0.180	0.08	0.569	379	-0.012	-0.08	0.447	4.50***
Pre-index return	253	0.058	0.07	0.152	399	-0.001	0.01	0.166	4.65***
Pre-abnormal return	249	0.141	0.02	0.554	379	-0.010	-0.06	0.433	3.64***
Post-firm return	214	-0.014	-0.35	1.119	342	0.259	-0.10	1.289	-2.64***
Post-index return	214	0.014	-0.06	0.336	342	0.034	-0.02	0.321	-0.67
Post-abnormal return	214	-0.028	-0.32	1.081	342	0.226	-0.06	1.250	-2.64***
R&D news	253	0.312	0	0.464	311	0.119	0	0.324	5.60***
Bid-ask spread	251	0.247	0.08	1.339	381	0.191	0.10	0.358	0.64
Stock return volatility	253	0.037	0.03	0.019	399	0.035	0.03	0.016	1.28
MTB	219	5.161	3.39	4.586	381	4.114	2.85	3.847	2.85***
Firm age	253	11.743	11.00	6.195	399	10.637	10.00	5.295	2.35**
Public firm age	251	5.840	5.19	3.541	399	4.750	4.09	3.424	3.87***
Firm size	253	1.977	2.00	0.603	399	2.086	2.09	0.469	-2.45**

Notes: This table provides sample statistics for 250 issuing and 397 non-issuing observations included in the probit regression. The variables are described in Table 2. *, **, and *** denote the pair-wise correlations are significantly different from zero at the 10%, 5%, and 1% levels, respectively

Table 7 shows sample statistics for issuing and non-issuing firms including the experimental and control variables. The variables are described in Table 2. The average survival time is 7 months[17] for issuing firms, which means that firms can sustain operations for less than one year before the cash balance falls to zero. In comparison, non-issuing firms have an average survival time of 25 months. Mean-comparison tests of the experimental variables are the same as in section 4.1. With regard to the control variables, *MTB*, *firm age*, *public firm age* and *firm size* are all statistically significant. *MTB* is positive and statistically significant ($p < 0.01$). The mean public firm age is 6 years, indicating that biotechnology firms tend to be quite young. *Firm age* and *public firm* age are both positive and statistically significant ($p < 0.01$), which implies that older firms are more likely to issue equity than younger firms. In the probit regression, we include only the *public firm age* variable. The *firm size* variable is negative and statistically significant ($p < 0.05$), which indicates that smaller firms are more likely seek external financing. The stock return volatility variable is statistically insignificant ($p > 0.10$). We exclude the stock return volatility control variable from the regression models due to correlation with several of the experimental variables (see Table 3).

Table 8 presents the results from the probit regressions. We control for *bid-ask spread*, *public firm age* and *firm size*. In untabulated regressions we also control for growth opportunities using market-to-book (*MTB*) as a control variable, but exclude it from the above regression due to a reduction in sample size due to missing data. A discussion of the *MTB* variable is presented after the below section, which shows the main results.

The coefficient of *survival time* is positive and significant at the 1% level in all models, indicating that biotechnology firms are more likely to issue equity when they have a near-term need of cash. The marginal effect indicates that an increase of one unit in survival time increases the probability of an equity issue by between 79-109%. This is consistent with DeAngelo et al. (2010). Across most of the models, the intercept is negative and statistically significant, which implies that the probability of an equity issue is low when all explanatory variables take values close to zero. In models 2-4, we evaluate the mispricing hypothesis (H1), which states that biotechnology firms prior (future) abnormal stock return is positively (negatively) related to the probability of issuing new equity.

[17] Survival time (*survival time*) is computed as the inverse of the ratio of the sum of the company's cash and short-term investments at the end of the previous quarter divided by the absolute value of the net income in the previous firm quarter. A survival time of 0.456 is then equal to 2.2 firm quarters, or 6.6 firm months.

Table 8. Market timing when issuing new equity

Panel A. Probit regression results	Predicted Sign	(1)	(2)	(3)	(4)	(5)	(6)
Intercept		-0.846 (-2.80)	-0.856 (-2.69)	-1.085 (-3.14)	-1.031 (-2.85)	-0.464 (-1.34)	-0.712 (-1.70)
Survival time	+	2.152 [0.814]*** (7.85)	2.265 [0.858]*** (8.11)	2.714 [1.016]*** (7.71]	2.732 [1.025]*** (7.58)	2.002 [0.791]*** (6.86)	2.736 [1.086]*** (7.01)
Pre-abnormal return	+		0.496 [0.188]*** (3.94)		0.356 [0.134]*** (2.69)		0.278 [0.110]* (1.89)
Post-abnormal return	-			-0.154 [-0.058]* (-1.75)	-0.169 [-0.063]* (-1.85)		-0.156 [-0.062]* (-1.67)
R&D news	+					0.678 [0.265]*** (4.44)	0.447 [0.177]** (2.49)
Bid-ask spread	-	0.113 [0.043] (1.11)	0.080 [0.030] (0.73)	0.062 [0.023] (0.59)	0.042 [0.016] (0.40)	0.125 [0.049] (1.19)	0.052 [0.021] (0.49)
Public firm age		0.057 [0.022]*** (3.05)	0.054 [0.021]** (2.86)	0.094 [0.035]*** (4.09)	0.089 [0.033]*** (3.78)	0.068 [0.027]*** (3.48)	0.101 [0.040]*** (4.17)
Firm size		-0.084 [-0.032] (-0.65)	-0.102 [-0.039] (-0.77)	-0.191 [-0.072] (-1.23)	-0.222 [-0.083] (-1.40)	-0.285 [-0.113]* (-1.95)	-0.408 [-0.162] (-2.21)
Dummies for regions		Yes	Yes	Yes	Yes	Yes	Yes
Number of observations		529	520	437	428	478	386
χ^2-statistic (*p*-value)		92.55*** (0.000)	106.38*** (0.000)	83.45*** (0.000)	84.28*** (0.000)	109.61*** (0.000)	94.04*** (0.000)
Pseudo R^2		0.190	0.205	0.239	0.242	0.228	0.271
Panel B. Interaction effects							
Mean interaction effect for *Survival time * R&D news*							-0,173 (-0.28)
Mean interaction effect for *Survival time * Pre-abnormal return*							0,251 (1.03)
Mean interaction effect for *Pre-abnormal return * R&D news*							-0,191** (-2.21)

Notes: This table provides the estimates from the probit regressions (Panel A). The sample consists of 253 seasoned equity offerings (SEOs) of publicly listed European biotechnology firms during 1998-2012. The dependent variable equals 1 for issuing firms and 0 for non-issuing firms. The sample of non-issuing firms is constructed using a random number generator (without replacement) following Guo and Mech (2000). The variables are described in Table 2. *Survival time* is computed as the inverse of the ratio of the sum of the company's cash and short-term investments at the end of the previous quarter divided by the absolute value of the net income in the previous firm quarter. Firms that are profitable, or operate on a breakeven basis, are considered to have an infinite survival time, and hence, the inverse is zero. Similar to prior studies (e.g. Baker et al, 2003; DeAngelo et al., 2010), *pre-* and *post-abnormal stock return* refer to our measure of mispricing. *Pre-firm return* denotes the dividend- and split-adjusted stock return of the firm during the 6 months (120 trading days) prior to an equity issue announcement. *Pre-index return* denotes the dividend- and split-adjusted stock return of all other biotechnology firms (included in our sample) during the 6 months prior to the issue of new

equity. *Pre-abnormal return* is the difference between the *pre-firm return* and the *pre-index return*. *Post-firm return* denotes the dividend- and split-adjusted stock return of the firm during the 24 months (240 trading days) after an equity issue announcement. *Post-index return* denotes the dividend- and split-adjusted stock return of all other biotechnology firms (included in our sample) during the 24 months after the issue of new equity. *Post-abnormal return* is the difference between the *post-firm return* and the *post-index return*. *R&D news* is the measure related to adverse selection cost. *R&D news* is a dummy taking the value 1 if a disclosure of R&D is made in the 40 trading days preceding the equity issue announcement date, zero otherwise. *Bid-ask spread*, *public firm age* and *firm size* are control variables. We include region dummies as defined by La Porta et al (1998), which equal one if the firm is of French-, German-, or Scandinavian origin, otherwise zero (English-origin). In untabulated regressions we include MTB as a control, but exclude the variable from the above regression due to a reduction in sample size due to missing data. Inclusion/exclusion of MTB does not alter the overall results. We report coefficient estimates, marginal effects (within angle brackets), and, *z*-statistics for marginal effects (within brackets). All regressions contain robust standard errors. ***, **, and *, denote two-tail 1%, 5% and 10% significance, respectively. Panel B reports interaction effects using the methodology suggested by Norton et al. (2004). The mean interaction effect is reported with corresponding *z*-statistic within brackets.

In model 2, the firm's prior abnormal stock return (*pre-abnormal return*) is positively and statistically significant (*z*-statistic = 3.94), which indicates that biotechnology firms tend to time equity issues following positive abnormal stock returns. In model 3, the coefficient of *post-abnormal return* is negative and statistically significant at 10 percent level (*z*-statistic = -1.75). This indicates that biotechnology firms perform significantly worse relative to the market in general in the time period after the equity issue. A comparison of model (2) and (3) to model (1) shows that both *pre-abnormal return* and *post-abnormal return* provide incremental explanatory power on a stand-alone basis as the pseudo R^2 increases from 0.190 to 0.205 (model 2) and to 0.239 (model 3). Although the number of observations is reduced in model 3 and model 4, due to missing data for the post-abnormal return variable, the results are still robust. In summary, these findings lend support for the mispricing hypothesis (H1).

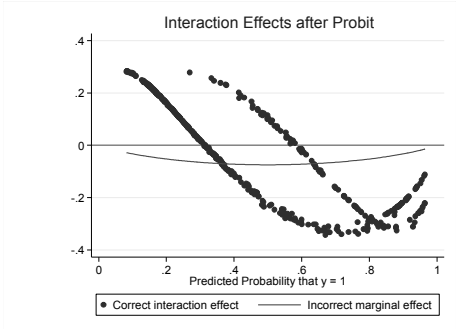
In models 5 and 6, we find support for the adverse selection costs hypothesis (H2) that managers are more likely to issue equity when asymmetric information (or adverse selection costs) is relatively low. In model 5, the coefficient of R&D news announcements (*R&D news*) is positive and statistically significant (*z*-statistic = 4.44). The marginal effect indicates that an increase of one unit in R&D news, i.e. going from the case when the discrete dummy variable R&D news = 0 to the case when R&D news = 1, increases the probability of an equity issue by 27%. A comparison between model (5) and model (1) shows that R&D news announcements provide incremental explanatory power (pseudo R^2 increases from 0.190 to 0.228). The results are robust (*z*-statistic = 2.63) when we include all R&D news announcements (positive and negative) as displayed in Table 5.

Carlson et al. (2006) argue that the stock price run-up prior to the seasoned equity offering (SEO) is a reflection of an increase in the value of growth options, with a subsequent need for capital to exercise them and the exercise explains the negative returns in the period after the

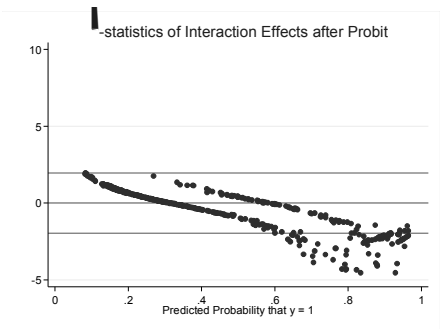
SEO. This suggests that the MTB variable may be intertwined with the pre- and/or post-abnormal return measure. In untabulated tests, we include the *MTB* variable in the probit regressions, as the sample statistics in Table 7 indicate that there is a statistically significant difference between issuing- and non-issuing firms. The *MTB* variable is statistically significant, but become insignificant when including the survival time variable in model 1, although Table 3 indicate there is no association between the two variables. The *MTB* variable remain insignificant when adding *pre-abnormal return*, but becomes significant by the additon of *post-abnormal return* (Table 3 indicate that the two variables are correlated). It is important to note that the main variables (*survival time*, *pre-abnormal return*, *post-abnormal return*, and, *R&D news*) are all robust and inclusion or exclusion of the *MTB* variable do not change the results.

Next, we examine interaction effects between *survival time*, *pre-abnormal return*) and, *R&D news*. Unlike the interaction effect in linear models, the interaction effect in non-linear models is conditional on the independent variables (Ai and Norton, 2003; Norton et al., 2004; Powers, 2005), and therefore, both the magnitude and statistical significance of the interaction term can vary across observations. We employ the methodology developed by Norton et al. (2004) to calculate the correct marginal effect of the interaction variables. Panel B of Table 8 reports both the mean interaction effects and corresponding z-statistics for the interaction variables. Although both *survival time* and *R&D news* are highly statistically significant (1% level), the mean interaction effect is not statistically significant (-0.173, *z*-statistics = -0.28). The interaction variables between *survival time* and *pre-abnormal return* is also statistically significant (0.251, *z*-statistics = 1.03). In contrast, the interaction variables between *pre-abnormal return* and *R&D news* (-0.191, *z*-statistics = -2.21) are statistically significant. Although *pre-abnormal return* and *R&D news* are likely to be intertwined (positive R&D news often lead to higher stock returns), the correlation between the variables in Table 3 indicates a value of only 0.088.

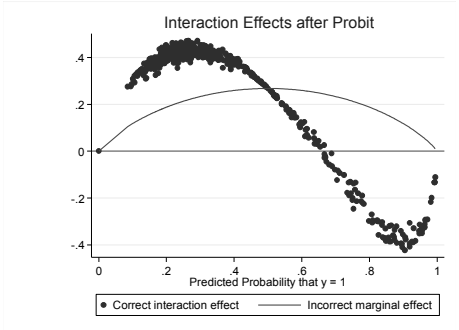
Figure 1. Interaction effects



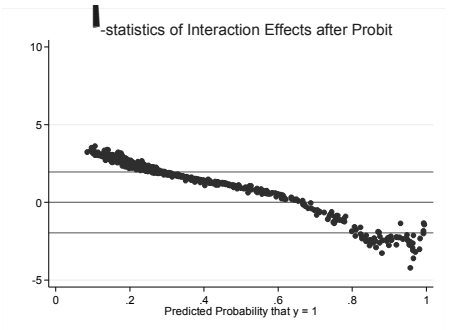
a. Survival time * R&D news



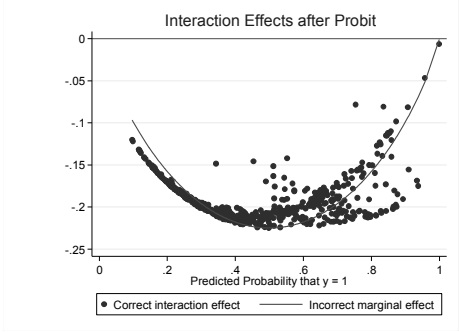
b. Survival time * R&D news



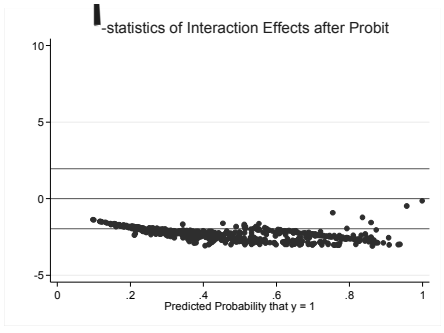
c. Survival time * Pre-abnormal return



d. Survival time * Pre-abnormal return



e. Pre-abnormal return * R&D news



f. Pre-abnormal return * R&D news

Notes: The following graphs display the interaction effects and corresponding z-statistics on the interaction variable reported in Table 8, estimated using Norton et al. (2004). The pairs of interaction variables include *survival time* and *R&D news* (graphs a and b), *survival time* and *pre-abnormal return* (graphs c and d), and, *pre-abnormal return* and *R&D news* (graphs e and f) reported in Table 8. The lines above and below 0 on the figures located on the right side represent the 5% significance levels (±1.96).

However, the interaction effect may have different signs for different values of covariates (Norton et al., 2004). Figure 1 displays the graphs of the distribution of marginal effects and the associated *z*-statistics over the entire range of predicted probabilities for our main models.

In Figure 1a and 1b, for firms with a predicted probability of issuing equity is around 0.2, the interaction effect between *survival time* and *R&D news* is largely positive, although statistically insignificant. If we look at the right hand side of Figure 1a, where the predicted probability is above 0.8, the interaction effect is largely negative and statistically significant for most observations. The main effects imply that firms that have are running out of cash (the *survival time* variable is close to one) and disclose positive R&D news are likely to issue new equity. Although the interaction term between *survival time* and *pre-abnormal return* is statistically insignificant, the right hand side of Figure 1c and 1d shows that when the predicted probability is between above 0.8, the interaction effect is largely negative and statistically significant for most observations. In Figure 1e and 1f, the interaction effect is negative and statistically significant across most observations.

5. Additional tests

In this section, we examine the association between pre-issue disclosures of R&D information and the stock market reaction at equity issue announcements. Korajczyk et al. (1991 and 1992) suggest the degree of asymmetric information is time-varying and that immediately following an information release, the information asymmetry between corporate insiders and outsiders are small. However, the information asymmetry increases over time, as corporate insiders receive private signals. Therefore, firms have incentives to issue new equity when the information asymmetry is small. Past empirical studies have examined if different types of pre-issue disclosures can reduce the price drop at equity announcements[18]. Korajczyk et al. (1991 and 1992) find that earnings disclosures prior to equity issues are able to reduce the

[18] Past studies have primarily used rights offerings and/or public offerings assuming a negative stock price reaction to issue announcements. For example, Korajczyk et al. (1991) use a sample of seasoned underwritten primary and secondary equity issue by US industrial firms for the period 1978-1983. Loderer and Mauer (1992) use a sample of primary offerings of seasoned common stock by US industrial firms, whereas Lin et al. (2008) use a sample of seasoned equity offerings of firms listed on the Taiwan Stock Exchange. To our knowledge, this study is the first that evaluates if pre-issue information disclosures have different effect on market reactions to differenct type of issuance methods. We evaluate the association between R&D disclosures and equity issue announcements of rights offerings and private placements, rather than evaluating if pre-issue disclosures can reduce the price-drop at equity issue announcements, as our descriptive statistics show that the two issuance methodes on average lead to different price reactions. In addition, not all rights offerings result in negative price reactions; 15 of 77 rights offerings in our sample result in a positive CAR (over a three-day period).

price drop at equity issue announcements and that the price reaction is positively associated with the time interval since the earnings disclosure. In contrast, Loderer and Mauer (1992) find that dividend disclosures are unable to reduce the price drop at the equity issue announcement. Similarly, Lin et al. (2008) find that pre-issue disclosures of major investments, financial forecast revisions and dividends are unable to reduce the price drop at announcements of rights offerings.

To examine if R&D disclosures are associated with the CAR at the equity issue announcement, we employ the conditional event-study methodology (Acharya, 1988). Before we present cross-sectional regression results, we display descriptive statistics of the distribution of cumulative abnormal returns (CARs) and distinguish between rights offerings and private placements.

5.1 Distribution of CARs for rights offerings and private placements

Table 9, panel A, presents distribution of CARs for rights offerings and private placements, respectively, sorted on different ranges. This panel displays that 80.5 of rights offerings and 56.9 percent of private placements results in a negative returns over a three-day event window. The table also shows that 58.5 and 75 percent of rights offerings and private placements, respectively, have CARs in the range of -5 to +5 percent. In an unreported graph, we plot the CARs against their frequency and find that the sample is slightly skewed to the left of zero[19].

5.2 Stock market reaction to equity issue announcements

Panel B of Table 9 reports abnormal returns and cumulative abnormal returns around equity issue announcements for rights offerings and private placements. The stock market reaction to rights offerings is negative and statistically significant. The mean abnormal return at the day of the equity issue announcement is -4.6 percent (t-statistic -6.35) for rights offerings and the seven-day cumulative abnormal return (the three days before and after the equity issue announcement) is -2.96 percent (t-statistic -14.46). This is consistent with prior studies that document negative to insignificant to positive reactions to rights offerings (see Eckbo and Masulis (1995) for a review of previous research). Contrary to rights offerings, the stock market reaction to private placements at the day of the announcement is positive, although not

[19] We perform the non parametric Wilcoxon signed rank test, which takes both the sign and magnitude of each equity issues CAR into account. We reject the null hypothesis of zero CAR with a *z*-value of 4.784. We use the logarithmic value of CAR (plus a constant) in the cross-sectional regressions.

Table 9. Stock market reaction to equity issue annoucements

Panel A. Distribution of CARs: Rights offerings and private placements

	Rights offerings		*Private placements*	
Magnitude	*n*	*Fraction (%)*	*n*	*Fraction (%)*
CAR ≤ -15.0%	1	1.3	4	2.3
-15.0% < CAR < -10.0%	8	10.4	4	2.3
-10.0% ≤ CAR < -5.0%	22	28.6	16	9.3
-5.0% ≤ CAR < -0.0%	31	40.3	74	43.0
0.0% ≤ CAR < 5.0%	14	18.2	55	32.0
5.0% ≤ CAR < 10.0%	1	1.3	9	5.2
10.0% ≤ CAR < 15.0%	0	0.0	5	2.9
15.0% ≤ CAR	0	0.0	5	2.9
Total	77	100	172	100

Notes: This table provides distribution of cumulative abnormal returns (CARs) for rights offerings and private placements.

Panel B. Abnormal returns around issue announcements

	Rights offerings		*Private placements*	
Day	*AR (%)*	*CAR (%)*	*AR (%)*	*CAR (%)*
-3	-0.708* (-1.67)	-0.708* (-1.67)	-0.389 (-1.53)	-0.389 (-1.53)
-2	0.425 (1.14)	-0.200 (-0.70)	0.123 (0.39)	-0.188 (-0.92)
-1	-0.534 (-1.34)	-0.472** (-2.03)	-0.035 (-0.11)	-0.174 (-1.01)
0	-4.601*** (-6.35)	-2.709*** (-9.94)	0.416 (0.58)	0.058 (0.26)
1	-1.989*** (-3.14)	-3.313*** (-13.14)	-0.452 (-0.99)	-0.151 (-0.76)
2	-0.290 (-0.61)	-3.143*** (-13.94)	0.021 (0.09)	-0.129 (-0.76)
3	-0.134 (-0.31)	-2.964*** (-14.46)	0.399 (1.35)	0.032 (0.21)

Notes: This table provides abnormal returns (AR) and cumulative abnormal returns (CARs) around issue announcements for rights offerings and private placements. *t*-statistics are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

statistically significant. This is consistent with several prior studies (e.g. Wruck, 1989; Hertzel and Smith, 1993; Janney and Folta, 2003)[20].

[20] Janney and Folta (2003) document a positive and significant stock market reaction to private placements for a sample of US biotechnology firms between 1973 and 1998.

Next we examine the association between pre-issue disclosures of R&D and the CAR at the equity issue announcement. We employ the conditional event-study methodology (Acharya, 1988), but allow the variance of the managers' private information to vary across firms (Guo and Mech, 2000). We first run the probit regression on equation (1) and include the *R&D news*$_{day}$ variable as well to estimate the standard normal distribution function, N(Zi), and then calculate the standard normal density function, n(Zi), from this estimate. In the second stage regression, we then include the term n(Zi)/N(Zi), known as the Heckman's (1979) inverse Mills' ratio, to control for investors' expectations[21] and to correct for the selection bias problem[22] related to managers' equity issue decisions (Lin et al., 2008). In addition, the non-discretionary nature of disclosures in the biotechnology industry overcomes the common criticism of endogenous event in the event study literature (Schultz, 2003; Viswanathan and Wei, 2008). Regression results of the effects of R&D disclosures on CAR around issue announcements are reported in Table 10. If the coefficient on the variable *R&D news* is positive and statistically significant, it implies that R&D disclosures are associated with the stock price reaction at equity issue announcements. We also examine if the price reaction is dependent on the time interval between the R&D disclosure and the equity issue announcement. We use the inverse of the number of days between the equity issue announcement and the disclosure of R&D. Hence, we expect to see a positive association between the inverse of the interval between the R&D disclosures and the market reaction to equity issue announcements.

In model 2 of Table 10, the coefficient of the dummy variable *R&D news* is statistically insignificant, which indicates that R&D disclosures are not associated with the stock market reaction at equity issue announcement. Consistent with these results, the interval variable, *R&D news*$_{day}$, is also insignificant (see model 3 of Table 10). The issue type variable, which takes a value of one for rights offerings and zero for private placements, is negative and statistically significant ($p < 0.05$). This verifies the findings in Table 5 that rights offerings are associated with a negative stock market reaction. In untabulated regressions for private placements and rights offerings, separately, the R&D news variable remains statistically insignificant.

[21] By not controlling for investors' expectation (known as «truncated residuals»), in traditional event studies using OLS and GLS methods could induce inconsitent and inefficient estimation (Eckbo et al., 1990).
[22] Since R&D disclosures generally are mandatory in the biotechnology industry, we do not believe the self-selection problem is a major issue in this setting.

Table 10. Regression results of the effects of R&D disclosures on CAR around issue announcements

	(1)	(2)	(3)	(4)
Constant	1.090 (0.000)	1.088 (0.000)	1.089 (0.000)	1.089 (0.000)
Panel A. Variables related to R&D disclosures				
R&D news		0.001 (0.823)		0.000 (0.984)
R&D news, day			0.008 (0.334)	0.008 (0.368)
Panel B. Controls				
Bid-ask spread	0.003 (0.124)	0.003 (0.128)	0.003 (0.111)	0.003 (0.132)
Stock return volatility	0.072 (0.534)	0.075 (0.521)	0.072 (0.539)	0.072 (0.539)
Firm age	0.000 (0.914)	0.000 (0.805)	0.000 (0.883)	0.000 (0.879)
Firm size	0.000 (0.890)	0.000 (0.969)	0.000 (0.957)	0.000 (0.968)
Survival time	-0.001 (0.947)	0.001 (0.923)	0.001 (0.945)	0.001 (0.940)
Momentum	0.014 (0.370)	0.015 (0.334)	0.015 (0.332)	0.015 (0.336)
Market liquidity	-0.003 (0.361)	-0.003 (0.384)	-0.003 (0.368)	-0.003 (0.377)
Blockholder	0.010 (0.123)	0.010 (0.125)	0.010 (0.123)	0.010 (0.123)
Δ Blockholder	0.001 (0.116)	0.001 (0.111)	0.001 (0.119)	0.001 (0.118)
Rights offering	-0.008** (0.040)	-0.008** (0.048)	-0.008** (0.038)	-0.008* (0.051)
$n(Z_i) / N(Z_i)$	0.007 (0.375)	0.009 (0.349)	0.008 (0.314)	0.008 (0.366)
Dummies for regions	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Number of observations	203	203	203	203
Adj R^2	0.138	0.138	0.139	0.139
F-value	3.08	2.87	2.90	2.71
(p-value)	(0.000)	(0.000)	(0.000)	(0.001)

Notes: This table provides the estimates from the linear regressions. The original sample consists of 80 rights offering and 246 private placements made by publicly listed European biotechnology firms during 1998-2012. Due to missing data for several control variables, the data set is reduced to 203 observations. The dependent variable is the cumulative average abnormal (CAR) return estimated using a two-factor model (t_{-250} to t_{-21}) and measured over a 3-day event window (t_{-1} to t_{+1}). The two-factor model, as suggested by Sharpe et al. (2009) when using single industry data, comprise of two factors, of which one is the MSCI Europe index and the second factor is the equal-weighted dividend- and split-adjusted stock return of all other biotechnology firms (included in the sample) over the 6 months preceding the equity issue announcement date. The independent variables are

defined in Table 2. All regressions contain robust standard errors using the Huber-White sandwich estimators. *p*-values are displayed in parentheses. *, **, and *** denote the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively.

Although R&D disclosures are helpful for investors to anticipate equity issues, we do not find support that they are associated with the stock market reaction at the equity issue announcement. This finding is consistent with Guo and Mech (2000), Lin et al. (2008), Loderer and Mauer (1992) and Siougle (2007). Siougle (2007) examines the association of disclosures of indended uses of the SEO proceeds and the stock returns subsequent to the SEO and suggests that the insignificance of pre-issue disclosures to explain stock returns following an SEO is consistent with efficient pricing of this information by the underwriters.

6. Conclusions

When biotechnology firms publicly announce the progress of research projects, investors know these results is the outcome of a well-defined research plan set up by the firm in collaboration with regulatory authorities. Therefore, the mandatory disclosure contains both reliable and value-relevant information. Past studies of market timing in relation to disclosures of accounting information can be biased given the discretionary nature of accounting information. In comparison with previous studies on the mispricing theory and particularly those on the adverse selection cost theory, our measures are essentially unaffected by managerial discretion.

The empirical study is based on 87 biotechnology firms listed across Europe in the years 1998 through 2012. In total, these firms made 250 issues of new equity and 561 publicly disclosed announcements about the progress of their research projects. We find support for both the adverse selection cost theory and the mispricing hypothesis. They are significant explanatory factors on a stand-alone basis, and, notably, they provide incremental explanatory power beyond that of survival time. As the market mispricing hypothesis assume, managers can predict stock returns more accurately than investors can. New equity is issued to a considerably greater extent following positive abnormal stock returns. We also find that biotechnology firms on average generate negative abnormal returns after the equity issue announcement, although the mispricing measure is sensitive to the length of the selected time period prior to and after the equity issue announcement.

The adverse selection cost theory suggests that rational managers decide to issue new equity when there is relatively little asymmetric information between shareholders and management. We find that R&D news announcements are positively associated with issues of new equity. Although R&D news announcements are helpful to investors to anticipate equity issues our results indicate that R&D disclosures are not associated with the stock market reaction at issue announcements. It needs to be mentioned that, overall, a firm's survival time is the best indicator of a new equity issue and equity market timing theories are secondary considerations. On average, firms that issue new equity can sustain their ongoing operations less than a year.

The biotechnology industry is, arguably, different from other industries in the sense that firms usually operate with large negative free cash flows and have no other choice but to regularly ask investors for (equity) financing of their research projects. From an investor perspective, there is considerable asymmetric information and, given the inherent risk of the industry, a search for credible signals of a biotechnology firm's prospects seems to be a clear-cut requirement before buying into an issue of new shares. Although an investor's search for credible signals is particularly important in this setting, we are convinced that it is not unique to the biotechnology industry. In other words, our findings lend support for studying market timing not only from the point of view that managers want to capitalize on mispricing, but also from the point of view that they rationally go to equity markets when there is a chance that investors will understand the firm's prospects better. In the last decade, a vast amount of empirical support has been given to the idea that market timing is about opportunistic managers trying to capitalize on moments when markets are mispriced. The adverse selection cost theory seems to be an important factor to be considered when understanding firms' decisions to finance their ventures.

While the study is made on the basis of non-accounting information, the implications are likely to also cover the disclosure of accounting information. Although accounting information is discretionary it is, overall, one of the best indicators of firm performance. For many firms, it makes sense to issue new equity subsequent of the disclosure of e.g. a quarterly report, when the time-varying level of asymmetric information is comparatively low. Such behaviors are likely to be evidence of accounting information's relevance, and not necessarily provoked earnings management.

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III

Information asymmetry, R&D disclosures and the choice of equity-selling mechanisms

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Abstract

This study examines the impact of information asymmetry and corporate management monitoring on the choice among different mechanisms for selling equity. More specifically, I study the link between R&D disclosures and other measures of information asymmetry, in addition to ownership measures and firms' choices among various types of rights offerings and private placements. Using a hand-collected sample of mandatory and non-discretionary R&D disclosures from publically listed biotechnology firms, I find that firms tend to issue equity publicly rather than privately following credible R&D disclosures, i.e., when information asymmetry is low. By contrast, I find no support for the monitoring hypothesis. A detailed analysis by investor type confirms that monitoring does not seem to be an important determinant in the choice between private and public financing.

JEL-classification: G32
Keywords: Adverse selection; Equity financing; R&D disclosures; Seasoned equity offerings (SEOs); Rights offerings; Private placements; Monitoring

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1. Introduction

When corporate managers decide to raise capital externally by selling equity to finance new investment opportunities, they also must decide which type of equity-selling mechanism to employ: private or public financing[1,2]. Lerner (1994) shows that venture-backed private firms go public when equity valuations are high and employ private financing when equity valuations are lower. For public firms, two main theories have evolved that explain the rationale behind the choice of equity-selling mechanisms: the information asymmetry hypothesis and the monitoring hypothesis. The monitoring hypothesis suggests that private placements—which are associated with more concentrated ownership that can more effectively monitor management—are used when there is a perceived need for such monitoring (e.g., Shleifer and Vishny, 1986). According to the information asymmetry hypothesis, the degree of asymmetric information about firm value affects the choice of equity-selling mechanism (e.g., Hertzel and Smith, 1993). Eckbo and Masulis (1992) show that when the degree of asymmetric information about firm value is high, i.e., when the expected current shareholder take-up is expected to be low, firms may choose more costly standby rights offerings instead of pure uninsured equity rights offerings. However, the degree of asymmetric information is not fixed over time. The time-varying asymmetric information model by Korajczyk et al. (1991, 1992) suggests that few managers will have received a private signal immediately following a release of relevant information and the adverse selection problem is small. As time passes, the adverse selection problem becomes more severe. Therefore, managers have an incentive to issue equity publicly rather than privately following credible information releases.

This paper examines the impact of information asymmetry and the monitoring of corporate managers on the choice among various types of rights offerings and private placements in the biotechnology industry. I study the biotechnology industry for the following five reasons.

[1] A popular topic in the academic literature is why firms tend to use private placements in which direct costs can be 20 percent or more (Hertzel and Smith, 1993).

[2] The two most commonly used equity issuance methods for stock markets outside the US are rights offerings and private placements. A private placement is a non-public offering in which securities are typically sold to a small number of chosen private institutional investors (e.g., banks, insurance companies, pension funds, etc.). In a rights offering (or rights issue), existing shareholders are given the preemptive (preferential) "rights" or option to purchase a certain number of shares (on a pro rata basis) at a fixed price within a specified time. A rights offering can be either uninsured (non-underwritten) or insured (underwritten). There are two variants of insured rights offerings: standby rights and firm-commitment offers. In a standby rights offer, an investment bank guarantees that any unsubscribed rights or shares are taken up. In a firm-commitment offer, the investment bank assumes the risk of selling the shares to the market by buying the issue from the issuer. With the exceptions of Japan and France, firm-commitment underwritten offers have not yet spread outside the U.S. (Eckbo, 2008).

(1) Because of the relative scarcity of public information about firms' R&D activities and the importance of these activities to the operations of biotech firms, I use R&D disclosures as the major proxy for information asymmetry. Biotech firms differ from other research-intensive firms because their development processes are closely monitored by external regulatory authorities that have considerable experience in evaluating drugs with respect to issues such as efficacy and safety. Biotechnology projects must undergo a thorough and well-documented regulatory review process; therefore, there are mandatory non-discretionary evaluations of the value-creation process. Although disclosures of accounting information may be biased due to the discretionary nature of such information, value-relevant R&D disclosures are thus more likely to be a clean test of the information asymmetry hypothesis.

(2) Information asymmetry is particularly evident in R&D-intensive industries such as the high-technology sector (Himmelberg and Petersen, 1994) and particularly the biotechnology industry (Lerner et al., 2003; Hall, 2002). Because of the considerable information asymmetry associated with R&D (Hall and Lerner, 2009), managers generally know considerably more than outsiders about the specifications of products under development, their likelihood of success, the results of product feasibility tests, and marketing prospects (Aboody and Lev, 2000). Hall and Lerner (2009) argue that the marketplace for financing the development of R&D may look like the 'lemons' market, as suggested by Akerlof (1970, 2002). High-quality firms seeking external financing, therefore, have an incentive to reveal their qualities to the market place when such financing is accessible at low cost.

(3) Most biotech firms are in an early life-cycle stage and invest heavily and on a continuous basis in intangible assets such as research and development (R&D), but they can rarely fund these investments internally. Consequently, they depend on external financing and regularly turn to the equity markets for fresh capital.

(4) The industry-specific sample provides an opportunity to use more direct and less noisy proxies of information asymmetry, which increases the power of testing for the presence of information asymmetry.

(5) Because few biotech firms are profitable and investments are mainly in intangible assets, biotech firms cannot use debt financing and instead typically turn to the equity markets. Therefore, a sample of biotech firms enables a study of private versus public equity financing without having to consider alternative sources of external capital.

Past empirical research on the choice that firms have between private and public financing has verified the importance of both ownership control and asymmetric information[3], but the emphasis has been on ownership control. Using a sample of Swedish publicly listed firms over the period from 1986 to 1999, Cronqvist and Nilsson (2004) find that families' corporate control considerations are important determinants of the choice between private placements and rights offerings, i.e., family-controlled firms tend to avoid issuing methods that dilute the benefits of control or subject the firm to more monitoring. Wu (2004) examines the choice between private placements and public offerings using a sample of US high-technology public firms between 1986 and 1997. He finds partial support for the information asymmetry hypothesis by using microstructure variables as proxies for information asymmetry. However, contrary to prior studies (e.g., Wruck, 1989; Kahn and Winton, 1998), Wu finds that private placements do not result in enhanced monitoring of managers. Chen et al. (2010) examine firms' choices between seasoned equity offerings and private investment in public equity offerings and find that information asymmetry and weak operating performance are key determinants in the choice of equity-selling mechanisms. Gomes and Phillips (2012) verify the importance of information asymmetry as a key determinant in the choice of security type (debt, equity or convertibles) in public and private markets and in the choice of the market in which to issue securities.

The empirical data confirm that firms tend to issue equity publicly rather than privately following credible R&D disclosures, which supports the information asymmetry hypothesis. By contrast, I do not find any support for the monitoring hypothesis. A detailed decomposition of monitoring versus non-monitoring investors also supports the view that monitoring is not an important determinant in the decision about whether to issue equity privately or publicly. The main contribution of this paper is to verify the importance of information asymmetry on the choice between rights offerings and private placements and the use of mandatory non-discretionary R&D disclosures as a proxy for information asymmetry. This is the first study to extensively verify the importance of information asymmetry regarding the choice between private and public financing outside the US. This paper adds to the growing literature addressing the choice of equity-selling mechanisms (e.g., Hertzel and Smith, 1993; Cronqvist and Nilsson, 2004; Wu, 2004; Chen et al., 2010; Gomes and Phillips, 2012).

[3] Although firm size and firm age are frequently used as proxies for the level of information asymmetry in the literature, they do not fit well with the time-varying asymmetric information model developed by Korajczyk et al. (1991, 1992).

The remainder of the paper is outlined as follows. Section two provides a theoretical framework, an overview of prior studies and the research hypotheses. Section three discusses methodological issues related to the study. Section four contains the empirical results. Section five provides additional analyses, and section six concludes.

2. Theory and research hypotheses

When a firm without financial slack has an opportunity to accept a positive net present value project that requires equity financing, it faces a dilemma. Management, who is assumed to act in the interests of current shareholders, will choose to issue equity if the net issue benefit is non-negative, that is, when $b - [d + w(k)] \geq 0$, where b is the value of the project, d is the direct flotation cost and $w(k)$ is the expected wealth transfer from old to new investors. If the firms' managers believe the firm's stock is undervalued, issuing equity to outside investors is costly because it dilutes the value of its existing shareholder stock. If the total flotation cost of issuing exceeds the value of the project, the firm will decide not to issue equity and forego an investment opportunity, which Myers and Majluf (1984) refer to as the "underinvestment problem". Myers and Majluf assume that existing shareholders do not participate in the equity issue, i.e., the flotation method implicit in their model is a direct issue to outside investors. The researchers also rule out an informational role for underwriters.

Eckbo and Masulis (1992) extend the Myers and Majluf model to explain the adverse selection problem by issuers with access to alternative flotation methods, such as pure (uninsured) rights, standby rights and firm-commitment underwritten offerings. Eckbo and Masulis (1992) show that an adverse selection cost problem such as that presented by Myers and Majluf (1984) exists when the fraction of the stock issue (k) expected to be taken up by existing shareholders is less than 100 percent. For a given level of current shareholder take-up (below 100 percent), the greater the undervaluation of the firm's shares, the more likely the firm is not to issue equity. Eckbo and Masulis (1992) argue that certification by an underwriter can mitigate the adverse selection problem. Although k is largely beyond managerial control[4], managers are assumed to have better information than the market about k because subscription pre-commitments from existing shareholders give them a good

[4] The value of k is assumed to be an exogenous factor determined by shareholder characteristics, such as wealth constraints, diversification benefits, and benefits from maintaining a shareholder's proportional ownership of the issuer's equity (Bøhren et al, 1997; Eckbo and Masulis, 1992). In addition, investment funds may have rules that forbid ownership exceeding a certain percentage of any given company because of reporting regulations that may become applicable at that level of investment.

approximation of the expected take-up of the issue. If management believes *k* to be high, i.e., if existing shareholders are expected to buy and hold the new shares, a pure (uninsured) rights offer is the lowest-cost flotation method. In the extreme case of $k = 1$[5], current shareholders purchase and hold the entire issue, and there is no wealth transfer to outside investors such that $w(1) = 0$.[6] This is essentially equivalent to having access to an internal source of funds that is not disadvantaged by asymmetric information costs. In this case, both the subscription price[7] and the degree of undervaluation (or mispricing) are irrelevant to shareholders because there is no wealth transfer from current investors (no adverse selection). This implies that adverse selection is low in the pool of uninsured rights, and the market reaction to the announcement is expected to be relatively small (close to zero)[8]. However, if *k* is expected to be less than one, some undervalued firms may find it too costly to issue new equity because of the costs to existing shareholders of selling shares to outsiders at a price below the intrinsic value. Adverse selection effects, and thus *w(k)*, increase as *k* decreases. Hence, low-k issuers are likely to employ a more expensive flotation alternative (standby or firm-commitment) that involves underwriter certification to narrow—but not fully remove—the information asymmetry between the firm and the market as long as the sum of the expected certification benefit and the net project value exceeds the underwriter fee. A negative stock market reaction to rights offerings implies the presence of adverse selection costs. The average market reaction for a sample of US firms to the announcement of standby rights and firm-commitment underwritten is -1.3 and -2.5, respectively (Eckbo, 2008).

Under Myers and Majluf's information asymmetry model for public offerings, the "underinvestment problem" can be avoided if managers are able to convey their private information to the market at no cost. Hertzel and Smith (1993) extend the Myers and Majluf (1984) model to allow for the possibility that private placement investors can assess firm value through their negotiations with management and that private placements confer benefits similar to those suggested for mergers by Myers and Majluf (1984). When *k* is expected to be

[5] Eckbo and Masulis (1992) report average shareholder take-up above 90 percent in pure (uninsured) rights offerings compared to approximately 65 percent for standby rights. Consequently, it is reasonable to assume that $k < 0$ in the majority of rights offerings.

[6] Although there may also be asymmetric information among current shareholders, this study makes no such distinction, i.e., managers act in the interest of current shareholders and only consider wealth transfer effects from current shareholders to outside investors.

[7] Although a deeply discounted rights offering may help ensure the success of an offering, Heinkel and Schwartz (1986) and Loderer and Zimmermann (1988) argue that the subscription price is a signal of firm quality, and that a deep discount conveys negative information to outside investors about the true value of the issue. Managers are therefore reluctant to issue rights with a deep subscription-price discount (Smith, 1977).

[8] If the equity issue announcement discloses the existence of an investment project with a value that is higher than the market anticipates, the stock market reaction may even be positive.

low, in addition to hiring an underwriter (or when no underwriter agrees to underwrite the offering), issuers can attempt to minimize a costly[9] market reaction to SEOs (seasoned equity offerings) by choosing a private placement in which sophisticated investors are given access to proprietary firm information. Therefore, instead of foregoing an investment opportunity and issuing no equity, undervalued firms can choose a private placement over a public issue if this enables existing shareholders to retain a larger fraction of the firm, i.e., when the net present value of the investment opportunity exceeds the total cost of informing private investors about firm value. That is, $b \geq w(k)$ because private placements are assumed to have no direct flotation cost ($d = 0$).

In summary, the public[10] firm's choice between private and public financing may stem from information asymmetry about firm value, which is known as the information asymmetry hypothesis. Another determinant proposed by the theoretical literature is the monitoring hypothesis. The following sections provide details about these two theories.

2.1 The information asymmetry hypothesis

The information asymmetry hypothesis suggests that firms are more likely to choose private placements than public offerings when the degree of asymmetric information about firm value is high (and the expected take-up, k, by existing shareholders is assumed to be low) because private placement investors can learn the true value of the firm at some cost (Chemmanur and Fulghieri, 1999; Hertzel and Smith, 1993). Private placements generally involve fewer investors than do public offerings, which indicates that at a given level of information asymmetry, private placements incur lower information production costs (Wu, 2004). Consequently, firms with high information asymmetry may have strong incentives to issue equity privately instead of publicly to reduce the costs of information production. MacKie-Mason (1990) refers to the "hidden-information view" and shows that information problems appear to influence publicly traded firms' choices between private and public financing. According to the "hidden-information view", firms will seek better-informed investors when the hidden-information advantage is high or when the potential difference in valuations due to hidden-information is high (MacKie-Mason, 1990).

[9] Eckbo (2008) demonstrates that a stock market reaction of -2 percent to SEOs translates into an amount equal to 15 percent of the proceeds of the average issue, which is equivalent to more than three times the direct costs of an issue.

[10] Lerner (1994) shows that venture-backed private firms go public when valuations are high and employ private financing when equity values are lower.

Information asymmetries decrease when new value-relevant information is made public. Korajczyk et al. (1991, 1992) argue that information asymmetry is time varying and that, immediately following an information release, few managers will have received a private signal and the adverse selection problem is therefore small. However, as time passes, the adverse selection problem worsens as more managers receive private signals. Investors react to different types of information in the equity issuance setting. Korajczyk et al. (1991) and Denis and Sarin (2001) find that accounting earnings and earnings announcements, respectively, have a significant effect on the market's reaction to the issuance of new equity. Therefore, equity issues tend to follow informative earnings announcements. Information of a more discretionary character appears to be less informative. Loderer and Mauer (1992) find that dividend announcements do not reduce valuation uncertainty. Lin et al. (2008) document similar price reactions, although dividends appear to be associated with volume reactions. Most non-accounting disclosures are discretionary and firms tend to make more such disclosures prior to new equity issuances (Cooper and Grinder, 1996; Lang and Lundholm, 2000).

2.1.1 Information asymmetry, R&D and disclosures of R&D

Corporate investments in intangible assets create information asymmetries because managers can continually observe changes on an individual asset basis (e.g., a drug's pros and cons)[11], whereas outsiders obtain only highly aggregated information at discrete points of time, i.e., when R&D information is made public. The disclosure of R&D information is important for several reasons. First, R&D projects, such as a new drug under development, are unique to a developing firm. Investors generally derive little or no information about the firm's R&D projects by observing the R&D performance of other drugs. Second, although financial assets are traded in organized markets in which prices are observable and convey direct information about values, there are no organized markets for R&D in which prices are available. Third, because of accounting standards, investments in intangible assets, such as R&D, are generally immediately expensed and less often capitalized[12]. Given the relatively sparse amount of

[11] Even when a drug is tested in randomized and double-blinded clinical trials in which either the clinician, the patient or the company has direct information about the safety and efficacy of the drug being tested compared to a placebo, companies generally run additional pre-clinical activities in parallel from which they generally gain substantial knowledge about the drug.

[12] According to International Accounting Standards (IAS38), research costs should be expensed when they are incurred, and development costs can be capitalized if certain criteria are met. One such criterion is whether it is *probable* that the expected future economic benefits will flow to the entity or not.

public information about firms' R&D activities and the importance of these activities to the operations and profit potential of technology and science-based companies, R&D contributes substantially to information asymmetry between corporate insiders and outside investors (Aboody and Lev, 2000). Consequently, Hall and Lerner (2009) suggest that the marketplace for financing R&D looks like the "lemons" market modeled by Akerlof (1970). According to Akerlof's lemon principle (1970, 2002), high information asymmetry in the private equity market is more likely to attract bad-quality firms. In the model by Chemmanur (1993), high-quality firms have incentives to disclose their qualities to increase their market value, whereas low-quality firms have few reasons to reveal their qualities. This discrepancy in incentives implies an association between information asymmetry and firm quality. Managers of high-quality firms with external financing needs will therefore issue new equity when the market is most informed[13].

Biotech firms differ from other research-intensive firms in the sense that their development processes are typically closely monitored by external regulatory authorities with considerable experience in evaluating drugs with respect to issues such as efficacy and safety. Biotechnology projects must undergo a thorough and well-documented regulatory review process; therefore, there are mandatory non-discretionary evaluations of the value-creation process[14]. Thus, although accounting information has a weak association with the value of biotech firms (Dedman et al., 2008; McConomy and Xu, 2004), investors can rely on information that is verified by regulatory authorities acting independently. A candidate drug's progress in clinical trials is a strong signal to investors that the firm is creating value (e.g., Amir and Lev, 1996). R&D disclosures are generally mandatory, non-discretionary and value-relevant. Thus, in particular, I expect that firms are more likely to use rights offerings instead of private placements following credible R&D disclosures (the main proxy for information asymmetry), i.e., when information asymmetry is low. This leads to the first hypothesis:

H_1: Biotechnology firms use rights offerings to a greater extent after they have released disclosures of R&D.

[13] It is important to note that even if managers currently have no private information, they may prefer to wait to issue equity until investors become better informed.
[14] Biotech firms typically cooperate with regulatory authorities in the drug development process because failure to comply with recommendations may ultimately prolong the development process, inhibit a future drug

2.2 Corporate control – the monitoring hypothesis

Corporate governance problems, i.e., agency problems between managers and shareholders, can play a role in the choice of equity-selling mechanisms. In the R&D setting, two agency cost scenarios may co-exist. First, managers may spend cash on activities that simply benefit them (but not the existing shareholders). Second, risk-averse managers may be reluctant to, or even avoid, investing in uncertain and high-risk R&D projects.

The monitoring hypothesis suggests that private placements are used when there is a demand for monitoring. Private placements generally target a few sophisticated investors, which suggests that they will be associated with more concentrated ownership (Shleifer and Vishny, 1986; Kahn and Winton, 1998). The higher the level of ownership concentration, the easier it is for a small group of shareholders to influence management behavior through their voting power. By contrast, the more diverse the shareholding, the easier it is for management to expropriate current shareholders in favor of their own interests or to use cash inefficiently as the level of influence by non-management shareholders decreases (Mitchell, 1983). Under the monitoring hypothesis (Wruck, 1989), private placement investors are assumed to be active in monitoring management to ensure that the resources of the firm are efficiently used.

The empirical findings on the monitoring hypothesis suggest mixed results. Wruck (1989) proposes an ownership structure hypothesis and finds evidence that both changes in and the level of ownership concentration are important. Positive abnormal returns surrounding private placements were found that were directly related to changes in ownership level when the firms were at a low or a high level of ownership concentration after private placements. An inverse relationship was found for the sample of firms with a moderate level of ownership concentration after the placements. Several studies report a positive stock market reaction to the announcement of private placements (e.g., Wruck, 1989; Hertzel and Smith, 1993; Janney and Folta, 2003). A positive stock market reaction to private placements may reflect the market's belief that the new blockholder will play a positive role in monitoring management (Wruck, 1989). Eckbo (2008) provides an alternative explanation to the positive stock market reaction to private placements. Because finding a private placement investor who is willing to invest in the stock requires a favorable review of the issuing firms' future prospects, successful private placements can be viewed as the outcome of a positive selection process that is consistent with the positive stock market reaction to private placements.

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approval, and even lead to private lawsuits and enforcement actions by agencies such as the Securities and Exchange Commission (SEC).

Cronqvist and Nilsson (2004) find that family controlled firms avoid equity issue methods that dilute benefits or subject them to more monitoring. By contrast, Hertzel and Smith (1993) find that institutional ownership decreases after private placements. This lends no support to the monitoring hypothesis. Barclay et al. (2007) show that private placement investors typically are passive but acquire large blocks of stock. Nor does Wu (2004) find evidence for the monitoring view that private placement investors engage in more monitoring than public offering investors. Wu reports that private placements generally target a few institutional investors and because there are no formal methods for selecting private placement investors, managers' preferences can play a role in choosing them. In summary, if there is a demand for monitoring, I expect the level of ownership held by blockholders to increase after private placements. Thus, the second hypothesis is formulated as follows:

H_2: Biotechnology firms use private placements to a greater extent when the level of blockholder ownership is small.

However, it is important to note that monitoring and adverse selection effects are not mutually exclusive. On the basis of the level of asymmetric information (high vs. low) and ownership concentration (high vs. low), there are four different possible outcomes. To discriminate between the monitoring and information asymmetry hypotheses, I include an interaction variable between the proxies for information asymmetry and ownership concentration.

3. Data and model

3.1 Data

To construct the sample of rights offerings and private placements, I utilize the Thomson Reuters Datastream database over the 1990-2012 period to identify changes in the number of shares outstanding for a sample of European public biotechnology[15] firms. I then impose

[15] In this paper, I use the definition of biotechnology company that is common among industry practitioners: "a firm that engages in the research and development of drugs and was founded after Genentech (1976)". Therefore, companies developing tools, instruments, medical devices or providing technology-based services to other healthcare companies are excluded. Although the difference between pharmaceutical and biotechnology companies has become blurred as pharmaceutical companies have begun developing biologicals in addition to small molecules, the key differences are primarily along several dimensions (firm size, number of projects and sales). Most biotechnology companies generally have few clinical projects (and relatively small firm sizes); in addition, in only a few cases do biotechnology companies have products on the market.

several filters: (1) There must be a change of at least 5 percent of the outstanding common stock of a company[16] (the 5 percent cut-off is a commonly applied standard for significant

Table 1. Descriptive statistics

Panel A. Equity issues by year

	Rights offerings			Private Placements		
Year	*n*	*Fraction (%)*	*Amount raised (USD millions)*	*n*	*Fraction (%)*	*Amount raised (USD millions)*
1995	0	0.0%	0.0	1	0.4%	18.9
1996	2	2.2%	243.0	2	0.8%	110.4
1997	0	0.0%	0.0	0	0.0%	0.0
1998	2	2.2%	25.0	2	0.8%	17.8
1999	3	3.3%	46.9	3	1.3%	25.0
2000	0	0.0%	0.0	12	5.0%	168.9
2001	3	3.3%	69.6	3	1.3%	50.3
2002	3	3.3%	59.2	3	1.3%	18.0
2003	4	4.4%	89.6	6	2.5%	115.8
2004	6	6.6%	186.8	8	3.3%	170.6
2005	8	8.8%	312.8	21	8.8%	344.1
2006	4	4.4%	166.3	48	20.1%	1445.5
2007	7	7.7%	601.4	29	12.1%	849.2
2008	5	5.5%	201.6	19	7.9%	294.2
2009	13	14.3%	667.4	30	12.6%	466.9
2010	14	15.4%	684.0	27	11.3%	507.6
2011	9	9.9%	387.4	9	3.8%	178.2
2012	8	8.8%	198.6	16	6.7%	311.9
Total	86	100%	3939.6	226	100%	5093.2

Notes: This table contains the number of equity issuances, the fraction of the total equity issued in our sample through such mechanism and the total amount raised (in US dollars) per year for rights offerings and private placements.

Panel B. Size of equity issues

		Gross proceeds (USD millions)				**Fraction shares issued (%)**			
	n	Mean	Median	Min	Max	Mean	Median	Min	Max
Rights offerings	86	45.1	27.9	2.9	283.9	31.5	27.8	5.9	87.5
Uninsured	62	38.8	25.5	2.9	283.9	29.9	26.0	9.5	75.0
Underwritten	24	61.8	36.4	5.8	229.1	32.9	28.2	5.9	87.5
Private placements	226	21.4	12.9	0.4	359.2	13.2	9.1	1.0	74.0

Notes: This table shows descriptive statistics of the size of equity issuances.

[16] This filter automatically removes less frequently used financing methods, such as equity credit facilities (e.g., committed equity financing facilities (CEFFs) and standby equity distribution agreements)) and warrants issued pursuant to stock option plans are also excluded. Five convertible bond issuances are excluded because this issuance method is uncommon in Europe. In addition, nine firms report 14 issuances of rights offerings and private placements at the same time. These issuances are excluded because they cannot be assigned to one of the two groups. Of the 226 private placements, 19 are to existing investors only. Of the remaining 207 private placements, 18 are to new investors only, whereas the remaining 189 are to both existing and new shareholders.

shareholdings); and (2) Detailed information about the equity issuance had to be reported on corporate webpages or in the Factiva database, otherwise it was excluded. This collection method results in a final sample of 86 rights offerings and 226 private placements made by 91 firms. These numbers indicate that several companies raised external capital more than once over the sample period. Of the 78 firms that made private placements, 18 firms made one, 17 firms made two, and 43 firms made three or more. Of the 39 firms that made rights offerings, 17 firms made one, nine firms made two, and 13 firms made three or more[17]. Table 1 contains information about the private placements and rights offerings in the sample.

Panel A of Table 1 displays both the number and fraction of total equity issued in our sample by year through the rights offering and private placement mechanisms. The largest fraction of rights offerings occurred in 2009 and 2010. By contrast, private placements experienced a peak in 2006 with 48 (20.1 percent of the total amount issued in our sample via private placements), but there were only nine private placements (3.8 percent) in 2011. Panel B of Table 1 shows the size of equity issuances measured as the gross proceeds and the fraction of shares issued for each equity-selling mechanism. Gross proceeds and share proportions issued from rights offerings are in general larger than for private placements. Mean (median) gross proceeds from rights offerings are $45.1 ($27.9), whereas the corresponding figures for private placements are $21.4 ($12.9). The mean (median) fraction of shares issued in rights offerings is 31.5 (27.8) percent and 13.2 (9.1) percent for private placements.

3.2 Model

My main interest is to identify the determinants that affect the decision to raise equity capital through a rights offering or a private placement. In this section, I discuss the dependent variable (i.e., the equity announcement) and independent variables.

In Section 4, I employ a logit model to test the hypotheses regarding the choice between a rights offering and a private placement. In Section 5, I employ a nested logit model (McFadden, 1978, 1981) because this includes two decision levels. The first-level alternatives are rights offerings versus private placements, and the second-level alternatives are uninsured rights offerings and underwritten (standby) rights offerings.

The main proxies for measuring information asymmetry and monitoring are product-related R&D disclosures and blockholder ownership, respectively. I anticipate R&D disclosures to

[17] The regression models control for both year- and firm-specific effects.

play an important role in a firm's choice between private and public financing; after making R&D disclosures, firms generally pursue rights offerings to a larger extent. I use the following model:

$$Prob(Issue_i) = \alpha + \beta_1 R\&D\ news_i + \beta_2 Blockholder_i + \text{Controls} + \mu_i, \quad (1)$$

where *i* indexes a firm. The dependent variable equals 1 for rights offerings and 0 for private placements. The independent variables are classified into two categories: experimental variables and control variables. The experimental variables measure information asymmetry (*R&D news*) and ownership control (*Blockholder*). The control variables capture issue size and region dummies. Table 2 provides variable definitions.

Table 2. Variable definitions

Variable	Definition/description
R&D news	Dummy taking the value of 1 if a disclosure of R&D is made in days t_{-40} to t_0 preceding the equity issue announcement date; otherwise, the value is 0.
Bid-ask spread	The mean daily bid-ask spread over a six-month period preceding the announcement date of the equity issuance.
Trading volume	The average trading volume divided by the average number of shares outstanding over the previous six months.
Firm age	Number of years since the firm was incorporated.
Public firm age	Number of years since the firm went public.
Firm size	The log of the average market value of equity over a six-month period prior to the announcement date of the equity issuance.
Survival time	The cash balance (including marketable securities) scaled by net income from the preceding quarterly report. The inverse of the survival time is used in the regressions.
Momentum	The value-weighted index return from a broad European index (MSCI Europe) and an industry-specific index (NASDAQ biotechnology index) over the three months preceding the announcement date of the equity issuance.
Market liquidity	Dummy taking the value of 1 if there is an above-average number of IPOs undertaken by biotech firms on the NASDAQ/New York stock exchange in a given year; otherwise, the value is 0.
Blockholder	The sum of institutional and non-institutional ownership at the end of the previous fiscal year.
Issue size	The log value of the equity issuance amount. Each equity issuance is converted to US dollars using the exchange rate on the date of its announcement.
Take-up (*k*)	The fraction of the equity issue acquired by existing shareholders. Take-up is proxied by one minus the fraction of rights sold in the secondary market by assuming that each right issued in a rights offering only is traded once during the subscription period. The procedure for estimating expected take-up is described in Appendix.

Notes: This table provides variable definitions of experimental and control variables.

The Pearson correlation matrix for the independent variables used in the multivariate logit regressions is presented in Table 3. None of the bivariate correlations exceeds a value of 0.51.

Table 3. Pearson correlation matrix

	R&D news	Bid-ask spread	Trading volume	Firm age	Public firm age	Firm size	Survival time	Momentum	Market liquidity	Blockholder	Issue size
R&D news											
Bid-ask spread	0.064 (0.277)										
Trading volume	-0.036 (0.544)	-0.046 (0.436)									
Firm age	0.020 (0.728)	0.012 (0.841)	0.000 (0.997)								
Public firm age	0.012 (0.790)	-0.054 (0.359)	0.050 (0.394)	0.464*** (0.000)							
Firm size	0.120** (0.038)	0.308*** (0.000)	-0.128** (0.025)	0.102* (0.076)	0.204*** (0.000)						
Survival time	-0.034 (0.592)	0.019 (0.764)	-0.151** (0.017)	-0.128** (0.043)	-0.154** (0.015)	-0.368*** (0.000)					
Momentum	0.008 (0.890)	-0.036 (0.540)	-0.051 (0.380)	-0.006 (0.920)	-0.005 (0.936)	0.109 (0.055)	0.023 (0.717)				
Market liquidity	-0.039 (0.504)	0.011 (0.847)	0.092 (0.115)	0.078 (0.173)	0.039 (0.493)	0.146** (0.011)	-0.081 (0.202)	0.121** (0.033)			
Blockholder	0.002 (0.980)	-0.073 (0.230)	-0.239*** (0.000)	-0.243*** (0.000)	-0.151** (0.012)	-0.094 (0.115)	0.286*** (0.000)	0.078 (0.191)	-0.193*** (0.001)		
Issue size	0.300*** (0.000)	0.138** (0.017)	0.111* (0.055)	0.173*** (0.002)	0.096* (0.094)	0.505*** (0.000)	-0.420*** (0.000)	0.003 (0.957)	0.137** (0.016)	-0.222*** (0.000)	

Notes: This table shows pair-wise correlations for the experimental and control variables in the regression equations. The variables are described in Table 2. *, ** and *** denote that the pair-wise correlations are significantly different from zero at the 10%, 5%, and 1% levels, respectively. P-values are in brackets.

3.3 Variables associated with information asymmetry

3.3.1 Information asymmetry and R&D disclosures

Korajczyk et al. (1991, 1992) hypothesize that corporate managers can reduce information asymmetry prior to issuing equity by releasing information before the announcement date. To test the information asymmetry hypothesis, I include an R&D-related variable (R&D) in the analysis. R&D is a dummy variable that equals 1 if an R&D announcement occurs within 40 trading days prior to announcement of the equity issuance and 0 otherwise[18]. R&D news announcements can be either positive (e.g., a drug demonstrates efficacy against a pre-defined endpoint) or negative (e.g., the drug causes severe side effects). Whereas both positive and negative R&D news announcements reduce information asymmetry, negative news announcements do not carry a subsequent capital requirement and generally induce a significant negative share price reaction. Dittmar and Thakor (2007) argue that firms will issue equity when stock prices are high, but only if a high stock price coincides with low adverse selection. In this study, neither private placements nor rights offerings are preceded by negative R&D news announcements.

There are certain discretionary elements in the disclosure of R&D news announcements regarding biotechnology research projects in their early stages, in particular. Before initiation, regulatory authorities approve the design of a study, including primary and secondary endpoints, but they frequently do not scrutinize the clinical results before the biotech firm initiates the next phase. Opportunistic interpretations of results would, however, lead to serious discontent from both investors and regulatory authorities. In addition, R&D disclosures are generally mandatory, non-discretionary and value-relevant (e.g., Cerbioni and Parbonetti, 2007).

3.3.2 Other firm-specific variables associated with information asymmetry

Bid-ask spread

Glosten and Milgrom (1985) document the relationship between bid-ask spreads and information asymmetry by proposing that the larger the information asymmetry, the wider the spread. Bid-ask spread is measured as the mean daily relative bid-ask spread over a six-month period preceding the equity issuance.

[18] In an untabulated test, I verify that expansion of the window to 30 and 60 calendar days does not have a material effect on the inferences. A biotechnology company typically has few clinical research projects, and each project separately takes approximately one to three years to complete, which indicates that major clinical results are typically announced only a few times per year.

Stock return volatility

French and Roll (1986) find that stock return volatility is primarily related to the flow of information to investors, i.e., the higher the quality and quantity of information, the lower the stock return variability. Stock return volatility is measured as the standard deviation of daily stock returns over a six-month period prior to the equity issuance.

Trading volume (liquidity)

Frequently traded stocks tend to have greater information production, whereas less frequently traded stocks typically have more information problems (Diamond and Verrecchia, 1991). I measure trading volume as the average trading volume divided by the average number of shares outstanding over the previous six months.

Firm age and public firm age

Following James and Wier (1990), Krishnaswami et al. (1999) and Wu (2004), I use firm age to measure the potential information asymmetries that a firm faces. I include the log of firm age (number of years since the firm was founded) and public firm age (number of years since the firm went public) as proxies for the level of asymmetric information.

Firm size

Information asymmetry tends to decrease with firm size (e.g., Vermaelen, 1981). Large firms may face less information asymmetry because they tend to be more mature, have established and time-tested disclosure policies and practices, and receive more attention from the market and regulators (Diamond and Verrecchia (1991) and Harris (1994)). Because few biotech firms hold debt capital and investments in R&D are generally not capitalized, I include the average market value of equity over the six-month period prior to the announcement date of the equity issuance as a proxy for the level of information asymmetry (instead of the log of total assets)[19].

Financial distress (Survival time)

Firms in financial distress are generally considered to be suffering from severe information asymmetries, such as a firm that is undergoing debt restructuring (Gilson et al., 1990). Following Lerner et al. (2003), survival time is measured for each quarter as the firm's beginning-of-period cash balance scaled by net income. Net income is used as a proxy for cash flows because biotech firms tend to expense most investments immediately and, in

[19] Larger firms disclose more R&D news and are less dependent on individual news announcements. Therefore, firm size reduces scaling problems associated with news announcements.

addition, these firms rarely gain revenue from continuous operations. In the nested logit models, I use the inverse of the firms' survival time. Because there is no association between positive earnings and survival time (i.e., when earnings are positive, the survival time is infinite), the measure is set to zero for profitable firms (Lerner et al., 2003).

3.3.3 Market specific variables associated with information asymmetry

Business cycle (Momentum)

Choe et al. (1993) show that the volume of equity issuances is higher during periods of economic growth and after periods of a stock market run-up (which is an indication of momentum); these authors propose that firms face less adverse selection at business cycle peaks than at troughs. I measure business cycle (or momentum) as the value-weighted market return from a broad European index (MSCI Europe) and an industry-specific index (NASDAQ biotechnology) over the three months prior to the issuance ending the calendar month before the issue occurs.

Market liquidity

I measure market liquidity as an indicator variable that takes the value of 1 if there are an above-average number of IPOs (scaled by number of listed stocks) made by biotech firms on the NASDAQ/New York stock exchange in a given year, and 0 otherwise.

3.4 Ownership structure variable

Blockholder

Similar to several prior studies (e.g., Wruck, 1989; Wu, 2004), I measure ownership by the blockholder variable, which is defined as the sum of either institutional and/or non-institutional ownership that owns more than 5 percent of the outstanding shares of common stock at the end of the previous fiscal year. Changes in blockholder ownership are defined as the difference between the sum of institutional and non-institutional ownership owning more than 5 percent at the year-end of the previous fiscal year compared to the year-end after the issuance.

3.5 Control variables

I also include three control variables—issue size, take-up and regional dummies. These variables are briefly discussed below.

Issue size

Private placements tend to be smaller in issue size than public offerings[20]. This also holds for the fraction of shares issued. Issue size is measured as the log value of the equity issuance.

Take-up (k)

In the model by Eckbo and Masulis (1992), the adverse selection cost problem exists when the fraction of the stock issue expected to be taken up by existing shareholders (denoted *k*) is less than 100 percent. The procedure for estimating expected take-up is detailed in Appendix.

Region dummies

Market efficiency and the level of shareholder protection are known to vary across institutional settings. To mitigate this problem, I use dummies for the four regions specified by La Porta et al. (1998): Anglo-Saxon, Germanic, French and Scandinavian legal origins. I use the Anglo-Saxon legal system as the reference.

3.5 Interaction effects

I also examine interaction effects between *R&D news* and *blockholder*. Unlike the interaction effect in linear models, the interaction effect in non-linear models is conditional on the independent variables (Ai and Norton, 2003; Norton et al., 2004; Powers, 2005); therefore, both the magnitude and statistical significance of the interaction term can vary across observations. For example, when one continuous variable (*blockholder*) and one dummy variable (*R&D news*) are interacted, the interaction effect is the discrete difference (with respect to *R&D news*) of the single derivative (with respect to *blockholder*). In the probit model, the correct marginal effect of a change in the interaction variable between the *R&D news* dummy variable and *blockholder* is:

$$\frac{\Delta \frac{\partial F(u)}{\partial blockholder}}{\Delta R\&D\ news} = (\beta_1 + \beta_{12}) * f[(\beta_1 + \beta_{12}) * blockholder + \beta_2 + X\beta] - \beta_1 * f(\beta_1 * blockholder + X\beta) \quad (2)$$

[20] The board of directors is typically given authorization by the prior annual shareholders meeting to resolve the directed issuance of new shares with deviation from the existing shareholders' pre-emptive rights. The authorization generally restricts the board of directors to issuing no more than 5 to 10 percent of the outstanding share capital on one or several occasions during the period before the next annual shareholders meeting. A private placement is typically completed over several days or overnight through an accelerated bookbuilding procedure. In rights offerings, the board's resolution to issue new shares is typically subject to approval at an extraordinary shareholders' meeting. It is important to note that this study does not try to explain the relationship between issue proceeds and equity-selling mechanism choices.

where $F(u) = \Pr(Issue)$, which is given in equation (1). Equation (2) demonstrates that the marginal effect of the interaction variable may not be zero even when β_{12} is zero. Consequently, the coefficient of the interaction term may have an incorrect magnitude, standard error or sign relative to the real interaction effect (Lel and Miller, 2008). I employ the methodology developed by Norton et al. (2004) to calculate the correct marginal effect of the interaction variables. Norton et al. (2004) show that the interaction effect may have different signs for different covariate values. Thus, I display the graphs of the distribution of marginal effects and the associated *z*-statistics over the entire range of predicted probabilities.

4. Empirical results

In this section, I present empirical results for tests of the predictions in Section 2. First, I present a univariate analysis of information asymmetry and monitoring in rights offerings and private placements. Next, I present results from the multivariate logit regressions regarding the choice of equity-selling mechanisms.

Table 4. Univariate analysis of information asymmetry and monitoring

	Rights offerings			**Private placements**			**Difference**	
	Mean	*Median*	*Std*	*Mean*	*Median*	*Std*	*Mean*	*Median*
Information asymmetry								
R&D news	0.625	1.000	0.487	0.164	0.000	0.371	0.461***	1.000***
Bid-ask spread	0.386	0.093	2.173	0.183	0.078	0.641	0.203	0.015
Trading volume	3.141	1.851	3.490	3.391	2.298	4.220	0.251	-0.447
Firm age	12.888	12.000	5.168	11.335	11.000	6.356	1.553**	1.000***
Public firm age	6.269	5.244	3.769	5.929	5.293	3.647	0.341	-0.049
Firm size	1.899	1.954	0.629	1.990	1.999	0.617	-0.092	-0.045
Survival time	0.469	0.319	0.340	0.444	0.364	0.344	0.025	-0.045
Momentum	0.056	0.074	0.158	0.078	0.072	0.173	-0,022	0.002
Market liquidity	0.638	1.000	0.484	0.713	1.000	0.454	-0.075	0.000
Ownership structure								
Blockholder	0.313	0.259	0.272	0.268	0.258	0.249	0.044	0.001
Δ Blockholder	-0.035	0.000	0.202	0.198	0.000	1.838	-0.233*	0.000
Others								
Issue size	1.405	1.437	0.461	1.034	1.109	0.519	0.370***	0.328***
Take-up (*k*)	0.741	0.781	0.169	0.632	0.645	0.172	0.109***	0.136***
n		86			226			

Notes: The variables are described in Table 2. *, ** and *** denote that the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively. Differences in mean values between rights offerings and private placements for each variable are calculated using a two-sample mean-comparison test with unequal variances. Differences in median values between rights offerings and private placements for each variable are calculated using the Wilcoxon rank-sum test.

4.1 Univariate analysis of information asymmetry and monitoring

Panel A of Table 4 shows the univariate analysis. I employ two tests: a two-sample mean-comparison test with unequal variances and the non-parametric Wilcoxon rank-sum test. I include several information asymmetry measures (for detailed definitions of the variables, see Table 2). The information asymmetry proxy, R&D news, provides support for the information asymmetry hypothesis, whereas the ownership variable (blockholder) does not support the monitoring hypothesis. Of the rights offerings, 61 percent are preceded by the disclosure of R&D news, whereas 17 percent of private placements disclose R&D news prior to the equity issue announcement. The mean-comparison test is positive and statistically significant ($p < 0.01$). The mean blockholder ownership for rights offerings and private placements are 31.3 and 26.8 percent, respectively. The mean-comparison test indicates that there is no difference between rights offerings and private placements ($p > 0.10$).

4.2 The choice of equity-selling mechanisms

The results of the multivariate logit regression analysis are summarized in Panel A of Table 5. Consistent with expectations, the coefficients for R&D news are positive and statistically significant (1 percent level). The results are robust when controlled for issue size and take-up (see Model 3), which indicates that there is a higher probability that firms issue equity publicly rather than privately following credible R&D disclosures. The marginal effects show that firms that disclose R&D news are 40 percent more likely to choose a rights offering over a private placement. In untabulated tests, I calculate the predicted probabilities if R&D news is equal to 1 and all other variables are held constant. The predicted probabilities for rights offerings and private placements are 0.699 and 0.301, respectively. In Model 4, the proxy for the ownership variable (*Blockholder*) is insignificant (*z*-statistics = 1.08). However, when controlling for issue size and take-up, the blockholder variable is significant at the 5 percent level (*z*-statistics = 2.14).

Next, I examine other proxies for information asymmetry (see Panel B of Table 5). None of the other proxies are significant at the 5 percent level (untabulated). However, when controlling for the size of the issuance, three variables are significant (firm size, survival time and market liquidity). The firm size variable is negative, which indicates that smaller firms tend to issue equity publicly rather than privately. This contrasts with prior empirical studies (e.g., Cronqvist and Nilsson, 2005), which suggest that larger and older firms are more likely to issue equity publicly rather than privately. The financial distress variable (survival time) is

positive and statistically significant, which implies that firms with capital needs facing the risk of running out of cash tend to choose rights offerings over private placements. When including all variables (Model 9), the coefficient for R&D news is positive and statistically significant (z-statistics 4.002), which lends support for H1. By contrast, the coefficients for the blockholder variable and for the changes in blockholder ownership are both statistically insignificant, which indicates that monitoring is not an important determinant in the choice of equity-selling mechanisms (i.e., there is no support for H2). In untabulated tests, I examine whether there is a non-linear relationship between the level of blockholder ownership and the choice of public or private financing; however, the coefficient is statistically insignificant.

Table 5. Multivariate logit analysis: rights offerings vs. private placements

Panel A. R&D news and blockholder

	Predicted Sign	(1)	(2)	(3)	(4)	(5)	(6)
Intercept		-2.139	-1.749	-2.163	-1.477	-2.490	-2.480
Panel A. Information Asymmetry							
R&D news	+		1.196 [0.402]*** (6.17)	1.078 [0.358]*** (5.41)			1.074 [0.355]*** (5.31)
Panel B. Ownership							
Blockholder	+				0.366 [0.116] (1.08)	0.780 [0.238]** (2.14)	0.732 [0.217]* (1.83)
Panel C. Others							
Issue size		0.751 [0.231]*** (3.91)		0.448 [0.133]** (2.23)		0.860 [0.262]*** (4.27)	0.548 [0.162]** (2.57)
Take-up (*k*)	+	0.642 [0.342]*** (3.23)		0.638 [0.339]*** (3.42)		0.658 [0.351]*** (3.57)	0.688 [0.388]*** (3.22)
Dummies for regions		Yes	Yes	Yes	Yes	Yes	Yes
Number of observations		282	281	280	284	282	280
χ^2-statistic (*p*-value)		57.13*** (0.000)	71.58*** (0.000)	72.11*** (0.000)	41.34*** (0.000)	54.17*** (0.000)	76.19*** (0.000)
Pseudo R^2		0.187	0.266	0.282	0.142	0.210	0.298
Panel B. Interaction effect.							
Mean interaction effect for *R&D news* and *Blockholder*							-0.774 (0.313)

Notes: This table provides the estimates from the logit regressions (Panel A). The sample consists of 226 private placements and 86 rights offerings made by publicly listed European biotechnology firms during the 1995-2012 period. The dependent variable equals 1 for rights offerings and 0 for private placements. I report coefficient estimates, marginal effects (within angle brackets) and *z*-statistics for marginal effects (within brackets). All regressions contain White´s heteroskedastic-consistent standard errors. The variables are described in Table 2. *, ** and *** denote that the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively. Panel B reports interaction effects using the methodology suggested by Norton et al. (2004). The mean interaction effect is reported with corresponding *z*-statistics within brackets.

Panel B. Other measures of information asymmetry and blockholder

	Predicted Sign	(7)	(8)	(9)
Intercept		-1.374	-2.130	-2.583
Panel A. Information Asymmetry				
R&D news	+			1.201 [0.329]*** (4.002)
Bid-ask spread	-			-0.191 [-0.042] (-1.15)
Trading volume	+			-0.048 [-0.011] (-1.34)
Firm age	+			0.009 [0.002] (0.42)
Public firm age	+			0.078 [0.017]** (1.97)
Firm size	+			-1.817 [-0.404]*** (-4.81)
Survival time	-			0.936 [0.208]** (2.04)
Momentum	+			-0.465 [-0.103] (-0.42)
Market liquidity	+			-0.269 [-0.063] (-0.90)
Panel B. Ownership				
Blockholder	+			0.198 [0.044] (0.36)
Δ Blockholder	+	-0.169 [-0.053] (-1.09)	-0.289 [-0.086] (-0.50)	-0.101 [-0.022] (-1.48]
Panel C. Others				
Issue size			0.740 [0.221]*** (3.77)	2.490 [0.553]*** (5.65)
Take-up (*k*)			0.725 [0.361]*** (3.42)	0.651 [0.340]*** (3.21)
Dummies for regions		Yes	Yes	Yes
Number of observations		284	282	230
χ^2-statistic (*p*-value)		42.88*** (0.000)	59.13*** (0.000)	89.77*** (0.000)
Pseudo R^2		0.146	0.193	0.487

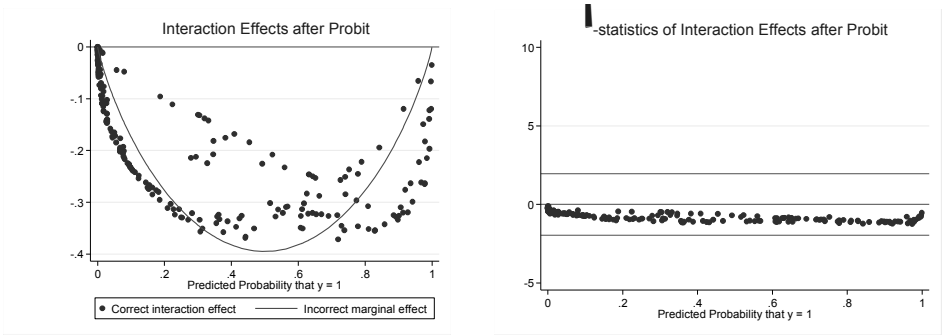
Notes: This table provides the estimates from the logit regressions. The sample consists of 226 private placements and 86 rights offerings made by publicly listed European biotechnology firms during the 1995-2012 period. The dependent variable equals 1 for rights offerings and 0 for private placements. I report coefficient estimates, marginal effects (within angle brackets) and *z*-statistics for marginal effects (within brackets). All

regressions contain White´s heteroskedastic-consistent standard errors. The variables are described in Table 2. *, ** and *** denote that the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively.

4.2.1 Interaction effects

Next, I examine interaction effects between asymmetric information (*R&D news*) and ownership concentration (*Blockholder*). The lowest level of information asymmetry may occur in cases where firms with concentrated ownership have disclosed R&D information, which according to theory implies that these firms are more likely to use (uninsured) rights offerings rather than private placements. Employing similar reasoning, the highest level of asymmetric information may occur in cases where the firm ownership is dispersed and no R&D information has been disclosed. In this latter case, firms have incentives to choose private placements rather than (uninsured) rights offerings.

Figure 1. Interaction effects – Blockholder and R&D news



Notes: The graphs above display the interaction effects and corresponding *z*-statistics on the interaction variable reported in Table 5, estimated using Norton et al. (2004). The pair of interaction variables include *Blockholder* and *R&D news*. The lines above and below 0 on the figure to the right represent 5 percent significance levels (±1.96).

Unlike the interaction effect in linear models, the interaction effect in non-linear models is conditional on the independent variables (Ai and Norton, 2003; Norton et al., 2004; Powers, 2005) therefore; both the magnitude and statistical significance of the interaction term can vary across observations. I employ the methodology developed by Norton et al. (2004) to calculate the correct marginal effect of the interaction variables. Panel B of Table 5 reports both the mean interaction effect and the corresponding *z*-statistics for the interaction variable. The mean interaction effect is not statistically significant (-0.774, *z*-statistics = -1.01). However, the interaction effect may have different signs for different values of covariates (Norton et al., 2004). Figure 1 displays the graphs of the distribution of the marginal effects and associated *z*-statistics over the entire range of predicted probabilities for the main models.

The interaction effects are largely negative and statistically insignificant for most observations, which implies that there is no association between information asymmetry and ownership concentration with respect to the choice between private and public financing.

4.3 Additional analysis of monitoring

The theoretical literature explains that private placements are often motivated by management monitoring because private placements are associated with concentrated ownership and restrictions on post-placement trading (e.g., Wruck, 1989; Kahn and Winton, 1998). Although concentrated ownership enhances monitoring incentives (Shleifer and Vishny, 1986), the ownership concentration measure may be limited because private placements do not necessarily improve monitoring if ownership is concentrated in the hands of passive investors. Barclay et al. (2007) show that private placement investors typically are passive despite their acquisitions of large blocks of stock. An alternative hypothesis might be related to managerial entrenchment (e.g., Wruck, 1989); Wu (2004) argues that because there is no formal way to select the investors for private placements, managerial preferences (e.g., investors who are aligned with and vote in favor of the managers selected) can play a role in the choice of private placement investors. In the US, most private placements involve restricted shares (issued pursuant to registration exemptions under Regulation D or Regulation S), which typically indicates that the shares purchased in such private placements cannot be sold until two years after they are purchased (issued)[21]. No such regulation on private placements exists in Europe, which enables a clean-test of economic determinants that drives the choice of equity-selling mechanisms as opposed to regulatory differences[22].

To further evaluate the monitoring hypothesis, I follow Wu (2004) and decompose aggregate ownership according to the identities of blockholders and study changes in ownership structure on investor identity levels before and after equity issuance announcements. Consistent with several prior studies (e.g., Admati and Pfleiderer, 1994; Sahlman, 1990), pension funds and venture capital funds are classified as monitoring agents. Ownership data are mainly collected from annual reports and proxy statements. Pre-issuance ownership data are collected from the nearest year prior to the equity issuance announcement date. Post-

[21] For example, in the sample of private placements by Wu (2004), 37 private placements are unrestricted, whereas 301 are restricted.

[22] Nevertheless, when a private placement is directed only to new private placement investor(s), approval from existing shareholders is frequently required in cases in which the existing shareholders hold a large fraction of the shares in the firm. For example, on March 6, 2013, Active Biotech announced that its two largest shareholders, with a joint holding of votes and shares of approximately 44 percent, had approved a private placement to a new outside investor.

issuance ownership data are collected from the nearest year after the first trading day of the newly issued shares. Table 6 presents changes in ownership concentration for private placements (Panel A) and rights offerings (Panel B).[23]

Table 6. Detailed univariate analysis of monitoring

	Pre-issue ownership (%)		Post-issue ownership (%)		Change in ownership (%)		Number of observations
	Mean	*Median*	*Mean*	*Median*	*Mean*	*Median*	
Panel A. Private placements.							
Blockholders	40.5	38.1	37.6	33.1	-2.9**	-5.0***	136
Institutional blockholders	32.8	26.3	30.5	25.7	-2.2*	-0.6**	118
Venture funds	27.9	19.4	18.2	14.8	-9.7***	-4.6***	48
Pension funds	11.9	8.2	15.4	9.9	3.5*	1.7	31
Others	21.5	16.5	20.8	15.4	-0.7	-1.1	89
Non institutional blockholders	28.3	15.5	23.9	13.7	-4.4***	-1.8***	54
Panel B. Rights offerings.							
Blockholders	46.6	44.1	42.2	31.4	-4.4*	-12.7	51
Institutional blockholders	39.5	32.5	38.2	25.8	-1.3	6.7	45
Venture funds	29.3	24.5	21.3	12.9	-8.0***	-11.6**	18
Pension funds	7.9	6.9	8.5	6.9	0.7	0.0	11
Others	32.2	20.3	30.1	14.1	-2.1	-6.2	33
Non institutional blockholders	21.8	11.8	18.4	7.7	-3.4***	-4.1***	25

Notes: This table provides a univariate analysis of monitoring. Ownership data are obtained from annual reports and the Amadeus database. Venture capital funds, including private equity funds, are identified from the National Venture Capital Association (NVCA), the European Private Equity and Venture Capital Association (EVCA) and IPO prospectuses. Pension funds are identified from the Pension Handbook and Morningstar's Mutual Fund Sourcebook. The ownership structure is categorized at year-end if no date of ownership structure is given. "Blockholders" refers to owners holding at least 5 percent of shares. I categorize blockholders as institutional or non-institutional. Pension funds, insurance companies, mutual funds, venture capital funds, corporate partners, banks, foundations and endowments are categorized as institutional blockholders. Individuals, families and non- financial companies are classified as non-institutional blockholders. Venture funds and pension funds are referred to as monitoring and the rest are referred to as non-monitoring. *, ** and *** denote that the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively.

[23] The ownership data are based on 5 percent threshold levels, i.e., shareholders owning a minimum of 5 percent or more. As a result, a two-sample mean-comparisons test and a Wilcoxon matched-pairs signed-ranks test (non-parametric test) only compare data for which there are available data points both before and after the issuance announcement.

On an aggregate level, the mean (median) blockholder ownership decreases significantly by 2.9 (5.0) percent and 4.4 (12.7) percent for private placements and rights offerings, respectively. Although the decrease in blockholder ownership in private placements is smaller in relative terms, the smaller pre-issue ownership levels in private placements compared to rights offerings do not support the view that private placements are motivated by a demand for monitoring.

To further illustrate the changes in ownership concentration, I decompose blockholders into institutional and non-institutional categories. Pension funds, venture capital funds, mutual funds, insurance companies and banks are classified as institutional blockholders. Individuals and families are classified as non-institutional blockholders. Institutional blockholders are further classified as either monitoring (venture capital funds and pension funds) or non-monitoring. Venture capital funds, including private equity funds, are identified from numerous sources, including the National Venture Capital Association (NVCA), the European Private Equity and Venture Capital Association (EVCA) and from IPO prospectuses. Pension funds are identified from the Pension Handbook and Morningstar's Mutual Fund Sourcebook. I crosscheck and confirm—and if necessary correct—the information with the classification in the Amadeus database.

The decomposition highlights a few interesting observations that are illustrated in Table 6. Panel A shows that the mean (median) institutional blockholder ownership decreases significantly in private placements but not in rights offerings. Furthermore, studying the two monitoring classes (venture capital funds and pension funds) separately reveals certain interesting results. For private placements, the mean (median) venture fund ownership significantly decreases by 9.7 (4.6) percent. Although the mean (but not the median) pension fund ownership increases for private placements (3.5 percent, statistically significant at the 10 percent level), the net effect of monitoring shareholders is negative and statistically significant (not tabulated). For rights offerings, the change in venture fund ownership is negative and statistically significant, whereas the change in pension fund ownership is statistically insignificant. Untabulated tests show that there is no significant difference between private placements and rights offerings for either venture capital ownership or pension fund ownership, which seems to be inconsistent with the monitoring hypothesis that private placements are motivated by a demand for monitoring.

5. Additional tests

5.1 Uninsured vs. underwritten rights offerings

Firms issuing equity publicly can choose between an uninsured rights offering and the more expensive underwritten rights offers, such as standby rights and firm-commitment offers[24]. The adverse selection model by Eckbo and Masulis (1992) suggests that firms should employ lower-cost flotation methods, such as pure (uninsured rights), when managers believe the expected take-up (k) by existing shareholders will be high. With intermediate expected levels of k, firms should use standby rights, whereas firms should employ firm-commitment underwritten offers with lower expected levels of k. Firm-commitment underwritten offers have not yet spread outside the US—with the exception of Japan and France (Eckbo, 2008). Consistent with this prediction, the actual shareholder take-up is higher for uninsured rights offerings than for standby rights offerings (mean and median values of take-up are displayed in Appendix.

Following Cronqvist and Nilsson (2005), I employ a nested logit model (McFadden, 1978, 1981) to examine the second-level decision between uninsured vs. standby rights offerings. The proxies for information asymmetry, except for the bid-ask spread and firm size, are statistically insignificant in all models (untabulated). Although the results indicate that larger firms are more likely to use standbys than smaller firms, an alternative explanation may be that underwriters do not take on standbys (and are even less likely to take on firm-commitment offers) from small firms with illiquid stocks because of the financial and reputational risk of being unable to sell the shares to the market; this observation might indicate that there are determinants in addition to information asymmetry that impact the choice between uninsured and standby rights offers.

5.2 Subscription pre-commitments

High-k issuers selecting uninsured rights have an incentive to inform the market about their private information regarding subscription pre-commitments from large shareholders for several reasons. First, the value of any underpricing is captured mainly by existing shareholders (minimizing wealth transfers from current to new investors). Second,

[24] The underwriter is generally paid an underwriting fee for its commitment (to compensate for the risk of subscribing for shares that are not taken up by shareholders) and is frequently also paid an amount per share for each unsubscribed share purchased in connection with the rights issuance. The underwriting fee in an underwritten rights offering typically ranges from 2 to 6 percent of the total proceeds. In comparison, direct issuance costs associated with an uninsured rights offering are generally 1 percent to 2 percent of total proceeds.

subscription pre-commitments by large shareholders are, in practice, likely to influence the subscription decisions of small and relatively uninformed shareholders. Third, subscription pre-commitments may help debilitate any negative market reaction to the announcement of the issuance and reduce the likelihood of offer failure. Following this reasoning, actual shareholder take-up and subscription pre-commitments are expected to be higher for uninsured rights than for standby rights.

In this study, the proportion of rights offerings with pre-commitments is 61.6 percent, i.e., 66.1 percent for uninsured rights and 50.0 percent for standby rights. Table 7 shows total[25] subscription pre-commitments as percentages of shares issued for uninsured and standby rights.

Table 7. Subscription pre-commitments and actual subscription data

	Subscription pre-commitments in percentage of shares issued		Percentage of issue subscribed			
	Mean	*Median*	*Mean*	*Median*	*Min*	*Max*
Uninsured rights	48.0	53.4	89.4	100.0	21.1	100.0
Standby rights	26.8	8.0	99.3	100.0	91.8	100.0

Notes: This table reports the mean (median) percentage of the share issue pre-committed to be subscribed and the percentage of the issue subscribed for uninsured and standby rights offers by European biotechnology firms during the 1995-2012 period. The data are primarily collected from prospectuses, press release information from corporate webpages and the Factiva database.

The mean (median) subscription pre-commitment for uninsured rights is 48.0 (53.4) percent. As expected, the mean (median) subscription pre-commitments for standby rights is significantly lower, at 26.8 (8.0) percent. Actual subscription rights in uninsured rights offers average 89.4 percent compared to 99.3 percent for standby rights. A large fraction (76 percent) of the uninsured rights have an actual percentage of issuance subscribed that exceeds 90 percent. However, six uninsured rights report have actual percentages of subscribed issuance in the range of 20 to 30 percent, with a minimum of 21.1 percent.

In the nested logit model between uninsured vs. standby rights offerings, I include a dummy variable that equals 1 if there are subscription pre-commitments[26]. The coefficient on subscription pre-commitment is insignificant, which suggests that a subscription pre-

[25] The total subscription pre-commitment is the sum of the pro-rata allotment and the pre-commitment to exercise rights beyond the pro-rata allocation should other shareholders not fully exercise their rights.
[26] In an untabulated test, I verify the results that setting the threshold levels at 50 percent, 75 percent or 95 percent did not have any effect on the inferences.

commitment is not an important determinant between the choice of an uninsured and a standby rights offering.

5.3 Stock market response to rights offerings and private placements

Similar to Cronqvist and Nilsson (2004), I examine whether the stock market reactions to the announcement of rights offerings and private placements are consistent with the findings previously reported. Stock market reactions provide important information about whether there are adverse selection costs. According to the shareholder take-up model from Eckbo and Masulis (1992), the market reaction to SEOs should be most negative for firm commitment offerings (where the potential for wealth transfer is greatest) and least negative (or zero) for pure rights, with standby rights in between. Several studies (e.g., Korajczyk et al., 1990; Lucas and McDonald, 1990, Choe et al., 1992; Eckbo and Masulis, 1992) report negative stock market reactions to standbys and firm-commitment offers. The negative stock market reaction is consistent with the view that outside investors are hedging to compensate for their informational disadvantage because those SEOs that tend to be issued are likely to be overpriced (and thus the term "adverse selection"). The positive stock market reaction to private placements, which may be viewed as a means of reducing adverse selection costs, may be motivated by two alternative explanations. First, finding a private placement investor willing to invest requires a favorable review of the issuing firms' future prospects. Consequently, successful private placements can be viewed as the outcome of a positive selection process, which is consistent with positive stock market reactions at the announcement of private placements (Eckbo, 2008). Second, a positive stock market reaction to private placements may reflect the market's belief that the new blockholder will play a positive role in monitoring management (Wruck, 1989).

I use the event-study methodology (e.g., Brown and Warner, 1985; Campbell et al., 1997) to document the stock-price reaction to announcements of rights offerings and private placements. The market model[27] is used to estimate predicted returns. The estimation period includes day -250 through -30, with day 0 being the public announcement of the equity issue.

[27] For robustness reasons, I also employ two additional models: 1) the Fama-French three factor model and 2) a two-factor model, in which the first factor is the market index (MSCI Europe) and the second factor is an industry index (STOXX Europe 600 Healthcare). Sharpe et al. (1999) suggest using a second factor when the sample is comprised of rims in a single industry in order to explain more of the variation in the normal return. All models yield similar results.

Abnormal returns are the difference between a firm's predicted and actual stock prices. Cumulative abnormal returns are formed by summing and then averaging the abnormal returns. Panel A of Table 8 reports average abnormal returns and cumulative average abnormal returns (CARs) around equity issue announcements for uninsured rights, standby rights and private placements.

Table 8. Stock price behavior before and around issue announcements

Panel A. Stock price behavior around issue announcements

	Rights offerings				Private placements	
	Uninsured rights		*Standby rights*			
Day	*AR (%)*	*CAR (%)*	*AR (%)*	*CAR (%)*	*AR (%)*	*CAR (%)*
-3	-0.236 (-0.51)	-0.236 (-0.51)	-0.830 (-0.84)	-0.830 (-0.84)	-0.307 (-1.35)	-0.307 (-1.35)
-2	0.526 (1.16)	0.205 (0.45)	0.416 (0.66)	-0.292 (-0.43)	0.282 (0.88)	-0.018 (-0.06)
-1	-0.790** (-2.05)	-0.289 (-0.70)	0.090 (0.09)	-0.187 (-0.21)	-0.318 (-1.07)	-0.198 (-0.73)
0	-4.263*** (-5.33)	-2.382*** (-4.89)	-5.639*** (-4.39)	-2.982*** (-3.34)	1.240* (1.65)	0.448 (0.99)
1	-1.824** (-2.43)	-2.946*** (-5.91)	-1.700** (-2.28)	-3.427*** (-3.77)	-0.611 (-1.53)	0.128 (0.31)
2	-0.181 (-0.33)	-2.763*** (-5.52)	-0.218 (-0.31)	-3.217*** (-3.80)	-0.241 (-1.07)	0.018 (0.05)
3	0.268 (0.54)	-2.457*** (-4.90)	-1.174 (-1.07)	-3.423*** (-3.74)	0.133 (0.52)	0.067 (0.18)

Notes: This table provides average abnormal returns and cumulative average abnormal returns (CARs) around issue announcements for rights offerings and private placements. Abnormal returns are calculated as the difference between actual returns and predicted returns. Predicted returns are estimated using a single-factor model over a time window of day t_{-250} to day t_{-21}. *t*-statistics are reported in parentheses. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel B. Pre-announcement abnormal stock price behavior

	Rights offerings		Private placements
	Uninsured rights	*Standby rights*	
Abnormal return [-60,-2]	-5.57* (-1.85)	12.39 (1.50)	12.78*** (4.17)

Notes: This table provides average abnormal returns for rights offerings and private placements in the 3-month period preceding the equity issue announcement date (day -60 through day -2). *t*-statistics are reported in parentheses. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The mean abnormal return on the day of the equity issuance announcement for pure (uninsured) rights is -4.3 percent (*t*-statistic = -5.33) and the three-day (+1, -1) cumulative average abnormal return is -2.9 percent (*t*-statistic -5.91). In comparison, the average day-zero market reaction to standbys is -5.6 percent (*t*-statistic = -4.39). This is consistent with prior studies that document negative reactions to rights offerings (e.g., Eckbo and Masulis, 1992; Eckbo, 2008). The negative stock market reaction to pure and standby rights offerings is consistent with the existence of adverse selection costs, and shareholder take-up by existing shareholders is less than one ($k < 1$). Contrary to rights offerings, the stock market reaction to private placements on the day of announcement is positive and statistically significant at the 10 percent level (1.24 percent, *t*-statistic 1.65). This is consistent with several prior studies (e.g., Wruck, 1989; Hertzel and Smith, 1993; Janney and Folta, 2003). For example, Janney and Folta (2003) document CARs over a three-day period (-1, +1) of 2.65 percent for a sample of US biotechnology firms between 1973 and 1998.[28]

To provide additional context to the stock market reactions to rights offerings and private placements, I examine the average abnormal stock price run-up over the three months before the announcement date for uninsured rights, standbys and private placements (see Panel B of Table 8). Consistent with the adverse selection hypothesis, standbys are associated with a positive stock market run-up of 12.4 percent prior to the announcement, but are not statistically significant (*t*-statistic = 1.50). This is consistent with the view that adverse selection problems arise when undervalued firms with low expected shareholder take-up do not issue equity, whereas issuing firms that go ahead with standby rights tend to be overvalued, on average. Because the probability of being overvalued is greater following a period of a stock price run-up, it is reasonable to expect that the sample of standbys will have a positive stock price run-up. By contrast, there is evidence of basically no stock price run-up before uninsured rights offers (-5.6 percent, *t*-statistic = -1.85).

In summary, the results from these additional tests indicate that the stock market reacts negatively to the disclosure of uninsured standby rights, according to the predictions. The

[28] Although private placements are frequently employed in the biotechnology industry, and although the stock market reacts positively to announcements of such placements, the disclosure of investor identity tends to be a strategic decision by managers. For example, issuing firms only report the investor identity in less than one-third of the 226 private placements in this study, a variable that may convey important information to potential investors. This figure is significantly lower than the one found in the study by Janney and Folta (2003), who report that approximately 50 percent of private placements convey information about investor identity. An untabulated mean-comparison test shows that CARs to firms that disclose investor identity in private placements is 1.7 percent higher (1.18 percent vs. -0.52 percent) than CARs to private placement firms that do not disclose investor identity.

positive stock market reaction to private placements may be driven by a favorable review of the issuing firms' future prospects rather than by the belief that the new blockholder will play a positive role in monitoring management.

6. Conclusions

This paper examines the impact of of information asymmetry and monitoring on the choice of equity-selling mechanisms. The empirical study is based on 86 rights offerings and 226 private placements made by all publicly listed European biotechnology firms during the 1995-2012 period. The results provide evidence that information asymmetry is an important determinant of the choice of equity-selling mechanisms, whereas no support is found for the monitoring hypothesis.

The information asymmetry hypothesis suggests that rational corporate managers acting in the interest of existing shareholders issue equity publicly rather than privately when information asymmetry about firm value is low (Chemmanur and Fulghieri, 1999; Hertzel and Smith, 1993). The time-varying asymmetric information model by Korajczyk et al. (1991, 1992) suggests that information asymmetry is not fixed over time and that equity issues occur following credible information disclosures. This paper uses R&D disclosures as the main proxy for measuring information asymmetry and finds evidence that there is a higher probability that firms will issue equity publicly rather than privately following credible R&D disclosures, i.e., when information asymmetry is low.

The monitoring hypothesis suggests that private placements are used when there is a demand for monitoring because private placements are associated with more concentrated ownership (e.g., Shleifer and Vishny, 1986). The results of the analysis in this study indicate that monitoring is not an important determinant in the choice of equity-selling mechanisms. A detailed analysis of investor identities shows that the mean (median) of venture capital ownership decreases for both private placements and rights offerings and that there are no differences in means (medians) between the two equity issuance methods. Although there is an increase in pension fund ownership following private placements, the net effect of monitoring agents is negative.

Although the adverse selection costs hypothesis provides a rational and clear prediction for which issue method is preferred based on the expected take-up levels of existing shareholders,

the monitoring hypothesis is more problematic because managerial objectives may play a role. Wu and Wang (2005) argue that private placements may be inferior to uninsured rights as a flotation method in cases where entrenched managers want to avoid creating a monitoring blockholder. Wu (2004) suggests that private placements may be preferred in cases where managers find investors willing to align with managers (in return for an offer price discount). Furthermore, Hertzel and Smith (1993) propose that the relative importance of private placements for resolving information asymmetries about firm value versus monitoring management may depend on firm size. Morck et al. (1988) propose that monitoring and aligning managerial incentives may be relatively less important for small firms, which constitute the majority of the firms in this study and which typically tend to have high managerial ownership compared to large firms.

The biotechnology industry is, arguably, different from other industries in the sense that firms typically operate with large negative free cash flows and have no other choice but to regularly ask investors for (equity) financing for their research projects. In other words, the findings lend support for studying the choice of equity-selling mechanisms based on the argument that managers rationally go to public equity markets when there is a chance that investors will better understand the firm's prospects. This is consistent with the adverse selection model by Eckbo and Masulis (1992), which suggests that firms will employ lower-cost flotation methods when the level of asymmetric information about firm value is low, i.e., when the expected level of take-up in the equity issuance is high.

Further research can investigate questions such as: How does the private/public equity choice interact with alliance funding? What is the relationship between the future performance of a project and the choice of equity-selling mechanisms? How are private placement investors chosen and what type of investors are likely to participate in private placements?

Appendix. Estimation of expected shareholder take-up (*k*)

This section describes the three-step procedure to estimate shareholder take-up. In the first step, actual take-up is calculated for all firms selecting a rights offering. The fraction of rights traded is observable during the subscription period and assuming that each right is only traded once, take-up is defined as one minus the fraction of rights traded in the rights offering. In the second step, a linear regression model of actual shareholder take-up is employed using several *ex ante* explanatory variables, including ownership concentration (blockholder), issue size,

firm size, price discount and prior returns (run-up). In the third step, the coefficient estimates are used to calculate predicted values of shareholder take-up for the firms in the sample.

Table 9 reports actual shareholder take-up (*k*) in the rights offering sample. The model by Eckbo and Masulis (1992) predicts that high-*k* issuers will choose uninsured rights, whereas low-k issuers will choose standby rights. Consistent with this prediction, Table 9 displays that actual shareholder take-up is higher for uninsured rights offerings than for standby rights offerings. The mean (median) take-up for uninsured rights is 74.9 (77.5) percent, whereas the mean (median) take-up for standby rights is 69.5 (71.0) percent.

Table 9. Shareholder take-up in seasoned equity offerings by European biotechnology firms, 1995-2012

	n	*Mean*	*Std*	*25%*	*50%*	*75%*
Uninsured rights	54	74.9	0.163	61.1	77.5	89.1
Standby rights	18	69.5	0.219	55.1	71.0	89.3
Total	72	73.6	0.177			

Notes: This table reports shareholder take-up levels (k) for uninsured and standby rights by European biotechnology firms during 1995-2012. Take-up is defined as the fraction of the issue acquired by the existing shareholders. $k \in [0, 1]$. Assuming that each right issued in a rights offering only is traded once, take-up is proxied by one minus the fraction of rights sold in the secondary market (Bøhren et al., 1997). Data on the number of rights sold in the secondary market were obtained from stock exchanges, such as the NASDAQ OMX Group.

The *ex ante* explanatory variables are proxies for determinants affecting existing shareholders' likelihood to take part in the equity issue. Several of the explanatory variables have previously been used in Bøhren et al. (1997), Cronqvist and Nilsson (2004) and Balachandran et al. (2008).[29] Ownership concentration (blockholder), which is defined as the sum of institutional and non-institutional ownership owning more than 5 percent at the year-end of the previous fiscal year, shows that a large pre-issue shareholder ownership by existing blockholders increases the probability that the issue is value-maximizing, which may increase other shareholders' propensity to participate (Cronqvist and Nilsson, 2004). In addition, Balachandran et al. (2008) argue that large shareholders may have incentives to preserve their proportional ownership due to monitoring and control-oriented benefits. The log of issue size shows that the larger the equity issue, the greater is the likelihood that existing shareholders

[29] As Balachandran et al. (2008) point out, a range of variables are excluded due to potential multicollinearity problems. For this reason, I exclude stock return volatility from the model, which is correlated with run-up. In untabulated tests I exclude firm size from the model, as firm size may be correlated with issue size, and verify that the results are robust.

face capital or diversification constraints preventing them from participating in the equity issue. The log market value of equity (firm size) shows that a larger firm provides a higher-quality signal about the investment (Balachandran et al., 2008) and larger firms tend to have dispersed ownership, which can increase existing shareholders' participation (Cronqvist and Nilsson, 2004). Price discount shows the larger the price discount, the greater is the probability of existing shareholder participation. Prior return (run-up), which is defined as the stock return over a six-month period prior to the equity issuance, shows that a positive stock price performance in the period preceding the equity issue announcement may induce shareholders to participate in the equity issue. The regression results are displayed in Table 10.

Table 10. Regression model for existing shareholder take-up (*k*)

	Predicted Sign	Coefficient	*t*-statistic
Intercept		0.718***	3.11
Blockholder	+	0.494***	3.92
Issue size	-	-0.297**	-2.33
Firm size	+	0.119	1.17
Price discount	+	-0.054	-0.31
Run-up	+	0.111*	1.77
Number of observations		72	
R^2		0.363	
F-value		11.66	
(*p*-value)		(0.000)	

Notes: This table provides the estimates from the linear regressions of expected take-up. The sample consists of 54 uninsured rights offerings and 18 standby rights offerings. Take-up is defined one minus the fraction of rights sold in the secondary market (Bøhren et al., 1997). *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 10 shows that the coefficients for several of the explanatory variables (e.g. blockholder, issue size and run-up) have their signs according to predictions and are statistically significant. The coefficient estimates from this model are used to calculate expected shareholder take-up for the firms in the sample.

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IV

Acquisitions, alliances and post-acquisition R&D performance

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Abstract

This paper examines the short-term and real long-term performance of acquisitions and their association with alliances. More specifically, I examine whether acquirers' prior alliances with target firms are positively associated with short-term stock market reactions to acquisition announcements as well as firms' post-acquisition operating performance. Using a sample of 219 biopharmaceutical acquisitions from 1998 to 2012, I find that returns to bidders are essentially zero, whereas target shareholders gain significantly more. Contrary to past empirical research, I do not find evidence that alliances with target firms prior to acquisitions are associated with positive bidder returns, which indicates that acquiring firms do not gain informational advantages from prior alliances. Using a hand-collected dataset, I examine the long-term post-acquisition operating performances of 383 R&D projects. I find that R&D projects that are co-developed preceding the acquisition are no more likely to advance to subsequent stages of development than are R&D projects that are not preceded by alliances. However, acquiring firms with prior alliances with target firms are more likely to pay higher bid premiums (86 percent versus 56 percent), which raises the issue of a possible winner's curse in the biopharmaceutical industry. Although an alliance provides an opportunity for the acquiring firm to learn more about the quality of the asset and mitigate informational disadvantages, it does not necessarily eliminate the problems associated with information asymmetry.

JEL-classification: G14, G34
Keywords: Mergers and acquisitions (M&As); Alliance; R&D; Operating performance; Biopharmaceutical industry

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1. Introduction

Acquisitions and alliances have become increasingly important vehicles for accessing innovations and supplementing internal R&D pipelines following the recent well-known deterioration of R&D productivity[1] and the patent cliff[2] problem in the pharmaceutical industry. For example, between 1997 and 2000, the average number of deals between pharmaceutical and biotechnology firms with total deal valuations exceeding $100 million was 15 per year, whereas the average number of deals in the 2006-2012 period was 81 per year (Deloitte Recap). Similarly, the number of acquisitions averaged seven per year in the 1998-2004 period, compared with 22 per year in the 2005-2012 period (data source: Securities Data Corporation). As acquisitions have become more popular, the empirical literature has focused on whether acquiring firms' shareholders experience a wealth effect from mergers and acquisitions as well as identifying factors that contribute to the success of acquisitions.

Several studies have suggested that information asymmetry may significantly affect the performances of acquisitions (e.g., Eckbo et al., 1990; Balakrishnan and Koza, 1993; Coff, 1999), problems that may explain why abnormal returns in the years following mergers are predominantly negative (e.g., Agrawal et al., 1992; Loughran and Vijh, 1997). Information asymmetry further complicates the post-acquisition management of target firms with intangible assets such as research and development (R&D), as acquirers typically cannot verify targets' quality prior to acquisition (Akerlof, 1970). Rodriguez and Higgins (2003) find that little or no value is created for acquiring firms' shareholders when a significant portion of a target firm's value consists of intangible assets due to difficulties associated with the valuation of intangible assets. Nanda and Williamson (1995) suggest that an alliance provides an opportunity for an acquiring firm to learn more about the quality of the asset and mitigate the firm's informational disadvantage. However, Ball et al. (1991) show that learning opportunities do not enable bidders to overcome the winner's curse.

Past empirical research on the interaction between alliances and acquisitions has been primarily short-term in focus (e.g., Reuer and Koza, 2000; Higgins and Rodriguez, 2006;

[1] The R&D productivity problem concerns the substantial increase in R&D spending over the past several decades, while the number of newly approved drugs has remained fairly constant. Between 1975 and 1985, the number of new drugs approved by the US FDA per billion US dollars spent averaged 37 per year. For comparison, the same ratio for the period 2005 to 2012 averaged 0.6 per year.

[2] Between 2012 and 2018, drugs currently selling for more than $290 billion will face patent expiration (data source: EvaluatePharma).

Mantecon and Chatfield, 2007). For example, Higgins and Rodriguez (2006),[3] using a sample of 160 biopharmaceutical acquisitions between 1994 and 2001, find that overall abnormal returns for acquiring firms are 3.9 percent and are positively associated with prior alliances with target firms. This finding suggests that alliances can mitigate asymmetric information between targets and bidders. Grabowski and Kyle (2008) and Higgins and Rodriguez (2006) suggest that it would be interesting to study long-term interactions between alliances and acquisitions as they relate to R&D performance. This paper employs an extensive dataset of 219 biopharmaceutical acquisitions between 1998 and 2012 with a collective transaction value of $306 billion and examines whether an acquirer's previous alliance with a target firm is positively associated with short-term stock market reactions[4] as well as with the firm's post-acquisition R&D performance.

I focus on acquisitions in the biopharmaceutical industry for several reasons. First, pharmaceutical firms engage intensively in both alliances and mergers and acquisitions with biopharmaceutical companies to supplement their internal R&D portfolios. Second, information asymmetry problems are especially prevalent in R&D-intensive industries such as those in the high-technology sector (Himmelberg and Petersen, 1994), notably the biotechnology industry (Hall, 2002; Lerner et al., 2003). Third, extensive public data are available on the research portfolios of both acquiring and target firms' research portfolios, providing an opportunity to directly examine the effects of individual R&D projects on project-level rather than firm-level performance in post-acquisition periods.

This paper makes four main contributions to the literature. First, I document that returns to bidders are nearly zero, whereas target shareholders gain significantly more. Second, and contrary to several prior studies, I do not find that establishing alliances with target firms prior to acquisitions is positively associated with bidder returns.[5] Third, I verify these prior findings

[3] Higgins and Rodriquez (2006) also examine changes in research pipeline scores one year post-acquisition. However, they do not examine whether pipeline improvements for acquiring firms are different for acquisitions that are preceded by alliances.

[4] An efficient stock market (see Fama, 1970) provides an unbiased assessment of the gains that may result from acquisitions. Because stock prices reflect the market's assessment of all future cash flows, they provide an immediate estimate of the likely gains or losses from each acquisition.

[5] This does not mean that the results from the study by Higgins and Rodriguez (2006) are incorrect. One potential reason could be that neither this analysis nor the study by Higgins and Rodriguez (2006) control for the propensity to engage in an acquisition in a cross-sectional analysis, as is suggested by Danzon et al. (2007). If the market largely anticipates the alliance partner to be acquired, there will be no or little stock market reaction at the time of the acquisition announcement. Because the time period of their study extends from 1994 to 2001, whereas this study uses a newer dataset (1998-2012), there may simply be a change that has occurred over time. An alternative reason could be that although an alliance provides an opportunity for the acquiring firm to learn more about the quality of the asset, it may not eliminate problem associated with information asymmetry.

by examining the effects of real long-term interactions between alliances and acquisitions on R&D performance. Using a hand-collected dataset of R&D projects, I examine the long-term operating performance of 383 R&D projects in the post-acquisition period. Controlling for project-specific risk and other factors and isolating imperfect information,[6] this study finds that R&D projects that are co-developed before acquisition are no more likely to advance to subsequent stages of development than R&D projects not preceded by alliances. Fourth, this study documents that bid premiums average 65.4 percent, which is significantly higher than those observed in prior studies, where bid premiums typically range from 20 to 40 percent. Consistent with the view that informed buyers are willing to pay higher premiums than uninformed buyers, who require discounts to cover informational disadvantages, this study documents that acquiring firms with prior alliances with target firms are more likely to pay significantly higher premiums (86 versus 56 percent). This raises the question of a potential winner's curse in the biopharmaceutical industry.

The paper proceeds as follows. Section 2 provides a brief description of the pharmaceutical industry and a literature review. Section 3 describes the data and the methodology used. Section 4 reports the empirical results, and Section 5 concludes.

2. Literature review

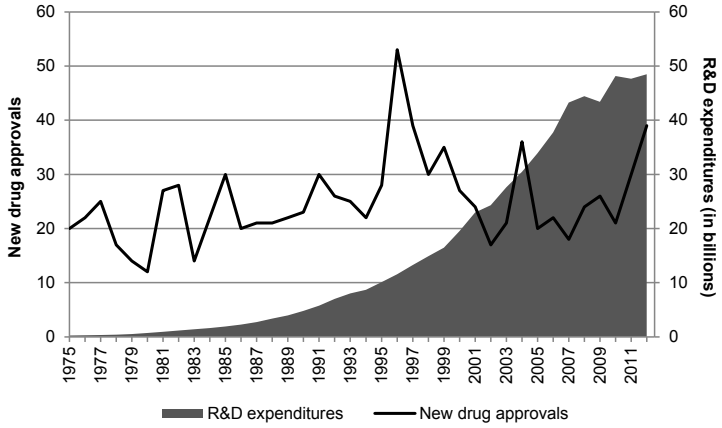
2.1 The pharmaceutical industry

Over the past several decades, R&D productivity in the pharmaceutical industry has declined (DiMasi et al., 2003; Cockburn, 2006); R&D spending has increased substantially, but the number of new drug approvals has remained relatively constant (Figure 1). In the period between 1975 and 1985, the number of new drugs approved by the US FDA per billion US dollars spent averaged 37 per year. In comparison, the same ratio for the sub-periods of 1986-1997, 1998-2004, and 2005-2012 were 4.8, 1.3, and 0.6 per year, respectively, a change that is mainly due to the significantly higher costs of developing new drugs (DiMasi et al., 1991, 2003)[7] accompanied by higher attrition rates of drug development.

[6] A key advantage of this setting is the isolation of imperfect information, whereas studies that examine the performance of R&D projects that are licensed out to pharmaceutical firms or vertically integrated can be driven by either imperfect information (lower-quality R&D projects that are licensed out) or perfect information (R&D projects that are licensed out due to gains-from-trade).

[7] The average cost of bringing a drug to market, including the cost of product failures, rose from an estimated $138 million in 1975 to approximately $1.3 billion in 2006 (DiMasi and Grabowski, 2007).

Figure 1. R&D productivity in the pharmaceutical industry



Notes: This figure displays new drug approvals (left axis) by the US Food and Drug Administration (FDA) and R&D expenditures (right axis) for pharmaceutical companies in the United States from 1975 to 2012. New drug approvals represent new chemical entities (NMEs). R&D expenditures are inflation-adjusted to 2012-year values using CPI data from the Bureau of Labor Statistics. Data on new drug approvals were collected from FDA.gov, and R&D expenditures data were obtained from the Pharmaceutical Research and Manufacturers of America webpage.

Over the same time period, the industry has been subject to legislative changes[8], and several major commercial products have undergone patent expirations[9] followed by intense price competition from generics. In response to these trends, pharmaceutical companies have adopted several strategies: 1) engage in horizontal mergers to achieve greater economies of scale and scope, 2) acquire biotechnology companies to obtain access to certain projects and/or technologies, 3) increase alliance activity, 4) outsource R&D activities (i.e., vertical disintegration), 5) increase internal R&D efforts, 6) acquire existing mature products through licensing agreements and 7) change their fundamental business model (Higgins and Rodriguez, 2006; Grabowski and Kyle, 2008).

2.2 Mergers, acquisitions and alliances

Over the past 20 years, the pharmaceutical industry has become increasingly concentrated; in 1989, the 10 largest pharmaceutical firms accounted for 28.3 percent of the global market, whereas in 2009, the 10 largest firms accounted for 45.2 percent of the global market

[8] The 1984 Waxman-Hatch Act in the US allowed generics to enter the market without the need for clinical tests of safety and efficacy (Grabowski, 2007).

[9] On November 30, 2011, the patent of Lipitor, the best-selling drug in the pharmaceutical industry, expired. Lipitor had peak sales of $13.4 billion per year and brought in a total of more than $120 billion in its 14 years on the market. EvaluatePharma estimates that $290 billion of sales are at risk from patent expirations between 2012 and 2018. In 2013, only patents of drugs that currently have annual sales of $29 billion will expire.

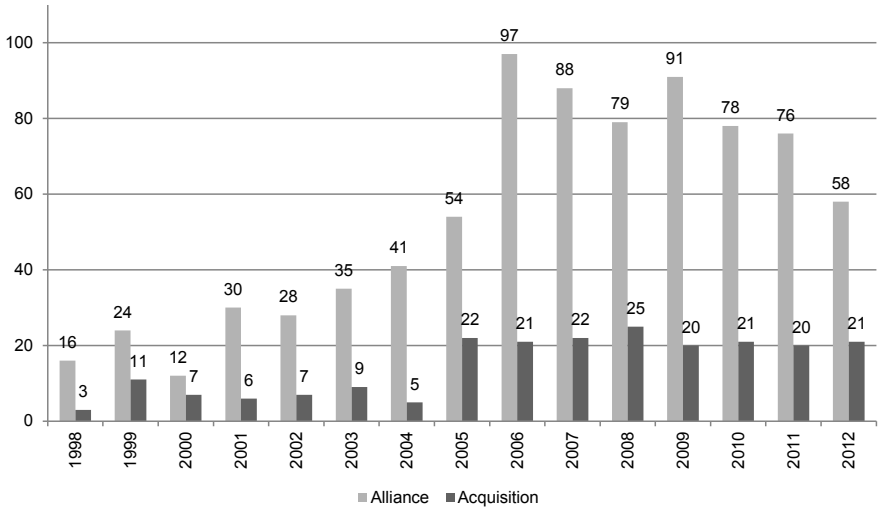
(Grabowski and Kyle, 2008). This shift has mainly resulted from a series of large-scale mergers concentrated within certain periods of time as well as several acquisitions of biopharmaceutical firms. The first merger wave started in the 1989-1990 period, during which the yearly value of pharmaceutical mergers surpassed that of any other year in the 1980s (Ravenscraft and Long, 2000). The second merger wave began in the mid-1990s and continued into the 2000s (Koenig and Mezick, 2004; Danzon et al., 2007). This was followed by a relatively silent period of large-scale mergers over the 2000s until 2009.[10]

Because it takes approximately 10-15 years to develop new drugs, pharmaceutical companies have increasingly relied on alliances to complement their R&D pipelines. The number of alliances between pharmaceutical and biotechnology firms with deal valuations exceeding $100 million has increased more than five-fold; in 1997-2000, the average number of deals was 15 per year, whereas the average number of deals per year was 81 between 2006 and 2012 (Figure 2). Over the same period, the number of acquisitions increased substantially. This study focuses on the acquisition of biotechnology companies and alliances preceding acquisitions.

Recent research has found that the key driver of M&A activity in the pharmaceutical industry is the need to fill gaps in companies' pipelines following the expirations of patents of major commercial products. Danzon et al. (2007), using a sample of 202 biotechnology and pharmaceutical mergers between 1998 and 2001, show that pharmaceutical firms that have relatively old portfolios of marketed drugs exhibit relatively high propensities to acquire firms. Higgins and Rodriguez (2006) find that firms in economic distress with weak pipeline scores and fewer years of market exclusivity for their drugs have relatively high probabilities of engaging in mergers. By employing a desperation index, they find a negative association between acquiring firms' cumulative abnormal returns and degree of desperation. Pisano (1991) suggests that acquiring biotechnology firms can be a risky strategy because there is no guarantee that an acquired firm's human capital will remain in place, especially when acquisitions are used to overcome weaknesses in internal capabilities.

[10] In 2009, Merck merged with Schering-Plough in a deal worth $41 billion, Pfizer purchased Wyeth for $68 billion and Roche acquired the remaining 44 percent of Genentech that it did not already own for nearly $44 billion.

Figure 2. Pharmaceutical-biotech deals (>$100 m) and acquisitions, 1998-2012



Notes: This figure shows the number of deals per year between pharmaceutical and biotech firms exceeding $100 million in total deal value (light grey) and acquisitions (dark grey) between 1998 and 2012. The number of deals per year include not only deals between acquiring and target firms in this study but also between pharmaceutical and biotech firms that, at the time of writing, have not resulted in subsequent acquisitions. Source: Deloitte Recap.

2.3 Wealth effect in M&As

The wealth effect in M&As has been extensively studied in the academic literature. Most studies suggest that the shareholders of acquired (c.f. target) firms realize significant positive abnormal returns, whereas returns to acquiring firms' shareholders are nearly zero (e.g., Eckbo, 2009; Huang and Walkling, 1987; Jensen and Ruback, 1983; Martynova and Renneboog, 2008). Bid premiums are typically in the range of 20-40 percent.

Past empirical studies of the pharmaceutical industry have documented positive stock returns for target firms, whereas the wealth effects for bidders are mixed. Higgins and Rodriguez (2006), using a sample of 160 R&D-related acquisitions in the 1994-2001 period, find that overall abnormal returns for acquiring firms are 3.9 percent, whereas target firms on average gain 16.0 percent. Hassan et al. (2007) find that acquiring firms gain 0.57 percent for US targets but lose 0.55 percent for foreign targets. Ravenscraft and Long (2000) evaluated average abnormal stock market reactions to the announcements of 65 pharmaceutical mergers[11] between 1985 and 1996 and found that average returns to target and bidder firms

[11] Ravenscraft and Long (2000) examine mergers between pharmaceutical companies. In this study, the term "mergers and acquisitions" (or M&A) refers to acquisitions of biotechnology companies.

were 13.3 and -2.2 percent, respectively. Consequently, it remains unclear whether bidder returns gain or lose upon announcements of acquisitions.

2.4. Information asymmetry and alliances

Because of the asymmetric distribution of information between the parties involved in transactions, a corporate acquisition gives rise to adverse selection (Myers & Majluf, 1984). Although corporate bidders have access to publicly available information and due diligence information about target companies, they have only imperfect information about a target company's future cash flow contribution and the prospects of a competing bid. Information asymmetry problems are more common in certain industries than in others and are especially common in R&D-intensive industries such as the high-technology sector (Himmelberg and Petersen, 1994) and the biotechnology industry[12] (Lerner et al., 2003; Hall, 2002), owing to large investments in intangible assets. Investments in intangible assets such as research and development (R&D) create information asymmetries because corporate insiders (i.e., managers) can continuously observe changes on an individual-asset basis, whereas outsiders obtain only highly aggregated information at discrete points in time when R&D information is made public (Aboody and Lev, 2000). Rodriguez and Higgins (2003) find that, due to the difficulties associated with the valuation of intangible assets, little or no value is created for the acquiring firms' shareholders when a significant portion of a target firm's value consists of intangible assets.

The acquisition literature has examined variables such prior alliances with target firms, methods of payment, the use of contingent payments, toehold investments, acquisition premiums, degree of relatedness between acquirers and targets and acquirers' acquisition experience as factors in acquisition performance (e.g., Mantecon, 2009; Reuer, 2005). An alliance[13] provides an opportunity for an acquiring firm to learn more about the quality of the asset and mitigate its informational disadvantages (e.g., Nanda and Williamson, 1995). Several studies (e.g., Mantecon and Chatfield, 2007; Reuer and Koza, 2000) suggest that

[12] Given the considerable information asymmetry associated with R&D (Hall and Lerner, 2009), managers generally know considerably more than outsiders do about the specification of products under development, their likelihood of success, the results of product feasibility tests, and marketing prospects (Aboody and Lev, 2000). Because R&D projects, such as new drugs under development, are unique to the developing firm, investors can generally derive little or no information about a firm's R&D projects by observing the R&D performances of other drugs.

[13] Alliances and joint ventures are used interchangeably in the finance and strategic literature. In a joint venture, two companies invest funds and jointly operate assets in a new company that is jointly owned. A strategic alliance is a legal agreement between two (or more) companies to share access to their technology or other

alliances can mitigate asymmetric information between targets and bidders. In addition, the role of information-producing intermediaries has been studied in the finance literature. Leland and Pyle (1977), for example, argue that "moral hazard problems can be alleviated if the firm gathering the information becomes an intermediary, buying and holding assets on the basis of its specialized information." Empirical studies (e.g., Chan et al., 1997; Porrini, 2004; Higgins and Rodriguez, 2006; Mantecon, 2009) also find that positive announcement periods and abnormal returns to acquirers are positively associated with prior alliances with target firms. However, Ball et al. (1991) show that learning opportunities do not enable bidders to avoid the winner's curse. Pisano (1997) finds that biotech firms exploit their informational advantage regarding the quality of their drug candidates by licensing to pharmaceutical firms candidates that have relatively poor prospects. Mantecon (2009) verifies the importance of the use of alliances in cross-border acquisitions, but the small fraction of alliances preceding acquisitions suggests that preferences for control outweigh gains derived from information exchanges in alliances made prior to acquisitions.[14] Therefore, the question of whether prior alliances can mitigate information asymmetries in acquisitions remains unanswered. Consequently, I hypothesize that:

H_1: Cumulative abnormal returns of acquiring firms are positively associated with prior alliances with target firms.

2.5. Post-acquisition performance

A key challenge in analyzing mergers and acquisitions is to find appropriate measures of transaction success in addition to the commonly used cumulative abnormal returns. While most empirical research on mergers and acquisitions focuses on short-term stock returns surrounding announcement dates, some studies have examined the long-term performance of acquiring firms after mergers and acquisitions by measuring a stock's abnormal performance or examining changes in operating performance using accounting data from the post-merger period. Most empirical studies find predominantly negative post-merger performance in the

assets. Unlike a joint venture, a strategic alliance does not create a new company. This study exclusively focuses on alliances.

[14] In the study of Mantecon (2009), only 4.51% of cross-border acquisitions were jointly owned in joint-ventures.

years following mergers.[15] Agrawal et al. (1992) examine post-merger performance in a sample of 937 US mergers, reporting significant negative abnormal returns of approximately 10 percent over the five-year post-merger period. Loughran and Vijh (1997) find significant negative abnormal returns of 15.9 percent less than matching firms during the five-year period after acquisition. Several studies suggest that the problems associated with information asymmetry may significantly affect the likelihood and performance implications of acquisitions (e.g., Eckbo et al., 1990; Balakrishnan and Koza, 1993; Coff, 1999). An alternative to abnormal stock performance as a measure of long-term performance is adopted by Healy et al. (1992), who use accounting data to study changes in post-acquisition operating performance in a sample of 50 US mergers. They document significant improvements in asset productivity of such firms relative to their respective industry averages, leading to higher operating cash flow returns. However, accounting information may be a poor indicator of transaction success for development-stage research-intensive target companies (Amir and Lev, 1996). Large investments in R&D that are immediately expensed and less frequently capitalized will have two major consequences.[16] First, current performance measures are excessively low (often negative), although one may expect that the more negative current performance is, the more positive future performance is likely to be. Second, measures of current resources and equity are excessively low because few investments are booked as assets. Higgins and Rodriguez (2006) adopt an alternative approach to measuring operating performance in a sample of biopharmaceutical companies by evaluating changes in research pipelines and in the revenues[17] of acquiring firms in the year following acquisition. They find positive changes in acquiring firms' score values and product sales figures in the year following acquisitions. However, they do not examine whether pipeline improvements in acquiring firms differ for acquisitions that are preceded by alliances. Grabowski and Kyle

[15] This result led Jensen and Ruback (1983) to make the following comment: "These post-outcome negative abnormal returns are unsettling because they are inconsistent with market efficiency and suggest that changes in stock prices during takeovers overestimate the future efficiency gains from mergers."

[16] For these firms, accounting information will explain very little of the cross-sectional variation in stock price (e.g., Amir and Lev, 1996; Ely et al., 2003).

[17] Although revenues probably provide the best indicator of transaction success in the long term, a majority of acquisitions in the biopharmaceutical industry involve development-stage companies with no currently approved drugs. In this analysis, the lead R&D projects of 66 percent of companies considered were in the regulatory stage or before. Because marketed drugs must go through an extensive review process by regulatory authorities, such as the FDA, there is reason to believe that information asymmetries are less pronounced for drugs that have been approved for marketing. For approved drugs, there are likely to be other determinants not necessarily attributable to asymmetric information that are more important. Sanofi's acquisition of Genzyme provides an illustrative example. According to the SEC-filings (SC 14D9/ SC 14D9/A), there were major differences of opinion regarding peak sales of the multiple sclerosis drug Lemtrada (although the drug was not yet approved). Genzyme projected peak sales of $3.5 billion per year, while Sanofi projected about $700 million. The companies resolved their difference by agreeing to contingent value rights (CVRs).

(2008) and Higgins and Rodriguez (2006) suggest that it would be interesting to study the long-term effects on R&D performance of interactions between alliances and acquisitions.

Several prior studies have examined the effects of alliances on R&D and innovation, although not within the context of mergers and acquisitions. Pisano (1997) examines the performances of vertically integrated projects versus collaborative projects in the biopharmaceutical industry, finding that collaborative projects have a higher failure rate than vertically integrated projects and concluding that biotechnology firms are likely to exploit their informational advantages and license out low-quality projects. In contrast, Nicholson et al. (2005) do not find a "lemons" problem in what they call the market for know-how. They evaluate productivity at each phase of the drug development process for 900 firms over the 1988-2000 period, finding that products developed in alliances are relatively likely to succeed, at least in later stages of clinical development and especially when the licensee is a large firm. In the context of mergers and acquisitions, if an alliance with a target firm provides an acquiring firm with an informational advantage, i.e., mitigates information asymmetry, then R&D projects co-developed prior to an acquisition should be more likely to advance than projects not preceded by an alliance. Higgins and Rodriquez (2006) argue that it is likely that pre-acquisition information-gathering activities lead to more successful post-acquisition integration. To empirically test this prediction, I hypothesize the following:

H_2: An acquirer's previous alliance with a target correlates positively with post-acquisition R&D performance.

3. Data and methodology

3.1 Data

3.1.1 Sample of acquisitions

The sample of acquisition deals was collected from several sources. I selected completed acquisitions, classified as biotechnology, pharmaceuticals or life sciences in the Zephyr database for the years 1998-2012. This search method also identified acquisitions outside the biopharmaceutical sector; such acquisitions were deleted from the dataset. Unrelated transactions were considered to be those that involved the animal health business, over-the-

counter (OTC) or generic drugs, consumer products and medical devices. I also excluded merger transactions, asset purchases or similar transactions. Ten acquisitions were dropped from the final sample due to inadequate data, and two acquisitions were excluded due to the existence of call options embedded in the alliance contracts prior to acquisitions. The dataset obtained from the Zephyr database was supplemented by transactions data from the HBM Partners website (Pharma/Biotech M&A report) and the Deloitte Recap database. This filtering process yielded 219 acquisitions completed by 70 different firms.

Acquisition dates for the sample were verified using corporate webpages and the Factiva database. Stock price data were obtained from the Thomson Reuters Datastream database. Information on the relatedness of transactions was collected from press releases, obtained from either corporate webpages or the Factiva database, and from S1 filings of acquiring firms in the year prior to acquisition. Transaction details (such as the use of contingent payments and whether the acquisition was financed with cash, stock or both) were obtained from press releases on the corporate webpage or the Factiva database. Data on toehold investments were mainly collected from the Zephyr database and supplemented with information obtained from the Factiva database.

Table 1, Panel A, provides summary statistics for biopharmaceutical acquisitions by year, including the number of acquisitions and mean and median values. In total, 219 biopharmaceutical firms, with a total deal value of $306 billion, were acquired over the 15-year period. There were variations in the number of acquisitions per year. The number of acquired companies reached a record high of 25 acquisitions in 2008, whereas only five firms were acquired in 2004. The number of biopharmaceutical acquisitions was significantly higher in more recent years than at the beginning of the period: 22 percent of the acquisitions occurred between 1998 and 2004, whereas 78 percent occurred between 2005 and 2012. The average (median) deal value was $1,250 ($505). The difference between mean and median deal values indicates that some much larger acquisitions occurred during these years.

Table 1. Summary statistics

Panel A. Biopharmaceutical acquisitions by year

Year	*n*	*Fraction (%)*	*Value ($m)*	*Mean value ($m)*	*Median value ($m)*
1998	3	1	1,500	500	580
1999	11	5	11,598	1,054	550
2000	6	3	4,991	713	575
2001	6	3	20,937	3,490	1,060
2002	7	3	1,307	187	123
2003	9	4	6,152	684	400
2004	5	2	5,543	1,109	1,014
2005	22	10	17,786	808	289
2006	21	10	30,390	1,447	500
2007	22	10	32,234	1,465	357
2008	25	11	70,779	2,831	285
2009	20	9	14,253	713	523
2010	21	10	18,045	859	281
2011	20	9	50,840	2,542	477
2012	21	9	19,446	1,023	563
Total	219	100	305,801	1,250	505

Notes: Panel A provides summary statistics for the sample of 219 biopharmaceutical acquisitions for the period between 1998 and 2012.

Panel B. Biopharmaceutical acquisitions by year, public vs. private target firms

	Public firms				*Private firms*			
Year	*n*	*Value ($m)*	*Mean value ($m)*	*Median value ($m)*	*n*	*Value ($m)*	*Mean value ($m)*	*Median value ($m)*
1998	3	1,500	500	580	0	0	n.a.	n.a.
1999	10	10,948	1,095	539	1	650	650	650
2000	5	4,547	962	802	2	444	222	n.a.
2001	4	20,092	5,023	1,750	2	845	423	n.a.
2002	5	942	188	123	2	365	183	n.a.
2003	8	5,948	743	500	1	204	204	204
2004	3	5,128	1,709	1,300	2	415	208	n.a.
2005	10	14,742	1,474	1,168	12	3,044	254	238
2006	12	26,946	2,245	1,013	9	3,444	383	400
2007	7	26,127	3,732	2,600	15	6,107	407	347
2008	19	69,334	3,503	416	6	1,445	259	235
2009	9	8,590	954	637	11	5,663	515	505
2010	9	13,763	1,529	722	12	4,283	357	355
2011	10	44,862	4,486	438	10	5,978	598	502
2012	11	13,065	1,070	563	10	6,382	677	415
Total	124	266,532			95	39,268		

Panel B provides summary statistics for the sample of 124 public and 95 private biopharmaceutical acquisitions for the period between 1998 and 2012.

Panel C. Total number of acquisitions per firm

Total number of acquisitions	Total number of firms
16	1
11	1
10	2
9	1
8	1
7	3
6	4
5	3
4	3
3	9
2	14
1	28
219	70

Notes: Panel C details the total number of acquisitions per firm for the sample of 219 biopharmaceutical acquisitions for the period between 1998 and 2012.

Table 1, Panel B, details the distribution of public and private biopharmaceutical acquisitions by year. In total, 124 public biopharmaceutical acquisitions generated a total deal value of $267 billion, whereas 95 private biopharmaceutical acquisitions generated a total deal value of $39 billion. Table 1, Panel C, details the distribution of the number of acquisitions per firm. For example, 28 of the 70 firms in this sample were involved in one acquisition, whereas one firm (Pfizer) was involved in 16 acquisitions over the sample period.[18]

3.1.2. Alliance data

Alliance data were obtained from the Deloitte Recap database (formerly Recombinant Capital) and were confirmed using the Factiva database. Deloitte Recap provides comprehensive alliance and deal data with a focus on the pharmaceutical industry from 1973 to the present. The database provides a general description of the nature of the alliance and financial deal terms but does not include information about which R&D project is included in an alliance. To evaluate post-deal performance, I supplemented information about specific R&D projects that were included in alliances with information obtained from corporate

[18] Several studies in the acquisition literature have focused on the effect of acquirers' acquisition experience on acquisition performance but have found mixed results; several studies find no significant association between acquirers' acquisition experience and performance (Haleblian and Finkelstein, 1999; Lubatkin, 1983; Zollo and Singh, 1998), whereas some other studies find a positive relationship (e.g., Fowler and Schmidt, 1989; Hitt et al., 1993). Porrini (2004) and Hayward (2002) provide a comprehensive discussion of acquirers' acquisition experience and argue that although acquisition experience can play a role in the quality of inferences made in subsequent acquisitions, experiences of a prior target may be misapplied to the present target. In untabulated tests, I included a dummy variable equal to one if the acquiring firm acquired more than three firms during the sample period. I also examined alternative cut-off levels but found no association between acquisition experience

webpages and the Factiva database. The alliance data were also verified from an analysis of the project portfolios from the S1-filings of target firms prior to acquisition. Based on prior research, I expect that prior alliances provide opportunities for acquiring firms to learn about the quality of target firms.

3.1.3 Post-deal performance

To analyze the performance of R&D projects in clinical trials, I employed the following methodology. For the target firm, all R&D projects under development were collected from the most recent quarterly or annual report prior to the acquisition. I noted the product ID, molecular target, mechanism of action, indication, therapeutic area, stage of development and whether the R&D project was developed in collaboration with a partner. If a single R&D project had been developed against several indications, I assigned a dummy to the project that was assumed to be the primary indication. In a majority of cases, the indication that was most advanced in the R&D pipeline was the primary indication. To analyze the post-deal performance of R&D projects, I tracked the progress of R&D projects using the acquiring firm's quarterly and annual reports in the years following the acquisition. Most often, the acquiring firm assigned a new product ID to projects, which made data on the molecular target, mechanism of action and indication very helpful in matching R&D projects. For each subsequent year, I noted the stage of development of each acquired R&D project. In most cases, the acquiring firm did not continue development of all of a target firm's R&D projects. Consequently, R&D projects that did not appear in the acquiring firm's R&D portfolio post-acquisition were excluded from the analysis because classifying such projects as failures could bias the results.[19]

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and acquisition performance. Separately, I controlled for firm-specific effects. To ensure that the results were robust, I estimated a fixed effects model. The results did not change.

[19] For example, prior to Roche's acquisition of Memory Pharmaceuticals, the R&D portfolio of Memory Pharmaceuticals contained the following projects: MEM 3454 (Phase 2), MEM63908 (Phase 1), MEM 1003 (Phase 2), MEM 1414 (Phase 1), MEM 1917 (Preclinical), as well as inhibitors targeting PDE 10 and antagonists targeting 5-HT in preclinical trials. The only R&D projects that appeared in Roche's disclosed R&D pipeline post-acquisition were MEM 3454 (R1589) and MEM63908 (R4996), both developed against Alzheimer's disease and which were also included in their preceding alliance. Both projects disappeared from Roche's pipeline, according to the annual report and never advanced to another development stage. As illustrated in this case, only these two projects were included in the analysis.

3.2 Methodology

3.2.1 Event study methodology

I employed the event study methodology to measure stock price reactions around the time of acquisition announcements. First, I employed OLS regression methods to estimate predicted returns, using the following market model[20]:

$$R_{i,t} = \alpha_i + \beta_{i,m} R_{m,t} + \varepsilon_{i,t} \quad (1)$$

where $R_{i,t}$ is the daily market return of acquiring firm *i* over day *t*, $R_{m,t}$ is the return of the value-weighted market portfolio over day *t*, α_i and β_i are the parameters of the market model and $\varepsilon_{i,t}$ is a zero mean disturbance term. Predicted returns were estimated using ordinary least squares (OLS) over an estimation period of 221 days (the time period starting 250 days prior to the equity acquisition announcement and ending 30 days prior to the event). I used an event window of three days, which included the day of the announcement as well as the days before and after. The abnormal return is the difference between a firm's predicted and actual stock price for any given day, derived from the market model:

$$AR_{i,t} = R_{i,t} - \left(\hat{\alpha}_i + \hat{\beta}_{i,m} R_{m,t}\right) \quad (2)$$

where $\hat{\alpha}_i$ and $\hat{\beta}_{i,m}$ are estimates of the regression parameters. For each event in the sample, cumulative abnormal returns were calculated over the event window. The cumulative average abnormal returns across all events, *N*, in the sample are thus:

$$CAR = \frac{1}{N} \sum_{i=1}^{N} \sum_{t=t_1}^{t_2} AR_{i,t} \quad (3)$$

3.2.2 Combined firm returns

Past empirical research on stock market reactions to announcements of biopharmaceutical mergers or acquisitions focuses on the valuation effect on bidders and/or targets, whereas for a sample of large pharmaceutical mergers, only the study of Ravenscraft and Long (2000)

[20] For robustness reasons, I also employed two additional models: 1) the Fama-French three-factor model and 2) a two-factor model in which one factor is the market index (S&P500 index) and the second factor is an industry index (NASDAQ Biotechnology index). Sharpe et al. (1999) suggest using a second factor when the sample is comprised of firms in a single industry to explain more of the variation in the normal return. All models yielded similar results.

considers the valuation effect on combined firms, finding that the effects for combined firms are not significantly different from zero. Following Houston and Ryngaert (1994), cumulative abnormal returns of a combined firm were calculated as the weighted average of gains of bidder and target firms:

$$\frac{MV_{b,i}CAR_{b,i} + MV_{t,i}CAR_{t,i}}{MV_{b,i} + MV_{t,i}} \quad (4)$$

where $MV_{b,i}$ is the market value of the bidding firm's stock five days before the bid announcement date, $MV_{t,i}$ is the market value of the target firm's stock five days before the first acquisition bid of the target and $CAR_{b,i}$ and $CAR_{t,i}$ are the cumulative abnormal returns for the *i*th bidder and target, respectively, over an 11-day window. Statistical significance was evaluated using a *t*-test and a Wilcoxon signed-rank test.

3.2.3 Multivariate regression

To examine the effect of prior alliances with target firms on the cumulative abnormal returns of acquiring firms' shareholders, I used the following model:

$$CAR_i = \alpha + \beta_1 Alliance_i + Controls + \varepsilon_i \quad (5)$$

The dependent variable, cumulative average abnormal returns (CAR), was estimated using the market model (t_{-250} to t_{-21}) and measured over a three-day event window (t_{-1} to t_{+1}). The independent variables were classified into two categories: test variables and control variables.

The main variable of interest, *alliance*, is expected to improve an acquiring firm's ability to evaluate the scientific and managerial expertise of a biotechnology company. The alliance variable takes a value of 1 if the acquiring and target firms had an alliance prior to an acquisition and zero otherwise. A positive value of the coefficient for alliance indicates that an acquiring firm gained an informational advantage through the alliance. The results of the analysis of the interaction between alliance and CAR relates to the first hypothesis (H1).

I included ten control variables that have been used in prior studies in the acquisition literature (e.g., Higgins and Rodriguez, 2006; Mantecon, 2009; Travlos, 1987): relatedness, toehold, earnout, stock, market sentiment, public, cross border, R&D intensity, MV buyer, relative size, bid premium and public firm age. For example, relatedness measures the

similarity between the target and acquiring firms' operations. Acquiring firms with in-house scientific knowledge are expected to have an advantage when evaluating the target firm's operations. The relatedness variable takes a value of 1 if the acquiring and target firms operate in the same therapeutic area and zero otherwise. Toehold is a dummy taking a value of 1 if the acquiring firm owned shares of more than 5 percent in the target firm prior to the announcement of the acquisition and zero otherwise. The toehold variable measures the credibility of the bidding price to uninformed target shareholders. Earnout is a dummy taking a value of 1 if the acquisition contained any contingent payments and zero otherwise. If a buyer and seller have different opinions regarding, e.g., a drug's market potential, the deal can be structured so that it is contingent on the performance of the assets (e.g., Kohers and Ang, 2000; Reuer et al., 2004). Table 2 provides variable definitions.

Table 2. Variable definitions

Variable	Definition/description
CAR	Cumulative average abnormal returns, estimated using a single-factor model (t-250 to t-21) and measured over a three-day event window (t-1 to t+1).
Alliance	Dummy taking a value of 1 if acquiring and target firms had an alliance (i.e. a strategic alliance contract) prior to the acquisition; otherwise 0. A strategic alliance contract could be any of the following types: Co-development, collaboration or license.
Relatedness	Dummy taking a value of 1 if the acquiring firm had prior sales and/or research experience in the same therapeutic category as the target firm; otherwise 0.
Toehold	Dummy taking a value of 1 if the acquiring firm owned shares exceeding 5 percent in the target firm prior to the announcement of the acquisition; otherwise 0.
Earnout	Dummy taking a value of 1 if the acquisition included any contingent payments; otherwise 0.
Stock	Dummy taking a value of 1 if the bid offer contained any stock elements; otherwise 0.
Bid premium	Bid market value of equity divided by the average market value of equity in days t_{-20} to t_{-2}.
MV buyer/value	The ratio between the market value of equity of the acquiring firm 20 days prior to the announcement and the total value of the transaction.
Relative size	The target firm's pre-bid market value of equity divided by the sum of the acquiring and target firm's pre-bid market value of equity.
Market sentiment	NASDAQ biotechnology index performance in the three months prior to the bid announcement date.
Public	Dummy taking a value of 1 if the target firm is a publicly listed company; otherwise 0.
Cross border	Dummy taking a value of 1 if the acquiring firm and the target firm are from different countries.
R&D intensity	Research and development expenses/sales of the acquiring firm in the year preceding the acquisition announcement.
Public firm age	Number of years from IPO to year of acquisition.

Notes: This table provides variable definitions of test and control variables.

Table 3 presents descriptive statistics of the variables. The mean CAR is -0.4 percent for the 219 acquisitions. A widely held view among practitioners and academics is that alliance agreements often lead to complete acquisitions (e.g., Akhigbe et al., 2007; Grabowski, 2011).[21] Fifty acquisitions, or 23 percent of the full sample, were preceded by alliances, a percentage that is lower than the 59 percent reported by Higgins and Rodriguez (2006) but significantly higher than the 4.5 percent reported by Mantecon (2009). In the sample of alliances, the average number of years in an alliance prior to acquisitions was 5.0 years, with a maximum (minimum) of 20 (0.3) years (untabulated). Acquiring firms were likely to make acquisitions in therapeutic categories in which they had prior sales and/or research experience: 82 percent of acquisitions were classified in this category (relatedness). Acquiring firms held shares of 5 percent or more in target firms in 18 (or 8.2 percent of) acquisitions. In these 18 cases, the average percentage of shares held was 21.7 percent (untabulated). The use of earnout payments was recorded in 31.5 percent of acquisitions. However, the use of earnout payments was more common for private target firms (59 percent) than for public firms (10 percent). A majority of the acquisitions were purchased with cash; only 21 percent of the acquisitions included a stock element. The mean (median) bid premium for public target firms was 65.4 (51.4) percent, with a maximum (minimum) of 465 percent (5.6 percent). Eighty-one of the 124 acquisitions of public target firms had bid premiums above 40 percent, and 20 acquisitions had bid premiums above 100 percent. Acquiring firms were significantly larger than target firms: public target firms were approximately 10 percent the size of the sum of acquiring and public target firms. Among total acquisitions, 55.6 percent were acquisitions of public target firms, and 35.6 percent were cross-border acquisitions. A majority of target firms, 81.7 percent, were domiciled in the US, whereas 65.8 percent of acquiring firms were domiciled in the US (untabulated). On average, public target firms were acquired 9.7 years post-IPO.

[21] Pfizer's acquisition of Esperion Therapeutics provides an illustrative example. Pfizer announced on December 22, 2003, its intention to acquire Esperion Therapeutics for $1.3 billion in cash, representing a 54 percent premium to Esperion's average closing share price over the previous 20 trading days. Pfizer believed that Esperion's cardiovascular therapeutics would add a significant string to its own cardiovascular franchise, which was based on lipid-lowering drugs. Pfizer was developing a promising internal candidate drug (Torcetrapib), which was terminated in 2006. When Esperion published Phase 2 clinical results for ETC-216 to treat acute coronary syndromes (ACS), the data showed that the compound met the primary endpoint of reducing fatty plaque volume compared with the baseline. ETC-216 increases high-density lipoprotein (HDL; good) cholesterol, while Lipitor, Pfizer's blockbuster cholesterol drug, lowers low-density lipoprotein (LDL; bad) cholesterol. Pfizer gained access to ETC-216 following the acquisition of Pharmacia, with which Esperion already had had an alliance since 1998. According to the license deal, Pfizer already had US co-marketing rights to ETC-216 and an option to obtain ex-North American rights (Fazeli, 2003). The acquisition of Esperion was expected to add ETC-588 (Phase 2), ETC-642 and several other early-stage HDL drugs. However, Pfizer

Table 3. Descriptive statistics

	n	*Mean*	*Q1*	*Median*	*Q3*	*St. dev*
CAR	219	-0.004	-0.024	-0.0002	0.020	0.033
Alliance	219	0.228	0	0	0	0.421
Relatedness	219	0.822	0	1	1	0.383
Toehold	219	0.082	0	0	0	0.275
Earnout	219	0.315	0	0	1	0.466
Stock	219	0.210	0	0	0	0.408
Bid premium	124	0.654	0.305	0.514	0.770	0.614
MV Buyer/value	219	34.352	10.071	22.007	41.470	39.534
Relative size	124	0.097	0.007	0.037	0.141	0.144
Market sentiment	219	0.034	-0.034	0.031	0.093	0.136
Public	219	0.566	0	1	1	0.497
Cross border	219	0.356	0	0	1	0.480
R&D intensity	219	0.201	0.141	0.174	0.236	0.087
Public firm age	124	9.677	4	8	13	6.723

Notes: This table provides descriptive statistics of the dependent and independent variables. The variables are described in Table 2.

The Pearson correlation matrix for the independent variables used in the cross-sectional regressions is presented in Table 4. None of the bivariate correlations exceeds 0.58.

3.2.4 Measuring post-deal performance

Past empirical research has examined the effects of alliances on R&D and innovation. Pisano (1997), for example, examines the performance of vertically integrated projects versus collaborative projects in the biopharmaceutical industry, finding that collaborative projects have a higher failure rate than do vertically integrated projects and concluding that biotechnology firms are likely to exploit their informational advantages and out-license low-quality projects. In contrast, Nicholson et al. (2005) do not find support for a "lemons" problem in the market for know-how. They evaluate productivity at each phase of the drug development process for 900 firms over the 1988-2000 period and find that products developed in alliances are more likely to succeed, at least in the later stages of clinical development and especially when the licensee is a large firm.

suspended Esperion's R&D activities with respect to ETC-216 in 2007 and sold Esperion back to an investor syndicate in May 2008 for $22.75 million.

Table 4. Pearson correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Alliance													
2. Relatedness	0.225*** (0.001)												
3. Toehold	0.273*** (0.000)	0.035 (0.611)											
4. Earnout	-0.228*** (0.001)	0.018 (0.788)	-0.096 (0.159)										
5. Stock	-0.040 (0.555)	0.082 (0.225)	-0.032 (0.639)	-0.157** (0.020)									
6. Market sentiment	-0.098 (0.147)	0.086 (0.207)	-0.055 (0.419)	0.033 (0.624)	0.163** (0.016)								
7. Public	0.213*** (0.002)	0.046 (0.497)	0.161** (0.017)	-0.517*** (0.000)	0.270*** (0.000)	0.143** (0.035)							
8. Cross border	-0.018 (0.787)	0.028 (0.684)	0.021 (0.764)	-0.053 (0.436)	-0.196*** (0.004)	-0.019 (0.780)	-0.003 (0.963)						
9. R&D intensity	-0.056 (0.413)	-0.034 (0.619)	-0.049 (0.467)	0.148** (0.029)	0.410*** (0.000)	0.092 (0.173)	-0.019 (0.780)	-0.157** (0.020)					
10. MV buyer/value	0.155** (0.022)	-0.076 (0.265)	0.123* (0.069)	-0.032 (0.642)	-0.107 (0.114)	-0.238*** (0.000)	-0.122* (0.072)	-0.088 (0.197)	-0.022 (0.746)				
11. Relative size	-0.160* (0.076)	0.078 (0.390)	-0.026 (0.775)	-0.001 (0.991)	0.329*** (0.000)	0.097 (0.283)	n.a.	0.004 (0.969)	0.340*** (0.000)	-0.271*** (0.002)			
12. Bid premium	0.224** (0.012)	-0.122 (0.177)	0.155* (0.085)	-0.019 (0.830)	-0.196** (0.029)	-0.332*** (0.000)	n.a.	0.004 (0.969)	0.340*** (0.000)	0.583*** (0.000)	-0.265*** (0.003)		
13. Public firm age	-0.198** (0.028)	0.118 (0.191)	0.135 (0.150)	0.036 (0.690)	-0.211 (0.019)	0.144 (0.110)	n.a.	0.187** (0.038)	-0.304*** (0.001)	-0.224** (0.012)	0.180** (0.045)	0.180** (0.045)	

Notes: This table shows pair-wise correlations for the test and control variables in the regression equations. The variables are described in Table 2. The numbers listed horizontally across the top row correspond to the numbers and variables listed vertically in the table. *, **, and *** denote pair-wise correlations that are significantly different from zero at the 10%, 5%, and 1% levels, respectively. *p*-values are in brackets. n.a. denotes not available.

No previous studies have examined the performance of R&D projects after acquisition. The advantage in the present setting arises from the isolation of imperfect information, whereas R&D projects that are out-licensed or vertically integrated can be driven by either imperfect information (lower-quality R&D projects that are out-licensed) or perfect information (R&D projects that are out-licensed due to gains-from-trade). I examined whether R&D projects are more likely to succeed when acquisitions are preceded by alliances than when they are not preceded by prior alliances. I employed the model developed by Nicholson et al. (2005)[22], in which the probability that R&D project *j* originated by company *i* will advance to the next development stage (*A*=1) is a function of drug characteristics (X_j) and a dummy variable ($Alliance_{ij}$) that equals 1 if R&D project *j* of company *i* is developed in an alliance:

$$Prob(A_{ij} = 1) = \alpha + \beta_1 Alliance_{ij} + \beta_2 X_j + Controls + \mu_i \quad (6)$$

A positive and statistically significant coefficient for β_1 is consistent with the view that acquiring firms gain an informational advantage from a preceding alliance with target firms.

The present study focuses on R&D projects in any of the following stages of the drug development process: preclinical, Phase 1, Phase 2, Phase 3 and regulatory (FDA-filed).[23] The lead R&D projects of 66 percent of the companies considered were in the regulatory stage or earlier.[24] Because marketed drugs must undergo an extensive review process by regulatory authorities such as the FDA, there is reason to believe that information asymmetry is less pronounced for drugs that have been approved for marketing.

Information asymmetry may differ across individual stages of the development process.[25] In addition, different phases of research are characterized by different probabilities of success (DiMasi and Grabowski, 2007). Therefore, I performed five separate logit regressions for R&D projects that were in the preclinical stage, Phase 1, Phase 2, Phase 3 and the regulatory

[22] Nicholson et al. (2005) also control for firm size of the acquiring firm by specifying three categories: small companies that originated three or fewer drugs during the sample period, medium-sized companies that originated between four and 24 drugs, and large companies that originated 25 or more drugs. Due to the small variation in the dataset of the present study and because a majority of acquiring firms had more than 25 drugs in their research pipeline, I did not control for the characteristics of the involved firms.

[23] In general, the different phases can be described as follows. Phase 1 trials examine the safety of the drug with healthy volunteers. Phase 2 examines drug efficacy in small-scale patient groups. Phase 3 examines drug efficacy in large-scale patient groups. All pre-Phase 1 activities, such as preclinical research and preclinical development, are grouped into the preclinical category.

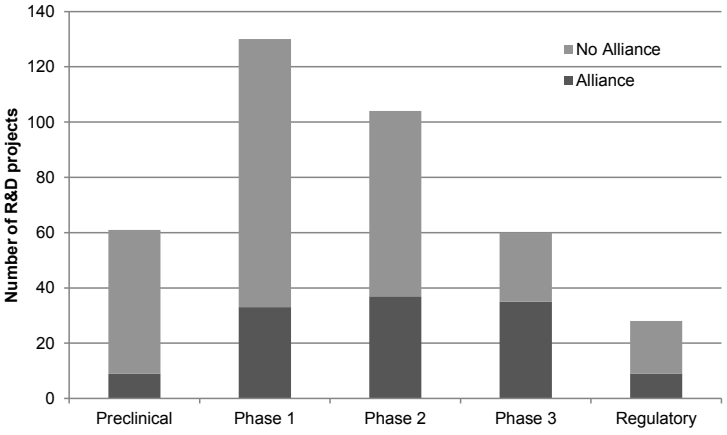
[24] More specifically, the distributions are as follows: 10% in regulatory, 10% in Phase 3, 26% in Phase 2, 8% in Phase 1, and 12% in the preclinical stage.

[25] Nicholson et al. (2005) argue that information asymmetry may be particularly severe in the preclinical phase before R&D projects have demonstrated safety and efficacy in humans.

phase. The dependent variable takes a value of 1 if the R&D project successfully completes a trial and is moved to the next stage and zero otherwise. To draw conclusions related to the second hypothesis (H2), I expect a positive association between prior alliances in the R&D project and R&D performance for a majority of the phases, especially in the later stages.

I included 13 indicator variables (as defined by the World Health Organization) for the R&D projects' therapeutic classes, as different therapeutic classes are associated with different probabilities of success (Kola and Landis, 2004).[26] For example, 51.7 percent of all R&D projects in various stages of development are related to cancer. Some of the other therapeutic classes are infectious diseases (9.9 percent), musculo-skeletal systems (8.1 percent), endocrinology (6.5 percent), and respiratory systems (6.3 percent). In total, 383 R&D projects included in the analysis passed at least one of the different stages. Figure 3 details the distribution of the R&D projects across the different stages.

Figure 3. Distribution of R&D projects per phase



Notes: This figure displays the distribution of R&D projects by phase. Dark blue indicates that the R&D project was developed in an alliance, whereas light blue indicates that the project did not originate in an alliance agreement.

[26] Knight (1921) distinguished between primary and secondary uncertainty. Primary uncertainty refers to the risk, regardless of whether a development project is undertaken in-house or licensed-in from a partner, that a project will fail. Secondary uncertainty is based on the risk that the project will turn out to be a lemon and is only a factor in projects that are licensed from external sources.

4. Empirical results

4.1. Bidder and target returns

Table 5 reports the cumulative abnormal returns (CARs) to bidders, targets, and combined firms. For robustness purposes, I studied the CARs for two event windows and the CARs for both the full 1998-2012 period and two sub-periods, 1998-2004 and 2005-2012, due to the significant increase in the number of acquisitions in the latter period. The two event windows are a three-day (-1, +1) event window and an 11-day (-5, +5) event window centered on the announcement date.

Table 5. Bidder, target and combined firms' cumulative abnormal returns by time period

Time period	n	Mean (%)	*t*-statistic	Median (%)	Signed-rank statistic (z)	*p*-value signed-rank statistic
Panel A. Cumulative abnormal returns – 1 day before to +1 day after the initial announcement						
Bidders						
1998-2012	219	-0.37	-1.14	-0.02	-2.96	0.003
1998-2004	47	-1.90**	-2.45	-1.26	-2.79	0.005
2005-2012	172	-0.10	-0.13	-0.08	-1.59	0.112
Targets						
1998-2012	124	29.45***	9.73	18.62	10.10	0.000
1998-2004	38	16.84***	7.37	14.48	5.68	0.000
2005-2012	86	35.05***	8.47	23.30	8.39	0.000
Combined firms						
1998-2012	124	0.48	1.44	0.36	1.68	0.094
1998-2004	38	-0.27	-0.38	-0.35	-0.53	0.595
2005-2012	86	0.81**	2.21	0.54	2.57	0.010
Panel B. Cumulative abnormal returns – 5 days before to +5 days after the initial announcement						
Bidders						
1998-2012	219	-0.57*	-1.87	-0.71	-3.71	0.000
1998-2004	47	-1.37***	-2.76	-1.26	-2.89	0.004
2005-2012	172	-0.22	-0.58	-0.64	-2.43	0.015
Targets						
1998-2012	124	16.49***	10.53	10.80	10.23	0.000
1998-2004	38	10.55***	7.24	8.81	5.66	0.000
2005-2012	86	19.12***	9.04	13.27	8.54	0.000
Combined firms						
1998-2012	124	0.13	0.52	-0.27	-0.49	0.626
1998-2004	38	-0.37	-0.66	-0.63	-1.59	0.111
2005-2012	86	0.35	1.42	0.02	0.64	0.525

Notes: This table shows cumulative abnormal returns (CARs) to bidders, targets, and combined firms. For robustness purposes, I included two event windows (3- and 11-day event windows) and two sub-periods (1998-2004 and 2005-2012) in the full 1998-2012 period. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

As reported in Table 5, Panel A, the CARs of bidders over a three-day event window for the full 1998-2012 period average -0.37 percent, which is not statistically significant. A sub-group analysis shows that the CARs for the sub-period 1998-2004 average -1.90 percent, which is statistically significant (*t*-statistic -2.45), while the CARs for the more recent period of 2005-2012 are negative (-0.10 percent) and are not statistically significant. Median returns are nearly identical to mean returns (Table 5). The returns to target firms are 29.45 percent (*t*-statistic 9.73) for the full 1998-2012 period. A sub-group analysis indicates that returns to target firms are significantly higher in more recent years: 35.05 percent (2005-2012) compared with 16.84 percent (1998-2004). For comparison, Higgins and Rodriguez (2006) report average abnormal returns of 16 percent to target shareholders, using a sample of 160 biopharmaceutical acquisitions from 1994 to 2001.

Panel B of Table 5 reports that CARs for bidders over an 11-day event window for the full 1998-2012 period were -0.57 percent (*t*-statistic -1.87). For the 1998-2004 and 2005-2012 sub-periods, the returns to bidders were -1.37 percent (*t*-statistic -2.76) and -0.22 percent (*t*-statistic -0.58), respectively. These findings confirm the results obtained for the shorter event window. In summary, the results indicate that bidder returns are, on average, close to zero, whereas target firms gain significantly more.

4.2. Combined firm returns

CARs were calculated for the combined firms following the methodology of Houston and Ryngaert (1994). As reported in Panel A of Table 5, over the three-day event window, CARs for the combined firms are not statistically significantly different from zero. Average CARs for the 1998-2004 and 2004-2012 sub-periods are -0.27 percent (*t*-statistic -0.38) and 0.81 percent (*t*-statistic 2.21), respectively. Target returns increased significantly over the latter time period (2005-2012), and returns to bidders also increased over the same time period.

Another way to compute total value created is to compute the dollar value created for each deal (target abnormal return times target market value plus bidder abnormal return times bidder market value). The sum of the dollar value for all 119 public acquisitions is $28.4 billion. Panel B of Table 5 reports CARs for combined firms over the 11-day event window. On average, CARs are not statistically significantly different from zero for the 1998-2012 period. In summary, these results indicate that average returns of combined firms over a three-day event window are positive but not statistically significant for the full 1998-2012 period, although they appear to be improving, as the 2005-2012 sub-period yields positive and

statistically significant results. This finding indicates that acquisitions create shareholder wealth.

4.3. Distribution of CARs to bidders

Table 6, Panel A, presents the distribution of CARs for bidders sorted by different ranges. The table includes the dispersion of cumulative abnormal returns from the study of Higgins and Rodriguez (2006) to display differences in the datasets (Higgins and Rodriguez's dataset covers the 1994-2001 sub-period, whereas this study covers the 1998-2012 period). The panel shows that 51 percent of the sample of firms in the 1998-2012 period generated negative returns and that 39 percent of firms in the 1994-2001 period generated negative returns. The table also shows that the majority of firms (90 percent) with CARs in the range of -5 to +5 percent are in the 1998-2012 sample, whereas only 50 percent of such firms are in the 1994-2001 sample. From this panel, it is also apparent that the fraction of firms with CARs in the range above +5 percent is significantly higher in the 1994-2001 period (39 percent) than in the 1998-2012 period (3 percent). I employed the Skewness/Kurtosis test for normality and found a *p*-value of less than 0.01, indicating that the null of normality is rejected.[27]

Table 6. Distribution of cumulative abnormal returns to bidders

Panel A. All firms

	1998-2012		*Higgins & Rodriguez (2006): 1994-2001*	
Magnitude	*n*	*Fraction (%)*	*n*	*Fraction (%)*
CAR ≤ -15.0%	1	0	4	3
-15.0% < CAR < -10.0%	2	1	3	2
-10.0% ≤ CAR < -5.0%	11	5	12	8
-5.0% ≤ CAR < -0.0%	99	45	41	26
0.0% ≤ CAR < 5.0%	99	45	38	24
5.0% ≤ CAR < 10.0%	4	2	29	18
10.0% ≤ CAR < 15.0%	3	1	17	11
15.0% ≤ CAR	0	0	16	10
Total	219	100	160	100

[27] As some values were negative, I repeated the Skewness/Kurtosis test using the logarithmic value of the CARs plus a constant. This transformation resulted in a *p*-value of 0.12; hence, the null can be rejected. Consequently, the logarithmic value of the CARs was employed in the cross-sectional regressions using CAR as a dependent variable.

Panel B. Public vs. private target firms

	Public target firms		*Private target firms*	
Magnitude	*n*	*Fraction (%)*	*n*	*Fraction (%)*
CAR ≤ -15.0%	1	1	0	0
-15.0% < CAR < -10.0%	2	2	0	0
-10.0% ≤ CAR < -5.0%	11	9	0	0
-5.0% ≤ CAR < -0.0%	57	46	42	44
0.0% ≤ CAR < 5.0%	49	40	50	53
5.0% ≤ CAR < 10.0%	2	2	2	2
10.0% ≤ CAR < 15.0%	2	2	1	1
15.0% ≤ CAR	0	0	0	0
Total	124	100	95	100

Notes: Panel A provides the distribution of cumulative abnormal returns (CARs) for bidder firms. For comparative purposes, the distribution of CARs from the study of Higgins and Rodriguez (2006) is included. Panel B provides the distribution of cumulative abnormal returns (CARs) for bidder firms when the target firm is either public or private.

Table 6, Panel B, presents the distribution of cumulative abnormal returns for bidders sorted by different ranges as well as for public and private target firms. The panel shows that 86 percent (97 percent) of firms with CARs in the range of -5 to +5 percent are public (private) target firms. Interestingly, 12 percent of bidders for public target firms have CARs of -5 percent or below, whereas the corresponding figure for private target firms is zero percent.

4.4 Univariate analysis of CARs of bidders

A univariate analysis of the relationship between CARs of bidders and a set of test variables—alliance, relatedness, earnout payments, and toehold investments—is reported in Table 7 (the variables are defined in Table 2.) The purpose of this section is to evaluate which of these mechanisms are most beneficial to acquiring firms. I anticipate that all four test variables should generate high CARs for acquiring firms, although I primarily focus on the alliance variable as a key indicator of whether information asymmetries can be mitigated.

In Table 7, Panel A reports CARs of acquiring firms for the overall sample, while Panel B reports CARs of bidders for public and private target firms. Panel A shows that mean (median) cumulative abnormal returns to bidders in the overall sample is -0.37 percent (-0.02), which is not statistically significant. This result contrasts with the results of Higgins and Rodriguez (2006), who find overall CARs of 3.91 percent. Panel B of Table 7 shows that mean CARs of bidders differ slightly, depending on whether the target firm is public or private, but this result is not statistically significant.

Table 7. Univariate analysis of cumulative abnormal returns to bidders

	n	Mean CAR (%)	*t*-test	Median CAR (%)	Max CAR (%)	Min CAR (%)
Panel A. Overall						
Acquirer CAR	219	-0.37		-0.02	13.42	-20.40
Alliance			0.61 (1.15)			
Prior alliance	50	0.11		0.22	4.39	-5.05
No prior alliance	169	-0.51		-0.09	13.42	-20.40
Relatedness			2.30*** (4.09)			
Prior sales or R&D experience	180	0.04		0.17	13.42	-20.40
No prior sales or R&D experience	39	-2.26		-1.21	1.14	-14.72
Toehold investments			-0.38 (-0.46)			
Prior toehold	18	-0.71		-0.45	4.39	-5.08
No prior toehold	201	-0.33		-0.01	13.42	-20.40
Earnout payments			-0.34 (-0.71)			
Earnout	69	-0.60		-0.09	11.67	-14.72
No earnout	150	-0.26		0.00	-20.40	13.42

Panel B. Public vs. private target firms

	Public firms			Private firms		
	n	Mean CAR(%)	t-test	n	Mean CAR(%)	t-test
Acquirer CAR	124	-0.89		95	0.31	
Alliance			1.35* (1.77)			0.04 (0.06)
Prior alliance	38	0.05		12	0.28	
No prior alliance	86	-1.30		83	0.32	
Relatedness			3.25*** (3.81)			0.69 (1.22)
Prior sales or R&D experience	100	-0.26		80	0.42	
No prior sales or R&D experience	24	-3.51		15	-0.27	
Toehold investments			0.27 (0.25)			1.39 (1.18)
Prior toehold	15	-0.65		3	-1.03	
No prior toehold	109	-0.92		92	0.36	
Earnout payments			-4.08*** (-3.70)			0.01 (0.01)
Earnout	13	-4.54		56	0.32	
No earnout	111	-0.46		39	0.31	

Notes: This table shows cumulative abnormal returns (CARs) to bidders. Panel A provides descriptive statistics for the overall sample, and Panel B reports on public and private firms separately. The variables are described in Table 2. The t-test measures whether each of the subcategories is statistically different from the others (differences in means). *t*-statistics are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Next, CARs are examined in relation to the alliance variable. Average CARs of firms with prior alliances with target firms are 0.11 percent, which is not statistically different from zero. By comparison, returns of firms without prior alliances with target firms are -0.51 percent (statistically different from zero at the 10 percent level). The difference in means is positive but not statistically significant. This finding indicates that prior alliances with target firms are not associated with higher bidder returns. Panel B of Table 7 shows that the difference in means between CARs of firms with prior alliances and CARs of firms without such alliances is positive and statistically significant at the 10 percent level when the target firm is publicly listed. Having a prior alliance with a target firm is more common among public target firms than private target firms; approximately 31 percent of public target firms have prior alliances with acquiring firms compared to only 13 percent of private target firms.

Table 7 additionally provides average CARs for other factors, such as related transactions, toeholds and earnout payments, that are associated with information asymmetry between bidder and target. Average CARs of firms in related transactions are 0.04 percent, which is not statistically different from zero, whereas returns to firms in non-related transactions are -2.26 percent (statistically significant at the 1 percent level). The difference in means is positive and statistically significant at the 1 percent level for the overall sample and for the sub-sample of public target firms. These descriptive statistics show that acquiring firms tend to acquire firms in therapeutic areas in which they either have prior research and/or sales experience; 82 percent of acquisitions are made within the same therapeutic area. Average CARs of firms with a prior toehold in the target firm is -0.71, which is not statistically different from zero. By comparison, average CARs of firms without a prior toehold is -0.33, which is also not statistically different from zero. The difference in means is -0.38, which is not statistically significant (*t*-statistic -0.46). The low proportion of prior toehold investments preceding acquisitions suggests that toehold investments are not an important determinant of CARs.

Finally, average CARs of firms in which transactions include earnout payments is -0.60 percent, which is not statistically different from zero. Average CARs of firms with no earnout payments are -0.33 percent, which is also not statistically different from zero. The difference in means is -0.34, which is not statistically significant (*t*-statistic -0.71). However, sub-group analysis shows that the difference in means is negative and statistically significant at the 1 percent level for public target firms. A potential explanation for the negative stock price reaction is that although contingent payments are used in acquisitions to address adverse

selection in the presence of information asymmetries (Akerlof, 1970), such payments may also signal a high degree of market uncertainty (Bruner, 2002). A comparison between public and private target firms shows that the use of contingent payments is much more common in acquisitions of private target firms (59 percent) than of public target firms (10 percent).

4.5 Multivariate regression analysis of CARs

The results from the regression analysis are reported in Table 8 across seven specifications of the test variables both separately and with controls. The dependent variable in these regressions is the three-day CAR for each acquiring firm in the sample. The first hypothesis (H1) refers to the alliance variable. I also included several control variables, such as relatedness, toehold, and earnout. The adjusted *R*-square values for the models are higher than those reported in other studies (e.g., Mantecon, 2009; Moeller & Schlingemann, 2005), and all models are characterized by statistically significant *F*-values. A comparison across the models in Table 8 shows that the variables provide incremental explanatory power.

In Model 1, the coefficient for the alliance variable is positive but statistically insignificant (*p*-value = 0.165). This indicates that acquiring firms do not gain from prior alliances with target firms (i.e., there is no support for H1). This result contrasts with the results of Higgins and Rodriguez (2006), Chan et al. (1997), Mantecon (2009) and Porrini (2004) but supports the view of Ball et al. (1991) that alliances do not necessarily help acquiring firms learn about the true quality of target firms. There are several reasons why prior alliances may play a role in the process of learning about the quality of target firms. For example, the nature of an alliance (licensing or co-development) may be an important factor in learning about the true quality of a target. In the majority of alliance agreements, buyers assume full responsibility for the development of R&D projects, in contrast to projects that are co-developed and in which scientists from both companies collaborate closely and exchange information. Furthermore, the study of Higgins and Rodriguez (2006) finds that target and acquiring firms have an average of four alliances prior to acquisitions, which is considerably more alliances than are observed in this study, where the average is approximately 1. Another important factor is whether the preceding alliance is primary or secondary in nature.[28]

[28] For example, on July 26, 2000, Immunex and Abgenix entered into a joint development and commercialization agreement for ABX-EGF in Phase 1, created by Abgenix. On December 17, 2001, Amgen acquired Immunex and thus inherited the ABX-EFG program. When Amgen acquired Abgenix on December 12, 2005, ABX-EFG was in the regulatory phase for colorectal cancer (primary indication) and in Phase 2 for other cancers.

Table 8. Bid announcement effect, private and public target firms

	Predicted Sign	(1)	(2)	(3)	(4)	(5)	(6)
Alliance	+	0.008				0.003	0.012
		(0.165)				(0.577)	(0.479)
Relatedness	+		0.022***			0.021***	0.022***
			(0.000)			(0.000)	(0.000)
Toehold	+			-0.003		-0.003	-0.005
				(0.688)		(0.721)	(0.393)
Earnout	+				-0.013**	-0.012**	-0.011*
					(0.027)	(0.035)	(0.076)
Stock	+	-0.010	-0.008	-0.010	-0.012*	-0.011*	-0.007
		(0.130)	(0.183)	(0.118)	(0.056)	(0.091)	(0.420)
Market sentiment	+	0.018	0.020	0.016	0.020	0.024	0.026
		(0.280)	(0.213)	(0.349)	(0.232)	(0.136)	(0.136)
Public	+	-0.011**	-0.010**	-0.009*	-0.016***	-0.016***	-0.017***
		(0.021)	(0.034)	(0.059)	(0.004)	(0.004)	(0.003)
Cross border	+	0.005	0.005	0.005	0.004	0.005	0.006
		(0.281)	(0.230)	(0.283)	(0.377)	(0.306)	(0.206)
R&D intensity	+/-	-0.039	-0.048	-0.033	-0.030	-0.048	-0.054
		(0.253)	(0.138)	(0.331)	(0.366)	(0.143)	(0.264)
MV buyer/value	-	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		(0.318)	(0.274)	(0.214)	(0.307)	(0.382)	(0.461)
Relatedness × Alliance							-0.040***
							(0.000)
Toehold × Alliance							0.007
							(0.454)
Earnout × Alliance							-0.005
							(0.703)
Stock × Alliance							-0.020*
							(0.087)
Market sentiment × Alliance							-0.030
							(0.344)
Public × Alliance							0.013
							(0.182)
Cross border × Alliance							-0.001
							(0.871)
R&D intensity × Alliance							0.130*
							(0.051)
MV buyer/value × Alliance							-0.0001
							(0.795)
Constant		0.004	0.011	-0.002	0.013	0.027	-0.001
		(0.864)	(0.584)	(0.910)	(0.548)	(0.206)	(0.907)
Year dummies		Yes	Yes	Yes	Yes	Yes	Yes
Firm-fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Number of observations		219	219	219	219	219	219
Adj R^2		0.065	0.124	0.057	0.078	0.133	0.194
F-value		2.90	4.87	2.65	3.31	4.03	4.33
(*p*-value)		(0.004)	(0.000)	(0.009)	(0.001)	(0.000)	(0.000)

Notes: This table provides the estimates of the linear regressions. The sample consists of 219 biopharmaceutical acquisitions of private and public targets firms in the years 1998-2012. The dependent variable is cumulative average abnormal returns (CARs) estimated using a single-factor model (t_{-250} to t_{-21}) and measured over a three-day event window (t_{-1} to t_{+1}). The independent variables are defined in Table 2. For robustness purposes, all *t*-tests are two-tailed and computed using the Huber-White-Sandwich estimator of variance, which produces consistent standard errors. *p*-values are displayed in parentheses. *, **, and *** indicate values that are significantly different from zero at the 10%, 5%, and 1% levels, respectively.

In Model 2, relatedness is positive and statistically significant (*p*-value < 0.000). This result suggests that the stock market favors acquisitions made in therapeutic areas similar to those in which an acquiring firm has prior sales and/or research experience. Put differently, diversifying acquisitions into areas in which an acquiring firm has no prior experience is

negatively associated with bidder returns. This supports the view of Haeussler (2007) that internal scientific capabilities are necessary for knowledge exploitation.

In Model 3, toehold investments are found to be statistically insignificant (p-value = 0.688). The low proportion of prior toehold investments suggests that they are not an important factor in bidder returns, a conclusion that is consistent with the findings of Mantecon (2009). In Model 4, earnout is negative and statistically significant (p-value = 0.027). This result contrasts that of Kohers and Ang (2000) and provides support for the view that earnout may signal a high degree of market uncertainty (Bruner, 2002). Model 5 includes all test and control variables, with results that are robust to prior specifications.

The main finding presented thus far is that there is no association between the alliance variable and stock market reactions with respect to acquiring firms. Firms with prior alliances that own shares in the target firm may deter other companies from acquiring the target firm. To examine this issue, I constructed interaction variables using the independent variables and the alliance dummy variable. The results are shown in Model 6. The interaction variable between toehold and alliance is statistically insignificant, which implies that acquiring firms with prior alliances and equity ownership in target firms do not necessarily bid from a favorable position. Contrary to expectations, the interaction variable between alliance and relatedness is negative and statistically significant (p-value < 0.000). One possible reason for this variable is that the informed buyer is willing to pay more, even when the stock market does not reward the purchase price.

The regressions were re-run for the sub-sample of public target firms. In this regression, I included some additional variables that are available for public firms: relative size, bid premium, and public firm age (Table 2 presents the variable definitions). Firms with prior alliances with target firms tend to pay significantly higher bid premiums than firms without prior alliances (86 versus 56 percent; untabulated). This result is consistent with the notion that informed buyers are willing to pay more, whereas uninformed buyers require discounts. The results, reported in Table 9, are similar to those for the overall sample. Although the univariate analysis for public target firms in Panel B of Table 7 indicates that the difference between the CARs of bidders with prior alliances and bidders without prior alliances is statistically significant at the 10 percent level when controlling for relative size, bid premium, and public firm age, the coefficient for the alliance variable is statistically insignificant (p-

value = 0.301). This result indicates that acquiring firms do not gain informational advantages from alliances prior to acquisitions.

Table 9. Bid announcement effect, public target firms

	Predicted Sign	(1)	(2)	(3)	(4)	(5)	(6)
Alliance	+	0.009 (0.301)				0.002 (0.791)	-0.010 (0.522)
Relatedness	+		0.035*** (0.000)			0.030*** (0.000)	0.028*** (0.000)
Toehold	+			-0.001 (0.880)		0.0001 (0.987)	-0.0003 (0.961)
Earnout	+				-0.037*** (0.009)	-0.038** (0.035)	-0.026* (0.052)
Stock	+	-0.005 (0.625)	-0.005 (0.565)	-0.009 (0.348)	-0.005 (0.571)	-0.003 (0.750)	-0.003 (0.747)
Market sentiment	+	0.027 (0.273)	0.030 (0.136)	0.024 (0.315)	0.032 (0.108)	0.035* (0.071)	0.028 (0.154)
Cross border	+	0.009 (0.275)	0.010 (0.126)	0.007 (0.294)	0.004 (0.485)	0.008 (0.210)	0.008 (0.215)
R&D intensity	+/-	-0.079 (0.157)	-0.116* (0.090)	-0.108 (0.132)	-0.093 (0.204)	-0.104 (0.144)	-0.095 (0.175)
MV buyer/value	-	0.0001 (0.389)	0.0001 (0.261)	0.0001 (0.286)	0.0001 (0.240)	0.0001 (0.255)	0.0001 (0.197)
Relative size	+	0.045 (0.180)	0.025 (0.249)	0.023 (0.354)	0.015 (0.504)	0.020 (0.358)	0.021 (0.438)
Bid premium	-	-0.004 (0.581)	-0.005 (0.635)	-0.005 (0.686)	-0.001 (0.706)	-0.002 (0.871)	-0.038 (0.162)
Bid premium^2		0.0001 (0.982)	0.0003 (0.929)	0.001 (0.862)	-0.001 (0.877)	-0.001 (0.857)	0.020* (0.073)
Public firm age	+/-	-0.0001 (0.590)	-0.0002 (0.736)	-0.0004 (0.554)	-0.0001 (0.664)	-0.0001 (0.968)	-0.0001 (0.997)
Relative size × Alliance							-0.008 (0.872)
Bid premium × Alliance							0.037 (0.209)
Bid premium^2 × Alliance							-0.022* (0.057)
Public firm age × Alliance							0.0003 (0.694)
Constant		-0.039 (0.306)	-0.018 (0.435)	0.013 (0.510)	0.010 (0.640)	-0.017 (0.448)	-0.007 (0.774)
Year dummies		Yes	Yes	Yes	Yes	Yes	Yes
Firm-fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Number of observations		124	124	124	124	124	124
Adj R^2		0.063	0.219	0.098	0.174	0.259	0.273
F-value		1.83	6.05	1.71	3.38	4.82	3.99
(*p*-value)		(0.063)	(0.000)	(0.087)	(0.001)	(0.000)	(0.000)

Notes: This table provides estimates of the linear regressions. The sample consists of 124 biopharmaceutical acquisitions of public target firms in the years 1998-2012. The dependent variable is cumulative average abnormal (CAR) returns, estimated using a single-factor model (t_{-250} to t_{-21}) and measured over a three-day event window (t_{-1} to t_{+1}). The independent variables are defined in Table 2. For robustness purposes, all *t*-tests are two-tailed and computed using the Huber-White-Sandwich estimator of variance, which produces consistent standard errors. *p*-values are displayed in parentheses. *, **, and *** denote indicate values that are significantly different from zero at the 10%, 5%, and 1% levels, respectively.

For the control variables, the results are consistent with the prior results for private and public target firms. The coefficient for the relatedness variable is positive and statistically significant (*p*-value < 0.000), whereas the coefficient for the toehold variable is statistically insignificant,

Table 10. Variations over time

	Predicted Sign	(1)	(2)	(3)	(4)
Alliance	+	0.0003	0.001	0.001	-0.013
		(0.940)	(0.948)	(0.818)	(0.352)
Relatedness	+	0.022***	0.023**	0.029***	0.025*
		(0.000)	(0.027)	(0.000)	(0.076)
Toehold	+	-0.006	-0.016	-0.001	-0.006
		(0.234)	(0.172)	(0.997)	(0.793)
Earnout	+	-0.004	0.020	-0.030**	0.017
		(0.454)	(0.407)	(0.033)	(0.368)
Stock	+	-0.014	-0.018	0.001	-0.035**
		(0.109)	(0.193)	(0.940)	(0.033)
Market sentiment	+	0.017	0.007	0.037*	0.013
		(0.231)	(0.730)	(0.074)	(0.638)
Cross border	+	0.005	-0.005	0.007	-0.014
		(0.169)	(0.552)	(0.260)	(0.317)
R&D intensity	+/-	-0.037	-0.100	-0.105	-0.256**
		(0.366)	(0.179)	(0.141)	(0.011)
MV buyer/value	-	0.0001	0.0001	0.0001	-0.0003
		(0.168)	(0.897)	(0.214)	(0.448)
Relative size	+			0.020	0.098**
				(0.364)	(0.022)
Bid premium	-			-0.005	-0.156**
				(0.726)	(0.022)
Bid premium^2				-0.0002	0.095*
				(0.883)	(0.054)
Public firm age	+/-			-0.0001	-0.003
				(0.883)	(0.307)
Time		-0.001	-0.028	0.009	-0.166**
		(0.939)	(0.328)	(0.443)	(0.019)
Alliance × Time			0.001		0.018
			(0.973)		(0.223)
Relatedness × Time			-0.002		0.009
			(0.855)		(0.602)
Toehold × Time			0.012		0.005
			(0.354)		(0.837)
Earnout × Time			-0.028		-0.061**
			(0.249)		(0.018)
Stock × Time			0.001		0.040*
			(0.952)		(0.060)
Market sentiment × Time			0.010		-0.008
			(0.725)		(0.844)
Cross border × Time			0.011		0.022
			(0.218)		(0.179)
R&D intensity × Time			0.129		0.297*
			(0.162)		(0.057)
MV buyer/value × Time			0.0001		0.0004
			(0.892)		(0.311)
Relative size × Time					-0.102**
					(0.036)
Bid premium × Time					0.170**
					(0.013)
Bid premium^2 × Time					-0.100**
					(0.044)
Public firm age × Time					0.003
					(0.180)
Constant		-0.014	0.005	-0.021	0.107
		(0.241)	(0.852)	(0.352)	(0.109)
Number of observations		219	219	124	124
Adj R^2		0.142	0.176	0.265	0.448
F-value		4.59	4.09	4.43	2.83
(*p*-value)		(0.000)	(0.000)	(0.000)	(0.000)

Notes: This table provides the estimates from the linear regressions. The sample consists of 124 biopharmaceutical acquisitions of public target firms in the years 1998-2012. The dependent variable is the cumulative average abnormal (CAR) returns estimated using a single-factor model (t_{-250} to t_{-21}) and measured over a 3-day event window (t_{-1} to t_{+1}). The independent variables are defined in Table 2. For robustness reasons, all *t*-tests are double-sided and computed using the Huber-White-Sandwich estimator of variance that produces consistent standard errors. *p*-values are displayed in parentheses. *, **, and *** denote that the value is significantly different from zero at the 10%, 5%, and 1% levels, respectively.

and the coefficient for the earnout variable remains negative and statistically significant (*p*-value = 0.009). For public firms, I included the bid premium (Travlos, 1987) and bid premium squared to examine whether there is a positive relationship between bidders and target returns up to a threshold. Contrary to expectations, the coefficient for bid premium squared is statistically insignificant, which indicates that there is no non-linear relationship between bidder returns and takeover premiums. However, in Model 6, the interaction between bid premium and alliance is statistically insignificant, whereas the interaction between bid premium squared and alliance is negative and statistically significant. This indicates that there is a non-linear relationship between bidder returns and takeover premiums when acquisitions are preceded by alliances.

Due to the significant increase in the number of alliances and acquisitions in the 2005-2012 period compared with the 1998-2004 period, I examined whether the results are robust to different time periods. The results are displayed in Table 10. Models 3 and 4 specify the same regressions for public firms but with four additional control variables included. For the sample of public and private firms, the time variable is statistically insignificant in Models 1 and 2, which indicates that returns to acquiring firms did not change over time. The interaction between alliance and time is statistically insignificant in both Models 2 and 4, which indicates that there is no change between the two time periods.

4.6 Post-acquisition R&D performance

The findings of the first section suggest that acquiring firms cannot exploit informational advantages from alliances with target firms prior to acquisitions.[29] It is therefore interesting to evaluate the long-term impact on R&D performance of the interaction between alliances and acquisitions. If an alliance with a target firm provides the acquiring firm with an informational advantage, i.e., mitigates information asymmetry, then R&D projects that are co-developed prior to acquisition should be more likely to advance to subsequent stages of development than should projects that are not preceded by such alliances.

I performed five separate logit regressions for R&D projects that were in the preclinical stage, Phase 1, Phase 2, Phase 3 and the regulatory phase. The dependent variable takes a value of 1 if an R&D project successfully completes a trial and moves to the next stage and zero otherwise. A positive and statistically significant coefficient for β_1 is consistent with the view

[29] A potential limitation of the short-term event study methodology is that the likelihood of acquisition of a target firm is already incorporated into the stock price at the time of the announcement.

that acquiring firms gain an informational advantage from prior alliances with target firms. Several control variables are included. The results from the logit regressions are presented in Table 11.

Table 11. Post-acquisition R&D performance

	Dependent variable: 1 if completed phase				
	Drugs that started Preclinical	Drugs that started Phase 1	Drugs that started Phase 2	Drugs that started Phase 3	Drugs that were submitted to regulatory authorities
Constant	15.793	-1.154	-15.215	15.083	16.079
Alliance	1.063 (0.347)	0.477*** (0.010)	0.572 (0.212)	0.937 (0.173)	1.022 (0.474)
Disease category dummies	Yes	Yes	Yes	Yes	Yes
Number of observations	61	130	104	60	28
χ^2-statistic (*p*-value)	182.18 (0.000)	13.50 (0.046)	539.11 (0.000)	524.94 (0.000)	169.56 (0.000)
Pseudo R^2	0.047	0.082	0.055	0.220	0.092

Notes: This table provides the estimates from of logit regressions. The dependent variable equals 1 if an R&D project that started a phase reaches the next phase, zero otherwise. The data were collected from corporate webpages, quarterly filings, S1-filings, and annual reports. *p*-values are in parentheses. All regressions contain White's heteroscedastic-consistent standard errors. *, **, and *** indicate values that are significantly different from zero at the 10%, 5%, and 1% levels, respectively.

The coefficients for the alliance variables are positive but only statistically significant for drugs that started Phase 1 (*p*-value = 0.010), which suggests that R&D projects developed through an alliance prior to an acquisition are more likely to complete Phase 1 trials than are R&D projects not developed through such an alliance. However, this finding does not hold for the other stages of development and does not lend overall support to the view that pharmaceutical firms gain informational advantages through prior alliances (i.e., there is no support for H2), at least not advantages that are sufficient to move R&D projects to the next stage. There are several potential reasons why this may be the case. The main purpose of Phase 1 clinical trials is to demonstrate the safety of a drug in healthy volunteers. In contrast, preclinical trials evaluate the efficacy of the drug in animals, whereas Phase 2 and Phase 3 trials are used to examine the efficacy (as well as safety) of a drug in patients who have the targeted disease. Because later-stage trials are no more likely than early-stage trials to succeed, advancing the drug in Phase 1 could be costly. Due to the significant costs of clinical trials, especially in the later stages of development, it is in the interest of developers that new projects fail earlier in development rather than later. Although cost reduction and increased R&D productivity are key objectives of any drug developer, an important question is what

organizational and strategic factors affect decision-making regarding advancement of a project to the next stage and the role of alliances.

Target firms generally have several R&D projects in different stages of development at a given time. In press releases announcing corporate acquisitions, acquiring firms generally state the acquisition motive and list the key R&D projects of the target firm. In untabulated tests, I included a dummy for R&D projects mentioned in press releases because non-core projects have a greater likelihood of being terminated or sold for strategic reasons. The dummy variable is statistically insignificant.

In summary, the results of this study indicate that acquiring firms do not gain an informational advantage from prior alliances and that several factors may play a role in the process of learning about the quality of target firms. For example, the nature of an alliance (e.g., whether scientists of both companies collaborate closely and exchange information or whether licensees assume full responsibility for development) and the number of alliances with a target firm may be important factors in learning about the true quality of a target. A closely related strand of research relates to the allocation of property rights. Aghion and Tirole (1994) argue that property rights (e.g., responsibility for the management of clinical trials) should be assigned to the R&D firm when the marginal impact of its activities on the product's value exceeds the marginal impact of the licensing firm's financial investment. Lerner and Merges (1998) empirically examine the allocation of property rights in biotech-pharmaceutical alliances and find evidence that biotech firms with more financial resources retain relatively large shares of property rights, which is consistent with the efficient allocation of rights. However, Lerner et al. (2003) find that deals signed during periods when it is difficult for biotechnology firms to raise private or public equity capital assign more property rights to licensees (usually pharmaceutical firms) and that these alliances are less likely to lead to the development of drugs approved by the FDA. Nicholson et al. (2006) suggest that this inefficiency in the allocation of rights most likely results from imperfections in the market for biotechnology deals.

It is important to note that although the likelihood of advancing R&D projects, except in cases of drugs that started Phase 1, is not associated with prior alliances with target firms, there are other potential advantages of establishing an alliance with a target firm. With respect to information asymmetry, a prior alliance with a target firm could place an acquiring firm in an advantageous negotiating position. For example, if the acquiring firm already has an alliance

with a target firm, that may deter other buyers from bidding because the contractual cash flow rights that are granted to the alliance partner often place a cap on the upside of the equity value of a small company (Ozmel et al., 2012).[30]

5. Conclusions

This paper has examined whether an acquirer's prior alliance with a target firm is positively associated with short-term stock market reactions to acquisition announcements as well as the real post-acquisition operating performances of firms. Empirical data were gathered from a sample of 219 biopharmaceutical acquisitions that occurred between 1998 and 2012, with a collective transaction value of $306 billion. The paper documents that returns to bidders are essentially zero, whereas target shareholders gain significantly more.

The main finding of this study is that there is no association between acquirers' prior alliances with target firms and short- or long-term performance. Using the event study methodology, I do not find support for the hypothesis that establishing alliances with target firms prior to acquisitions is associated with positive bidder returns, which indicates that acquiring firms do not gain informational advantages from prior alliances. This result contrasts those of several prior studies in the acquisition literature (e.g., Chan et al., 1997; Porrini, 2004; Higgins and Rodriguez, 2006; Mantecon, 2009), which may indicate that several factors affect the process of learning about the quality of a target firm. For example, the nature of an alliance (whether scientists of both companies collaborate closely and exchange information or whether the licensee assumes full responsibility for development), the number of alliances with a target firm and whether an alliance was inherited from an acquisition of another company may affect the process of learning about the true quality of a target.

An alternative to the short-term event study methodology would be to examine long-term operating performance in the post-acquisition period and its association with alliances. Such an approach provides an opportunity to directly examine the real performance of individual

[30] An example is Glaxosmithkline's acquisition of Human Genome Sciences. On April 19, 2012, the British pharmaceutical company GlaxoSmithKline (GSK) announced an unsolicited offer of $2.6 billion for Human Genome Sciences (HGS), representing an 81 percent premium over its closing stock price of $7.17 on April 18. GSK had been in partnership with HGS since 1993, and these companies were already collaborating on a number of projects, including the lupus drug Benlysta, while also promising experimental drugs for heart disease and diabetes. GSK chief executive Andrew Witty wrote to HGS in a public letter, saying he was prepared to commence a cash tender offer with no financing or due diligence conditions. Although other potential bidders were rumored, no other bidders emerged in the bidding process.

R&D projects at the project level rather than the firm level. Using a hand-collected dataset of 383 R&D projects in the post-acquisition period, I found that R&D projects that are co-developed prior to acquisitions are no more likely to advance than R&D projects not preceded by alliances, which indicates that acquiring firms do not gain informational advantages from alliances.

Consistent with the view that informed buyers are willing to pay higher premiums than uninformed buyers, who require discounts to compensate for their informational disadvantages, this study documents that acquiring firms with prior alliances with target firms are likely to pay significantly higher premiums than firms without such alliances (86 versus 56 percent). This finding raises the question of a potential winner's curse in the biopharmaceutical industry and may indicate that learning opportunities do not enable bidders to avoid the winner's curse (Ball et al., 1991). Although an alliance provides an opportunity for an acquiring firm to learn more about the quality of the asset and mitigate its informational disadvantages (e.g., Nanda and Williamson, 1995; Mantecon and Chatfield, 2007), it may not eliminate problems associated with information asymmetry.

The results of this study have implications for the acquisition strategies of pharmaceutical firms. Further research should examine situations in which alliances are an alternative to acquisitions and situations in which they are complementary. Additional research topics could include the determinants of significant bid premiums and whether there is a winner's curse in the biopharmaceutical industry.

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