Value Share Appropriation and Payment Structure in Biotechnology Licensing Deals: A Real Options Analysis

ABSTRACT

A main issue in patent licensing agreements is the contract payment structure and how this distributes the value created between the licensor and licensee. In this article, we analyze the key factors affecting the allocation of value between the licensor and licensee from a combined real options and bargaining perspective. In doing so, we explicitly recognize the value of real options embedded in the development process and the sequential structure of licensing contracts. We test our hypotheses on a sample of 175 licensing deals in the U.S. biopharmaceutical industry. Our results show that the value appropriated by the licensor is lower when a higher fraction of the payments comes from royalties, the agreement is signed in the later stages of technology development and the licensee has more prior managerial experience in licensing activities. Conversely, the value captured by the licensor is higher in licensing schemes where the licensee pays for development. The study contributes to the contract design literature in R&D alliances and provides insight for future research to incorporate real options to disentangle the complexities of inter-firm strategies in innovation ecosystems. We conclude with implications for the design and management of licensing deals and for policymaking.

Keywords: *licensing contracts, value appropriation, payment structure, real options, bargaining power*

1. INTRODUCTION

In recent years there has been an increasing diffusion of technology licensing (Ceccagnoli & Jiang, 2013; Hagedoorn, 2002; Somaya *et al*. 2011), mainly due to the emergence of open innovation (OI) processes in a wide range of organizational and industrial contexts (Chesbrough, 2003; Cheng & Huizingh, 2014; Gianiodis *et al.* 2014). Several studies have investigated the factors that explain the growing trend in technology licensing, focusing on the benefits firms may accrue in such inter-organizational relationships (Cassiman & Veugelers, 2006; Leone & Reichstein, 2012; Laursen *et al.*, 2010; Gambardella *et al.,* 2007; Katz & Shapiro, 1985; Sakakibara, 2010). Taken together, these studies highlight that licensing agreements represent a formal mechanism for transferring technological knowledge from licensor to licensee and, accordingly, are a key driver for promoting development of long-term innovative processes.

Other studies, by contrast, have investigated the drawbacks of these inter-organizational relationships, with a focus on the tension between value creation and value appropriation in asymmetric alliances (Hughes-Morgan & Yao, 2016; Ozmel *et al.,* 2017) and in the governance of R&D alliances between large and experienced companies vs. small and young ventures (see Adegbesan & Higgins, 2010). The latter might be at a disadvantage in terms of bargaining power (Higgins, 2007) with the risk of losing control over property rights on new technologies or may find it difficult to secure a consistent share of revenues arising from technology commercialization. By providing access to their technology, firms increase the risk of losing control of the technology and becoming dependent on the licensee for generating revenue (Fosfuri, 2006). As a result, many newly created ventures prefer not to ally with large and more experienced licensees and not to exploit potential technology-licensing opportunities (Arora & Fosfuri, 2003; Fosfuri, 2006).

From a contract design perspective, a main issue in patent license agreements is how to shape contract payment structure to resolve conflicting interests and enhance value creation in the long-term (Lynch & Shockley, 2017). As is known, license agreements usually provide monetary compensation for the patent owner in terms of fixed and variable payments. An initial (upfront) fixed fee usually remunerates the past R&D efforts of the innovator and patent owner; specified milestone payments are often given as incentives upon successful completion of interim R&D stages (Crama *et a*l., 2008). Variable fees normally take the form of royalties on sales from the use of the licensed technology. An effective contract payment structure, aimed at reducing the risk of knowledge leakage and achieving fair value appropriation, is needed to overcome problems associated with attaining collaboration between a licensor and licensee (Kotha *et al.,* 2018).

In this paper, we propose a novel approach to understanding value creation and capture by licensors and licensees in technology licensing which combines a bargaining power perspective (Higgins, 2007; Kotha *et al.*, 2018) with the real option approach (Trigeorgis, 1996; Ziedonis, 2007; Trigeorgis, & Reuer, 2017). We specifically analyze the factors affecting the allocation of value between a licensor (LR) and licensee (LE) from a combined bargaining and real options lens. In doing so, we explicitly account for the value of real options embedded in the R&D process (primarily related to decisions of development or discontinuation) and the sequential structure of licensing contracts.

We test our developed hypotheses on a sample of 175 licensing agreements conducted in the U.S. biopharmaceutical industry collected from Medtrack (Life Science Analytics) and Recap IQ – Deal Builder (Thomson Reuters) databases. The biopharmaceutical industry provides a suitable setting: since the emergence of biotechnology, large pharmaceutical companies have signed numerous licensing agreements with new entrant biotech firms that possessed R&D competences and capabilities that they were lacking (Pisano, 1991). Pharmaceutical companies have

consequently introduced seven of the top ten biotechnology drugs that have been marketed during the late 1990s (Edwards *et al.,* 2003).

Our results show that the value appropriated by the licensor is lower when a higher fraction of the payments comes from royalties, the license is signed in the later stages of technology development and the licensee has more experience in licensing activities. On the contrary, the value share of the licensor is higher in licensing schemes where the licensee pays for development. Our theory development and empirical results have a number of implications for the design of licensing contracts and for policy making that we discuss in the concluding section.

To our knowledge, this study represents the first attempt to combine bargaining power and real options arguments to explain the distribution of value associated with the payment structure of patent licensing contracts between licensors and licensees. In doing this, we contribute to the extant literature (Katz & Shapiro, 1985; Shepard, 1987; Anand, & Khanna, 2000; Arora & Gambardella, 2010) by recognizing that the value created by the license and appropriated by the two parties also depends on the contractual arrangements that assign the control over the critical decisions to be made during the licensing process. The closest related work from a valuation perspective is that of Higgins (2007), who examines the impact that firm bargaining position has on the allocation of broader control rights in biotech-pharma alliances and specifically on pharmaceutical firm shareholder value. Relative to the work of Higgins, we contribute by specifically modeling the value of control rights related to R&D development and market launch through real options valuation while taking the perspective of both parties and particularly the small biotech (licensor). While also controlling for the experience of the pharmaceutical and biotech firms, our results differ in terms of explicitly capturing the tradeoff between fixed payments and royalties and the impact of late stage of deal signing.

2. THEORY AND HYPOTHESES

2.1 Technology Licensing and Bargaining Power

Technology licensing agreements have become quite prevalent in the last decades, in part because the adoption of open innovation in a wide range of industry and institutional contexts has promoted various collaborative R&D arrangements (Poppo & Zenger, 2002; Elfenbein & Lerner, 2003; Argyres & Mayer, 2007; Reuer & Arino, 2007; Lazzarini *et al.* 2004). In shaping R&D collaboration through contractual agreements, firms are interested in both value creation and capture (Bhattacharyya & Lafontaine, 1995; Argyres & Mayer, 2007; Phene & Tallman, 2012). Accordingly, licensing partners are interested not only at designing contract deals for value creation but also at positioning themselves preferentially to capture it (Ozmel & Guler, 2015), decreasing the risk of knowledge leakage (Veer *et al.*, 2016; Frishammar *et al*., 2015) and rent dissipation (Fosfuri, 2006; Motohashi, 2008).

To face these risks effectively, firms have adopted new organizational practices, including the institutionalization of new intellectual property rights (IPR) practices (Hagedoorn & Zobel, 2015). For example, firms have negotiated the allocation of IPR across distinct modules of a product's system architecture (Henkel *et al.,* 2013), have bundled different IP mechanisms in different phases of the innovation process (Manzini & Lazzarotti, 2016), and have even resigned or transferred decision-making rights to another party to offset a potential partner's weaker bargaining power (Gambardella & Panico, 2014).

Generally, licensing agreements are viewed as a formal mechanism for promoting disclosure, transfer, and development of knowledge (Hagedoorn & Zobel, 2015; Hurmelinna *et al*., 2007). In this vein, licensing agreements shape firm's boundaries in terms of competences, efficiency, identity, and power (Santos & Eisenhardt, 2005). This includes the allocation of decision-making rights that, in turn, affect the distribution of gains between the parties (Elfenbein

& Lerner, 2003). In particular, power boundaries have recently gained in importance, partly because they affect how organizations control their broader set of exchange relations; competence and efficiency respectively enhance the value of the firm's resource portfolio (Zobel *et al*., 2016) and reduce the cost of governing such relationships (Miozzo *et al*., 2016).

From a power perspective, technology licensing is a suitable setting for analyzing strategies and processes for managing asymmetric relationships (Mehlman *et al*., 2010; Minshall *et al.,* 2010). Bargaining power, being "the ability of one party to a contract to be able to influence the terms and conditions of that contract or subsequent contracts in its own favor" (Argyres & Liebeskind, 1999: 55), can affect the distribution of a revenue stream whose magnitude and existence are uncertain *ex-ante*. We extend bargaining power arguments combined with a real options approach (Trigeorgis, & Reuer, 2017) to analyze contract payment structure in asymmetric inter-firm licensing agreements (Lerner & Merges, 1998; Santos and Eisenhardt, 2005; Khoury *et al*., 2017). We next develop a series of hypotheses, by applying a real options lens to value creation and appropriation in biotechnology R&D licensing.

2.2 Value Appropriation and Payment Structure in Biotechnology Licensing

Asymmetric relationships are commonplace in the biopharmaceutical industry where large incumbent pharmaceutical companies (licensees) commonly ally with small and often resource-constrained biotech firms to fill their R&D competences gap and nurture their product pipeline (Pisano, 1991; Lerner & Merges,1998; Phene & Tallman, 2012). Licensing agreements that develop new biotech products are often complex and involve uncertainty, making it difficult to specify *ex ante* all the features of the biotech products to be developed (Henderson & Cockburn, 1994; Pisano, 1990). Given this uncertainty, partner firms are often unable to bargain directly over the distribution of future income streams, but instead bargain over the 'pie-splitting' control rights

(Adegbesan & Higgins, 2010) that assign ownership and control of activities, decisions, and intermediate outcomes related to the creation and distribution of possible income streams. 'Pie-splitting' control rights reflect the *ex-ante* allocation of total value between the partners and embed real options (e.g., Ziedonis 2007; Cassimon *et a*l., 2011).

From a real options lens, the value created by a patent license agreement for the licensor and the licensee depends not only on the cash flows that will accrue and be divided among the parties, but also on the real options they will obtain from the sequential nature of the contract design and commercialization process (Lynch & Shockley, 2017). We assume that in negotiating the payment structure of the licensing contract, the parties will also account for the value of embedded real options, such as who controls the option to continue development or discontinue the R&D effort midstream and the option for subsequent market launch. We will treat, therefore, the total value of a license as the sum of the present value of the expected cash flows and the value of embedded real options, or Expanded NPV (Smit & Trigeorgis, 2017). Such options include the value of continuing or not to the next stage at any of the key phases of the R&D process (e.g., preclinical, Phase I, II, III, regulatory approval) and the option for commercialization or market launch, In this way, we take into account also the value of controlling the different interrelated decisions of the two parties that affect the execution of the licensing contract. Taken together, the bargaining power argument suggests that licensors (*licensees*) will use their advantages, skills and experience to get higher (*lower*) upfront fees and royalty payments (Kotha *et al*., 2018). Of course, in give-and-take negotiations there may be a natural tradeoff between the two, i.e., negotiating for a higher upfront fee may often require accepting lower future royalty payments and vice versa. The negotiation will also include the contractual schemes that will affect the real options available to the two parties (Bessy et al., 2004). The observed payment structure and contractual schemes will therefore be the

result of a bargaining process between the licensor and licensee, taking into account these tradeoffs and who controls the real options over the life of the contract.

The licensor and the licensee typically have a different preference and propensity for fixed fees vs. royalties. Adopting a bargaining perspective, while the licensor typically has a preference for fixed payments, especially when financially constrained (Kulatilaka & Li, 2006), the licensee most often has a preference for royalties as they better align the parties' interests, reducing risk exposure in case of failure of the licensed technology (Gallini & Wright, 1990; Bousquet *et al.* 1998; Gans & Stern, 2003). Also within a real options perspective, a contractual structure based more on royalty payments is beneficial to the licensee. A lower initial investment by the licensee limits the downside under uncertainty, while higher royalties increase flexibility as they will be paid only in case of positive future performance (Leone et al., 2015). Consistently with real options theory, a contractual structure with lower upfront payment and higher royalties will have a higher option value.

We then expect that within the negotiation of the contractual terms, with specific reference to the trade-off between upfront fees and royalty payments, the licensee will try to promote a balance more oriented towards the latter. A higher ratio of royalties to fixed payments is indicative, therefore, of a higher relative bargaining power of the licensee. This higher bargaining power also translates into contractual terms that allocate more option value to the licensee, thereby increasing its share of total value also in terms of real options. We expect, as a consequence, that higher royalties compared to fixed payments will be associated with a higher share of total value (including the value of real options) appropriated by the licensee. Accordingly, we hypothesize the following:

H1: *The share of total value accruing to the licensor (%LR) will decrease as the ratio of royalty to fixed payments (upfront fee plus milestone payments) gets higher.*

Most studies on licensing take a static approach and do not pay attention to how the partners' bargaining power may change over the innovation process. From a relative bargaining power perspective, the licensor has a relatively stronger bargaining position in the earlier stages of the innovation process due to the greater importance of technological skills, expertise and contribution to the development of the technology. In the later stages, the specialized complementary capabilities of the licensee related to the commercialization of the final product become more relevant (Teece, 1986). The possession of complementary capabilities allows licensees to capture the lion's share of benefits of the intellectual property underlying the contract (Lowe & Taylor, 1998). As a consequence, non-replicable technology-specific production and marketing capabilities may significantly affect the bargaining power in the negotiation of licensing contracts in favor of the licensee (Arora and Ceccagnoli, 2006). Potential licensees with stronger specialized complementary capabilities might also have incentives to internalize the development of the technology (Ceccagnoli et al., 2010), which further increases their bargaining power in the negotiation of the contract.

By the later stages the licensor will moreover have put a heavier financial commitment in terms of incurring R&D costs and, although it theoretically may control development, it typically has little incentive to abandon the project midstream as that may put its very survival at stake. At this stage, in fact, the licensor is likely to suffer from severe financial constraints and it may hardly find new equity or debt capital to cover its financing needs. In such a situation, signing the licensing contract may represent the only viable solution to fund the final needed development of the technology. Given, then, that the licensee will have a stronger bargaining position in the later stage of development of the technology, we expect the following:

H2: *The share of total value accruing to the licensor (%LR) will be lower in the later stage of technology development.*

Another key determinant of relative bargaining power is prior experience in licensing deals and subsequent relational capabilities (Hoang & Rothaermel, 2005; Gulati *et al*., 2009). More specifically, it has been shown that 'learning to contract' (Mayer & Argyres, 2004) represents a crucial general capability with important consequences for both the organization's and the alliance's performance (Adegbesan & Higgins, 2010). Prior alliance experience increases negotiation skills and significantly contributes to bargaining power (Thompson, 1990). In the context of international joint ventures, for example, the acquisition of knowledge in the local context through experience is known to affect the relative bargaining power of the JV partners (Inkpen & Beamish, 1997). Within the context of biotech R&D licensing, we note that while resource-constrained biotech firms may have a limited number of technologies to license out, pharmaceutical companies have often been systematically involved in several prior in-licensing activities. In addition, they may explore concurrently multiple options for developing new drugs (McGrath & Nerkar, 2004; Vassolo et al., 2004) or they can evaluate internal development (Anand et al, 2010). This increases the relative bargaining power of licensees since they are less dependent on any one alliance, being more committed to increasing their alliance portfolio (Leone & Reichstein, 2012). Taken together, prior in-licensing experience may help licensees to obtain a higher fraction of the value through superior knowledge of the process and enhanced skills and bargaining power (Kotha et al., 2018). We therefore expect the following:

H3: *The share of total value accruing to the licensor (%LR) will be lower when the licensee has more experience with patent in-licensing*.

Viewing the licensing scheme from a real options perspective, in turn, in terms of who controls development (the licensor, licensee or both), co-development may be worse for the

licensor or may involve mixed effects as the licensor would still have to pay part of the R&D costs, but it would not receive milestone payments during the co-development period. The real option to control development is also typically more valuable in the hands of the licensee than the licensor. If the licensee (big pharma) is in control of development, it has strong incentives to discontinue further development at a given interim stage in certain bad states and not pay future milestones and royalties to the licensor in those bad states following discontinuation. If the licensor is in control, however, it would be less likely to exercise the option to discontinue development as this may risk the very survival of a young biotech firm whose only (or one of few) product(s) may be the one(s) licensed out. In this sense as well, the licensor may be in a weaker bargaining position in terms of the ability and incentives to exercise the discontinuation option even when it contractually controls (or shares control of) the real option in theory. In many cases, the value of control of the discontinuation option to the licensor may not be sufficient to cover the extra R&D costs and loss of milestone payments incurred under co-development compared to the case that it alone controls development. In some cases, the value of controlling the discontinuation option may be higher (or the value of lost milestone payments lower) so the sign may reverse or may be insignificant when these opposite effects offset each other. For these reasons, the licensor will likely benefit more in terms of fixed payments and avoid incurring R&D costs out-of-pocket while not losing much in option value in relative terms when the licensee is responsible for development compared to the case that the licensor controls the development option. We therefore propose the following:

H4: *The share of total value accruing to the licensor (%LR) may be lower or mixed under co-development and will likely be higher under a licensing scheme where the licensee pays for development.*

3. METHODS

3.1. Data and Sample

To test the above hypotheses, we make an integrated use of two databases: Medtrack (Life Science Analytics) and Recap IQ – Deal Builder (Thomson Reuters). Medtrack provided data about the companies involved in each licensing deal and various characteristics such as the pipeline of drugs, number of licensed-in drugs, licensing deal terms, and funds raised via IPO and VC investments.[1] Recap IQ provided data on licensing deal size, upfront fees, milestones and royalties, number of molecules, therapy area, phase at deal signing, and type of deal. Such a primary, integrated dataset of licensing transactions was supplemented by two secondary sources: SEC filings and Orbis (Bureau Van Dijk) for filling information gaps on royalty rates and licensee's total assets as well as licensor's age, respectively. Additional data on consensus inputs for an NPV analysis of drugs by therapy area were obtained from the literature (e.g., DiMasi *et al*., 2003; 2016; Bogdan & Villiger, 2010).

The licensing deals were further categorized by scheme type (the licensee controls development, the licensor controls development, both co-develop), stage at deal signing, therapy area, royalty rate, upfront fees, milestone payments and so on. The collected data and dependent variable construction (% of total value accruing to the licensor or %LR) allowed testing a multi-stage compound option model (adjusted to account for success probabilities by R&D stage)

[1] The Medtrack database on biotech/pharma licensing deals contains data on each licensing deal by product name, therapeutic area, stage of R&D development, and licensing deal terms such as upfront fee, milestone payments and % royalties. For each leading partner name (e.g., Crucell NV) a company report gives a list of all past licensing deals for that company. For a given past deal (e.g., partnership of Crucell NV with Talecris Biotherapeutics on 12/17/2008) a % royalty rate is given. The deal-in-brief report gives the R&D stage or clinical phase (needed to value the licensing deal as a compound option), the therapeutic area (that allows estimating historical probabilities of success by stage and volatility by therapeutic area) and the licensing deal or financial terms. For example, the deal between Lilly and Icos made on 10/01/1998 for compound Cialis specifies: phase 2, erectile dysfunction, upfront payment of $75 m, several success milestone payments, and 20% royalty. There are also data on access to financing via IPO or venture capital (VC), and on the composition of product pipelines which enables examining the portfolio strategies of successful firms.

underlying biotech-pharma licensing deals and confirmed its validity and explanatory power in explaining the value share distribution among the parties (accounting for real options and for which party controls development) as observed in the actual licensing deals.

The Medtrack and Recap IQ databases contained 257 licensing deals between a specified licensor (LR) and licensee (LE) with complete licensing terms and other financial data over the period 2003-2013 that enabled our compound option pricing of each licensing deal. Table 1 provides a summary of the characteristics of these deals in terms of median upfront fees, typical R&D and sales milestones, royalty rates and number of deals signed by stage of R&D development. Of these, 26 deals were excluded due to missing data needed for estimation of the dependent variable (%LR) or key independent variables of our econometric model, and 56 deals were excluded due to the presence of outliers (e.g., unreasonably high royalties in some cases).

INSERT TABLE 1

The final dataset contains complete data enabling to construct our dependent and explanatory variables and run our regressions, with valid listwise observations on 175 licensing deals. The 175 licensing deals with complete data were then classified into three main licensing schemes, depending on whether the licensee (LE), the licensor (LR) or both parties (LE&LR jointly) control the development process and hence the continuation or abandonment option. These licensing schemes are summarized in Table 2.

INSERT TABLE 2

3.2. Estimation

Our base econometric analysis follows a standard OLS regression. For robustness, due to the dependent variable (%LR) being a censored ratio (between 0 and 1), we also use a Tobit analysis. The results of the Tobit regression, reported in Panel B of Table 4, confirm those of the OLS regression. When OLS regression is used, the dependent variable is log-transformed to better satisfy the OLS normality assumption. All independent variables (except for the dummies) are in log-transformed form. Our dependent and independent variables are described next.

Dependent Variable (Estimation of Expanded-NPVs and %LR)

For each licensing deal, the expected cash flows were projected for each licensed drug upon commercialization (following a standard peak sales lifecycle for each drug therapy as depicted in Figure 1 using peak sales estimates by therapy as in Appendix 1) and then discounted at the cost of capital (averaging 11% for the typical drug) back to the beginning of deal signing (t = 0), thus obtaining the underlying (gross) project value (V_0) representing a current claim on future cash in-flows for each drug.

INSERT FIGURE 1

These estimates differ depending on the drug's therapy area and by stage of deal signing (as this involves a different discounting horizon). Then each drug is valued as a multi-stage compound option (as illustrated in Figure 2) using binomial tree valuation, properly adjusted for the technical probabilities of success by R&D stage and therapy, to obtain the drug's total value or Expanded Net Present Value (E-NPV) that besides the standard NPV of expected cash flows also includes the value of embedded options (i.e., the real option value).[2]

[2] The value of the licensing deal between licensor and licensee was computed using a compound real option approach. Each stage of the research of a new drug is seen as a real option and the value of each stage is computed backwards

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INSERT FIGURE 2

In estimating the compound option value of each drug's multistage development process, the typical development costs by stage are used (each serving as the exercise price of the option to proceed to the next stage and so on), also accounting for the probabilities of success specified by stage and therapy (see Appendix 1). Depending on the therapy area, each drug is also classified into a volatility range based on recent average industry volatility estimates for the biotechnology sector obtained from Damodaran's public website:[3] low volatility (70%), medium volatility (85%), high volatility (100%). Figure 2 illustrates the compound-option valuation of a typical R&D drug at the discovery stage (t = 0) whose development is controlled by the innovator-licensor (LR). The Expanded-NPV to the licensor (E-NPV_LR) at t = 0 for the typical drug is shown at the left-most node ($13.29m).

The option-based valuation for a licensing deal is then adjusted to account for the additional stipulated licensing payments (upfront fee, R&D milestones, sales milestones, and sales royalties) for the licensor LR (who is stipulated to receive these payments) and the licensee LE (who makes these payments), obtaining the net total value of the licensing deal (including the value of the real options to develop or abandon the drug and the option to launch) to the licensor (E-NPV_LR) and

from the launch stage until the phase at deal signing. The backwards computation of each phase can be different depending on the contract type of the deal. Appendix 2 gives an example for a Phase II drug for the licensee for a deal of Scheme I where licensee controls. For the last launch option, for example, the option payoff for the licensee (LE) is of the form: $-M_{FDA} + \max (P_{mkt}*V_T*(1-R) - I_{mkt}; 0)$. MIL_{NDA} is the milestone paid to the licensor for successfully securing FDA approval; the remainder is the option to launch: the max between zero and the value of project cash inflows at launch time T, V_T, multiplied by the probability to market launch (P_{mkt}) and reduced by the fraction of royalties to value (R%) paid to the licensor. See Appendix 2 for option payoffs in early stages of the compound option.

[3] See http://pages.stern.nyu.edu/~adamodar/New_Home_Page/data.html. The volatility was assessed for groups of therapy areas as follows: 100% for cardiovascular, central nervous system, oncology and hematology, immunology and inflammation; 85% for respiratory, infectious diseases, and others; 70% for gastroenterology, rheumatology and osteoporosis, urology and women diseases, endocrine and metabolic disorders.

to the licensee (E-NPV_LR). An example of binomial valuation for a Phase II drug for the licensee for a Scheme I licensing deal is shown in Appendix 2. Care is taken in these estimations to account for the contingency that if in certain "bad" demand states (in the binomial option trees) the party who controls development and market launch (typically the LE) decides to abandon further drug development (or launch) at some stage, then in those bad states the binomial option tree of the other party (the LR) will reflect (suffer) the adverse consequences of the abandonment decision of the controlling party in that it will hence receive no subsequent milestones or sales royalty payments. The dependent variable (%LR) is then obtained as

$$\%LR = E\text{-}NPV\_LR / (E\text{-}NPV\_LR + E\text{-}NPV\_LE) \quad (1)$$

where %LR is the E-NPV of the licensor divided by the sum of the E-NPVs of the licensor and the licensee, measuring what fraction (in %) of the total value of the licensing deal, including any real option value, accrues to the licensor (LR). This is analogous to the "profit split ratio" commonly used in negotiations of licensing deals in the biopharmaceutical industry but with total value obtained from a real options perspective. The ratio varies between 0 and 1.[4] A sample of basic input data for select deals with estimations of E_NPVs for the licensor and licensee and the dependent variable, %LR, is shown in Appendix 3 (removed due to space limits).

A summary of the independent and control variables used in our econometric analysis and their source(s) are reported in Table 3. These are discussed below.

Independent Variables

[4] The stage when the deal was signed (and hence the number of stages remaining till commercialization in the compound option valuation), the volatility per drug therapy, the probabilities of technical success of the remaining R&D development stages, and the number of molecules per drug are all accounted for in the theoretical estimation of the depended variable (%LR).

Ratio of royalties to fixed payments (ROYALTIES_TO_FIXED). This ratio (in Ln) captures the inherent tradeoff between variable royalty and fixed payments, with higher fixed payments benefiting the licensor directly generally coming at the expense of lower royalties in a give-and-take bargaining process. Royalties on sales are computed by multiplying the royalty rate times the peak sales of each drug by therapy area. Fixed payments are the sum of the upfront fee and the various milestone payments.

Stage of development (LATESTAGE). A late stage dummy variable is used here taking value 1 for deals signed in late stages (clinical Phase II, Phase III and approval), and 0 otherwise (Preclinical and Phase I).

Licensee's degree of licensed-in drugs (LICENSED_IN_LE). This variable is defined as (Ln of) external drugs licensed-in from third parties divided by the total assets of the licensee (LE).

Co-development (CODEV). This is a dummy that takes value 1 for those deals involving co-development and 0 otherwise, intended to test the first part of H4. As noted, co-development likely has mixed effects. On one hand, it is beneficial to the licensor, as the licensee cannot decide single-handedly to abandon development and hence forego future milestone and royalty payments to the licensor in certain bad states. On the other hand, during co-development the licensor foregoes milestone payments from successful project progression while it shares part of the burden of incurring the R&D development costs. Hence, if the latter aspects dominate, the net effect may be negative but if the effects roughly offset each other the net effect may be insignificant. A negative sign on CODEV would suggest that co-development might make the licensor worse off whereas an insignificant impact would leave the licensor roughly neutral.

Licensing scheme (SCHEME_LE). To test the second part of our conjecture in H4 that the licensee's (LE's) control of development may be preferable for the licensor as it would result in more fixed payments to LR with no need to incur R&D costs, SCHEME_LE is a dummy variable that takes value 1 when the licensee controls development and 0 otherwise. A negative sign on CODEV and a positive sign on the SCHEME_LE variable would be in line with the conjecture that the licensor may be worse off when it agrees to co-development and better off in terms of fixed payments that matter the most when the licensee instead controls development.

Control variables

Licensor's age (AGE_LR). This variable, defined as Ln of the age of the licensor (LR), is computed starting from the licensor's incorporation date to 2013 (the most recent year in the dataset) and proxies for the survivability, size and experience of the licensor. A positive sign on AGE_LR would confirm that a more experienced licensor can obtain more value in bargaining.

Licensor's access to financing (FINACCESS_LR). This is a dummy that takes the value of 1 if the licensor has previously raised funding through an initial public offering (IPO) or venture capital (VC) financing, proxying for the LR's access to external financing and financial viability resulting in a stronger bargaining power. When the dummy takes value 0 it reflects financial constraints.

Percentage royalty rate on sales (% ROYALTY). This is computed as ln [1 + royalty rate (in decimal)] obtaining zero if the rate is zero for a specific deal. As royalties are to be received by the licensor, the higher the royalty rate as % of sales (defined in Ln), the better off the licensor will be, other things being constant.

INSERT TABLE 3

3.3. Main Results

Table 4 Panel A provides summary statistics on the dependent and main independent variables, and Panel B shows the correlation matrix among these variables.[5] Correlations are generally low, with no concerns for any serious collinearity problem (VIF scores in Table 4 Panel B are below 2). The only exception is a high positive correlation between LATESTAGE and %ROYALTY as the royalty rate generally increases in later stages of deal signing, as per industry practice (and seen in the last column of Table 1).

INSERT TABLE 4

Table 5 (Panel A using OLS and Panel B using Tobit regressions) presents our main results testing Hypotheses H1-H4 via 6 models (Models 1-6). It is based on the 175 deal transactions with complete data on all regression variables. The dependent variable, %LR, is the total value (E-NPV) of the licensor divided by the sum of total values (E-NPVs) of licensor and licensee, showing how much of the total value of the deal accrues to the licensor.

INSERT TABLE 5

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[5] It might be noted that in the summary statistics N is equal to 201 for some variables (after eliminating 56 deals containing outliers). As previously mentioned, 26 transactions were further excluded because of the presence of missing data. This reduces our final sample to 175 (= *N*) deals.

Table 5 Panel A presents the OLS regression results first. Model 1 shows a preliminary regression only with the control variables, namely AGE_LR, FINACCESS_LR, and %ROYALTY. Models 2-6 incrementally add more key explanatory variables, one at a time, showing the incremental effect of each added key variable related to each of our hypotheses (the last comprehensive Model 6 includes all variables combined). As expected, in Model 1 the licensor's share (% LR) increases with the licensor's (LR's) age, size and experience (AGE_LR) and access to financing (FINACCESS_LR). The positive sign of the coefficient associated with LR's age (significant at 10% level in Model 1, 5% in Models 2 and 3, and at 1% level in Models 4, 5 and 6) suggests that the older and more experienced the licensor, the higher its total value apportionment in a licensing negotiation because of a higher expected contribution to the candidate drug development and resulting higher bargaining power. The positive impact of access to external financing (reflected in the positive sign of the coefficient, which is statistically significant at 5% across models) for licensors that carried out an IPO or received VC financing, thus opening up doors for relationships with a broad range of investors, results in a higher negotiating power and, as a consequence, higher value share appropriation. This result on the positive incentives brought about by financing constraints to seek licensing alliances is analogous to the findings by Kulatilaka and Lin (2006) and Higgins (2007). Finally, the third control in Model 1, %ROYALTY, has a positive coefficient and is significant at the 1% level confirming, as anticipated, that the licensor is better off when attaining a higher royalty rate, other things held constant.

However, as Model 2 confirms, when also considering the impact of ROYALTIES-TO-FIXED, higher royalties typically come at the expense of receiving significantly less fixed payments, making the licensor worse off in net. The coefficient of ROYALTIES-TO-FIXED capturing the marginal effect on %LR is negative and significant at the 1% level in Model 2 (and across subsequent Models 3, 4, 5 and 6), providing confirmatory evidence of a binding tradeoff

between negotiated variable and fixed payments at the detriment of the licensor. If the licensor were to bargain for higher royalties, it would typically have to give up more value share in the form of fixed payments reflecting the higher bargaining power of the licensee. This supports H1. This explicit recognition of a tradeoff between fixed and royalty payments in the value share allocation is a contribution over Higgins (2007).

Model 3 is aimed at testing H2 by incrementally adding LATESTAGE to the above variables (of Model 2). The late stage dummy's negative and significant coefficient (at 5% in Models 3 and 5 and at 10% in Models 4 and 6) suggests a net loss of value for the licensor in later stages of drug development. Although signing a deal in later R&D stages might commonly enable the licensor to negotiate a higher % royalty rate in principle (as seen in the last column of Table 1), the resulting tradeoff involving sacrifice of commensurably more valuable fixed payments leaves the licensor worse off, making the marginal impact of LATESTAGE on %LR negative. As noted, this reflects a shift of bargaining power in favor of the licensee in the later R&D stages, in line with H2. Moreover, besides foregoing interim milestone payments, the later the stage the licensing deal is signed the more the licensor has already invested into drug development (in terms of money, effort and risk undertaken) in all previous phases. Such a heavy prior financial commitment would further discourage the licensor from late abandonment of the R&D program. Signing a deal earlier would instead lead to likely attainment of a lower % royalty rate (as confirmed to be the practice in these deals in the last column of Table 1) but also a lower cumulative fixed commitment of resources by the licensor while receiving more milestone payments. Further, as the final drug commercialization and market launch stage approaches, the relative potential contribution (in terms of marketing and distribution capabilities) and hence bargaining power of the licensee (pharmaceutical) increases at the expense of the licensor (biotech). In sum, the above supports H2. Thus, although pharmaceutical firms may relinquish

more control rights to biotechs in later stages of development (Higgins, 2007), these same control rights have less real option value to the biotech than the pharmaceutical firm as they are less likely to be exercised.

Model 4 considers the incremental effect of the licensee's experience with licensed-in drugs as percent of total assets (LICENSED_IN_LE). It confirms that the higher the licensee's (pharmaceutical's) experience with licensing-in activities, as measured by the degree of licensed-in drugs (LICENSED-IN_LE), the lower the licensor's total value apportionment, corroborating H3.[6] The related variable has a coefficient with a negative sign and although insignificant in the OLS Model 4 regression, it is significant at the 10% level in comprehensive Models 5 and 6 and in the corresponding Tobit regressions.

Model 5 includes a dummy for co-development CODEV and Model 6 incrementally considers a dummy for SCHEME_LE to differentiate the type of licensing schemes where either both parties jointly control or the licensee (LE) alone controls the development option to test H4. In Model 5, the coefficient of CODEV is negative but statistically insignificant, in line with the situation according to which the LR may be worse off or in net may be insignificantly affected in a co-development scheme. The statistical insignificance suggests potential offsetting mixed effects of this licensing scheme on licensor value apportionment. In Model 6, the coefficient of CODEV remains statistically insignificant. The variable SCHEME_LE in Model 6 has a positive coefficient (at 5% level) implying that the licensor is better off when the licensee pays for development. H4 is thus weakly supported. There are several reasons for the above mixed effect concerning CODEV. When the licensee controls development, the licensor would likely not incur as much in R&D costs and would receive more fixed payments (which are less risky and more valuable than

[6] Higgins (2007) similarly finds that pharmaceutical firms with expanding pipelines have more bargaining power and relinquish less control rights. Our result is more focused on greater experience with licensing-in and hence more open innovation policy (rather than mere pipeline expansion) by pharmaceuticals.

royalties) compared to co-development. By contrast, if the licensor controls development, it needs to incur all R&D costs on its own, which would make the licensor worse off compared to the scheme where the licensee controls the R&D program. It would also be less likely for the licensor to exercise the option not to continue development, which makes such an option less valuable to the licensor than to the licensee. Co-development also may not be a beneficial contractual scheme for the licensor as it would need to share the R&D costs (with the licensee) and would also forego milestone payments (from the licensee) during co-development. The coefficients and significance of all other variables remain as in the previous model regressions, confirming the robustness of the estimates. Model 6 in the OLS regressions (Panel A) of Table 5 has an Adjusted R^2 of 57.5%, with model F-stat of 30.42 (significant at 1%). The results of the Tobit regressions (in Panel B of Table 5) are very similar to those of the OLS regressions, with significant Model 6 Log-likelihood of 141.[7] Thus, our above hypotheses are broadly confirmed in both econometric specifications.

4. DISCUSSION, IMPLICATIONS AND CONCLUSIONS

This article has addressed the question of how the payment and contractual terms of a licensing deal affect the value allocation from technology licensing between the licensor and the licensee by combining a bargaining power and real options perspective. Specifically, we analyze how licensors and licensees share the total value created (including the real option value from controlling sequential development and the option to launch) when engaging in patent licensing

[7] The coefficients of the variables accounting for the royalty rate and the ratio between royalties and fixed payments have a three-star significance level; the coefficients of the variables accounting for the age and the access to financing of the licensor also have a three-star significance level; the late stage variable has a coefficient with one-star level of significance, the licensee experience variable (measured with licensed-in drugs as a percent of total assets) has a one-star significance, and the license scheme_LE variable a two-star significance. The co-development variable has a negative coefficient but is not significant in either regression. The economic interpretation of the coefficients of the Tobit regression is similar to that of the OLS regression.

deals. Consistently with our developed hypotheses, we have found that the total value appropriated by licensees will be higher when they have stronger experience in previous licensing deals and when licensing technologies are signed at a later stage. In later stages, the relative bargaining power naturally shifts more in favor of licensees as their potential contribution is more value-adding when the drug enters commercialization. Moreover, we have shown that contracts in which royalties represent a higher fraction of total payments reflect more bargaining power for the licensees and increase the share of value accruing to them. Finally, our empirical evidence reveals that the type of licensing contract scheme determining who controls the real development option matters, with the share of total value accruing to the licensor being lower or having mixed effects under co-development and likely being higher under a licensing scheme where the licensee controls development and thus pays the full costs.

This study contributes to the existing work by combining bargaining power and real options arguments to provide a novel explanation for the distribution of value associated with the payment structure of patent licensing contracts between licensors and licensees. In doing so, we contribute to the extant literature (Katz & Shapiro, 1985; Anand, & Khanna, 2000; Arora & Gambardella, 2010; Shepard, 1987; Higgins 2007) by recognizing that the value created by the license and appropriated by the two parties also depends on the contractual arrangements that assign the control over the critical decisions to be made during the licensing process and that the value of these control rights and resulting contingent decisions may be modeled using real options theory.

The theory and the empirical results presented in the article offer several implications for the design and management of licensing deals and for policymaking. First, in negotiating a license payment structure the parties need to consider also the value of real options related to the control of the development process (as well as the option to launch). This may result in a different understanding of the value creation process and to different expected outcomes regarding

contractual structure, value share appropriation and decision-making, as compared to what one would expect from a standard NPV analysis of licensing deals. For example, our results show that leaving the control of the development (and responsibility for payment of related costs) to the licensee (pharmaceutical firm) likely increases the value appropriated by the licensor (small biotech). More generally, considering the value of real options can potentially lead to different conclusions about the equilibrium conditions needed to successfully close a deal among the parties. In particular, our consideration of real options in conjunction with related bargaining arguments highlights that non-economic contractual terms related to the control over decisions at critical junctures during drug development can be as important (in obtaining the desired distribution of total value shares between the licensor and the licensee) as cash flow, cost or pure bargaining considerations. In this regard, our results differ from Higgins (2007) who finds that both fixed payments (milestones) and royalties are positively appreciated by the stock market and that they do not make a significant difference in extracting additional control rights. By contrast, we find that higher royalties come at the expense of lower fixed payments in the bargaining process and that is generally at the expense of the small biotech (licensor). Relatedly, we find that even if a biotech may acquire more control rights in later stages, those same optional control rights have less real option value in the hands of the biotech as they are less likely to be exercised by the biotech than by the pharmaceutical firm.

From a practical management perspective, our study helps managers responsible for licensing decisions to assess how they best can capture value from an open innovation strategy. Naturally, different licensing management and policy implications would result if one would take the perspective of the licensor, or of both parties *in equilibrium*. In the first case, one would need to address the considerable problems and challenges that one may encounter in the negotiation of the licensing scheme from the perspective of a small licensor. This is so because this is typically a

young, resource-constrained biotech firm with a limited number of drugs under development and limited experience with bargaining and deal making, as well as limited real options awareness. Our results show that licensors are at risk of appropriating a lower fraction of total value when they deal with more experienced licensees or when the technology is in the later stages of development. This might create an adverse selection problem hindering the closing of licensing agreements or allowing conditions partially expropriating the licensor. In these cases, inexperienced licensors might more carefully evaluate the terms of a potential deal, possibly with the support of experts or intermediaries, as is the case of very early stage university licensing examined by Kotha *et al*. (2018). However, the use of intermediaries itself requires some caution. Although the authors presume that intermediary managers act on behalf of inventors/licensors, intermediaries may have their own interest to push for lower interest payments as they get compensated only if a deal is signed. Such intermediaries may thus favor lower fixed payments and greater royalties.[8]

In terms of relevant policy implications, a policy maker might be concerned about licensors not being expropriated by more experienced and powerful licensees, as well as understand which conditions would make an equilibrium more likely given that any licensing contract needs to be mutually acceptable to both parties. The two above policy aspects may be interrelated: given that

[8] We find the opposite result in our sample of deals, which differ in that they are not so early stage (earliest is preclinical) and are for the most part negotiated directly between licensor and licensee without intermediaries. We find that striving for more royalties comes at the cost of lower fixed payments, which comes at the expense of the inventor/licensor. This differing result may be attributed to several causes. First, it may be that our later stage and more "mature" licensing deals are different from the very early university deals (right off university TTO). Second, it may be that when the deals are negotiated directly between LR and LE without intermediaries (but with the advice of experts on the side of the LR), the effect is what we find (i.e., that fixed payments are better for the inventor/LR) but that the preferences of the intermediary tilt the balance toward less fixed payments and more royalties in the interest of striking a deal. Third, it may be that intermediaries are not "altruistic", as the authors presume, but are self-interested like most other intermediary agents (e.g., in real estate or investment banking who are underpricing a house or an IPO) because their interest is to ensure that a deal is signed and get their cut rather than pushing for the best deal for the principal (the inventor/licensor in this case) and potentially end up with no deal (getting nothing).

in principle there may be multiple payment combinations or menus e.g., involving trading off fixed payments for royalties to achieve an acceptable equilibrium outcome to both, care must be taken in the design of a licensing scheme such that the licensor is not taken advantage of given its likely lesser experience, bargaining power and familiarity with real options.

Our study has certain limitations. First, our sample is restricted to the U.S. biotechnology context and needs to be replicated in other industries and countries in order to more generally validate our findings. Second, in analyzing licensing agreements in the biopharmaceutical sector, we focused only on dyadic relationships, capturing only a fraction of complex interdependencies amongst a large range of actors that operate in open innovation ecosystems (see Adner, 2017). Such interdependencies can no longer be exclusively managed *via* ownership mechanisms but increasingly rely on collaborative relational strategies. This raises several interesting questions for future work, such as: *how can multiple, interdependent entities allocate decision rights at the network level? Are there informal means to shape the behavior of partners beyond the use of a formal contract payment structure? To what extent do firms need to let go of some control in order to capture more value in their innovation ecosystem?* These open questions provide further opportunities to help disentangle the complexities of inter-firm strategies in R&D alliances and suggest further possibilities to extend our framework to study contractual mechanisms within these broader research streams. Future research on contract payment structures can thus progressively extend beyond the scope of the dyadic relationships analyzed here to the wider innovation ecosystem, considering how the focal firm increases its bargaining power and influences and shapes beneficially the structure of its real options.

REFERENCES

Adegbesan, J. A., & Higgins, M. J. (2010). The intra-alliance division of value created through collaboration. *Strategic Management Journal*, *32*(2), 187-211.

Adner, R. (2017). Ecosystem as structure: an actionable construct for strategy. *Journal of Management*, *43*(1), 39-58.

Ahuja, G., Lampert, C. M., & Novelli, E. (2013). The second face of appropriability: Generative appropriability and its determinants. *Academy of Management Review*, *38*(2), 248-269.

Anand, B. N., & Khanna, T. (2000). The structure of licensing contracts. *The Journal of Industrial Economics*, 48(1), 103-135.

Anand, J., Oriani, R., & Vassolo, R. S. (2010). Alliance activity as a dynamic capability in the face of a discontinuous technological change. *Organization Science*, 21(6), 1213-1232.

Argyres, N. S., & Liebeskind, J. P. (1999). Contractual commitments, bargaining power, and governance inseparability: Incorporating history into transaction cost theory. *Academy of Management Review*, *24*(1), 49-63.

Argyres, N., & Mayer, K. J. (2007). Contract design as a firm capability: An integration of learning and transaction cost perspectives. *Academy of Management Review*, *32*(4), 1060-1077.

Arora, A., & Fosfuri, A. (2003). Licensing the market for technology. *Journal of Economic Behavior & Organization*, *52*(2), 277-295.

Arora, A., & Gambardella, A. (2010). Ideas for rent: an overview of markets for technology. *Industrial and Corporate Change*, *19*(3), 775-803.

Arora, A., & Ceccagnoli, M., (2006). Patent protection, complementary assets and firm's incentives for technology licensing. *Management Science* 52, 535-554.

Arora, A., Fosfuri, A., & Gambardella, A. (2004). *Markets for technology: The economics of innovation and corporate strategy*. MIT press.

Athreye, S., & Cantwell, J. (2007). Creating competition? Globalisation and the emergence of new technology producers. *Research Policy*, 36(2), 209-226.

Bessy, C., Brousseau, E., & Saussier, S. (2004). Payment schemes in technology licensing agreements: a transaction cost approach. Working Paper, Université Paris X & ATOM.

Bhattacharyya, S., & Lafontaine, F. (1995). Double-sided moral hazard and the nature of share contracts. *The RAND Journal of Economics*, 761-781.

Bogdan, B., & Villiger, R. (2010). Valuation in life sciences. In *Valuation in Life Sciences* (pp. 67-303). Springer, Berlin, Heidelberg.

Bousquet, A., Cremer, H., Ivaldi, M., & Wolkowicz, M. (1998). Risk sharing in licensing. *International Journal of Industrial Organization*, 16(5), 535-554

Cassiman, B., & Veugelers, R. (2006). In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management Science*, *52*(1), 68-82.

Cassimon, D., De Backer, M., Engelen, P.J., Van Wouwe, M., & Yordanov, V., (2011). Incorporating technical risk in compound real option models to value a pharmaceutical R&D licensing opportunity. *Research Policy* 40, 1200-1216.

Ceccagnoli, M., Graham, S. J., Higgins, M. J., & Lee, J. (2010). Productivity and the role of complementary assets in firms' demand for technology innovations. *Industrial and Corporate Change*, 19(3), 839-869.

Ceccagnoli, M., & Jiang, L. (2013). The cost of integrating external technologies: Supply and demand drivers of value creation in the markets for technology. *Strategic Management Journal*, *34*(4), 404-425.

Cheng, C. C., & Huizingh, E. K. (2014). When is open innovation beneficial? The role of strategic orientation. *Journal of Product Innovation Management*, *31*(6), 1235-1253.

Chesbrough, H. (2003). The logic of open innovation: managing intellectual property. *California Management Review*, 33-58.

Crama, P., De Reyck, B., & Degraeve, Z. (2008). Milestone payments or royalties? Contract design for R&D licensing. *Operations Research* 56(6), 1539-1552.
Crama, P., De Reyck, B., Degraeve, Z., & Chong, W. (2007). R&D project valuation and licensing negotiations at Phytopharm plc. *Interfaces* 37, 472-487.
DiMasi, J. A., Grabowski, H. G., & Hansen, R. W. (2016). Innovation in the pharmaceutical industry: new estimates of R&D costs. *Journal of Health Economics*, *47*, 20-33.
DiMasi, J. A., Hansen, R. W., & Grabowski, H. G. (2003). The price of innovation: new estimates of drug development costs. *Journal of Health Economics*, *22*(2), 151-185.
DiMasi, J.A., (2001). New drug development in U.S. 1963-1999. *Clinical Pharmacology Therapeutics* 69, 286-296.
Edwards, M. G., Murray, F., & Yu, R. (2003). Value creation and sharing among universities, biotechnology and pharma. *Nature biotechnology*, *21*(6), 618.
Elfenbein, D. W., & Lerner, J. (2003). Ownership and control rights in Internet portal alliances, 1995-1999. *RAND Journal of Economics*, 356-369.
Fosfuri, A. (2006). The licensing dilemma: understanding the determinants of the rate of technology licensing. *Strategic Management Journal*, *27*(12), 1141-1158.
Frishammar, J., Ericsson, K., & Patel, P. C. (2015). The dark side of knowledge transfer: Exploring knowledge leakage in joint R&D projects. *Technovation*, *41*, 75-88.
Gallini, N. T., & Wright, B. D. (1990). Technology transfer under asymmetric information. *RAND Journal of Economics*, 147-160.
Gambardella, A., & Panico, C. (2014). On the management of open innovation. *Research Policy*, *43*(5), 903-913.
Gambardella, A., Giuri, P., & Luzzi, A. (2007). The market for patents in Europe. *Research Policy*, *36*(8), 1163-1183.
Gans, J. S., & Stern, S. (2003). The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. *Research Policy*, 32(2), 333-350.
Gianiodis, P. T., Ettlie, J. E., & Urbina, J. J. (2014). Open service innovation in the global banking industry: Inside-out versus outside-in strategies. *Academy of Management Perspectives*, *28*(1), 76-91.
Gulati, R., Lavie, D., & Singh, H. (2009). The nature of partnering experience and the gains from alliances. *Strategic Management Journal*, *30*(11), 1213-1233.
Gunther McGrath, R., & Nerkar, A. (2004). Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms. *Strategic Management Journal*, *25*(1), 1-21.
Hagedoorn, J. (2002). Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. *Research Policy*, *31*(4), 477-492.
Hagedoorn, J., & Zobel, A. K. (2015). The role of contracts and intellectual property rights in open innovation. *Technology Analysis & Strategic Management*, *27*(9), 1050-1067.
Hartmann, M., & Hassan, A., (2006). Application of real option analysis for pharmaceutical R&D project evaluation: empirical result from a survey. *Research Policy* 35, 343-354.
Henderson, R., & Cockburn, I. (1994). Measuring competence? Exploring firm effects in pharmaceutical research. *Strategic Management Journal*, *15*(S1), 63-84.
Henkel, J., Baldwin, C. Y., & Shih, W. (2013). IP modularity: Profiting from innovation by aligning product architecture with intellectual property. *California Management Review*, *55*(4), 65-82.
Higgins, M. J. (2007). The allocation of control rights in pharmaceutical alliances. *Journal of Corporate Finance*, 13(1), 58-75.
Hoang, H., & Rothaermel, F. T. (2005). The effect of general and partner-specific alliance experience on joint R&D project performance. *Academy of Management Journal*, *48*(2), 332-345.
Hughes-Morgan, M., & Yao, B. E. (2016). Rent Appropriation in strategic alliances: A study of technical alliances in pharmaceutical industry. *Long Range Planning*, *49*(2), 186-195.
Hurmelinna, P., Kyläheiko, K., & Jauhiainen, T. (2007). The Janus face of the appropriability regime in the protection of innovations: Theoretical re-appraisal and empirical analysis. *Technovation*, *27*(3), 133-144.

Inkpen, A. C., & Beamish, P. W. (1997). Knowledge, bargaining power, and the instability of international joint ventures. *Academy of Management Review*, *22*(1), 177-202.
Kamien, M.I., & Tauman, Y., (1986). Fees versus royalties and the private value of a patent. *Quarterly Journal of Economics* 101, 471-493.
Kani, M., & Motohashi, K. (2012). Understanding the technology market for patents: New insights from a licensing survey of Japanese firms. *Research Policy*, *41*(1), 226-235.
Katz, M. L., & Shapiro, C. (1985). On the licensing of innovations. *The RAND Journal of Economics*, 504-520.
Khoury, T. A., Pleggenkuhle-Miles, E. G., & Walter, J. (2017). Experiential Learning, Bargaining Power, and Exclusivity in Technology Licensing. *Journal of Management*, 0149206317693084.
Kotha, R., Crama, P., & Kim, P. H. (2018). Experience and signaling value in technology licensing contract payment structures. *Academy of Management Journal*, *61*(4), 1307-1342.
Kulatilaka N., & Lin L., (2006). Impact of Licensing on Investment and Financing of Technology Development. *Management Science*, *52*(12),1824-1837.
Laursen, K., & Salter, A. J. (2014). The paradox of openness: Appropriability, external search and collaboration. *Research Policy*, *43*(5), 867-878.
Laursen, K., Leone, M. I., & Torrisi, S. (2010). Technological exploration through licensing: new insights from the licensee's point of view. *Industrial and Corporate Change*, *19*(3), 871-897.
Lazzarini, S. G., Miller, G. J., & Zenger, T. R. (2004). Order with some law: Complementarity versus substitution of formal and informal arrangements. *Journal of Law, Economics, and Organization*, *20*(2), 261-298.
Leone, M. I., Oriani, R., & Reichstein, T. (2015). How much are flexibility and uncertainty worth in patent licensing?. *Economia e Politica Industriale,* 42(4), 371-394.
Leone, M. I., & Reichstein, T. (2012). Licensing-in fosters rapid invention! The effect of the grant-back clause and technological unfamiliarity. *Strategic Management Journal*, *33*(8), 965-985.
Lowe, J., & Taylor, P. (1998). R&D and technology purchase through license agreements: complementary strategies and complementary assets. *R&D Management*, 28(4), 263-278.
Lerner, J., & Merges, R. P. (1998). The control of technology alliances: An empirical analysis of the biotechnology industry. *The Journal of Industrial Economics*, *46*(2), 125-156.
Lynch, J., & Shockley, R. (2017). Valuation of a pharmaceutical licensing contract. *Journal of Applied Corporate Finance*, *29*(3), 80-88.
Macho-Stadler, I., Martinez-Giralt, X., & Perez-Castrillo, J.D. (1996). The role of information in licensing contract design. *Research Policy* 25, 43-57.
Manzini, R., & Lazzarotti, V. (2016). Intellectual property protection mechanisms in collaborative new product development. *R&D Management*, *46*(S2), 579-595.
Mayer, K. J., & Argyres, N. S. (2004). Learning to contract: Evidence from the personal computer industry. *Organization Science*, *15*(4), 394-410.
Mehlman, S. K., Uribe-Saucedo, S., Taylor, R. P., Slowinski, G., Carreras, E., & Arena, C. (2010). Better practices for managing intellectual assets in collaborations. *Research-Technology Management*, *53*(1), 55-66.
Minshall, T., Mortara, L., Valli, R., & Probert, D. (2010). Making "asymmetric" partnerships work. *Research-Technology Management*, *53*(3), 53-63.
Miozzo, M., Desyllas, P., Lee, H. F., & Miles, I. (2016). Innovation collaboration and appropriability by knowledge-intensive business services firms. *Research Policy*, *45*(7), 1337-1351.
Motohashi, K. (2008). Licensing or not licensing? An empirical analysis of the strategic use of patents by Japanese firms. *Research Policy*, *37*(9), 1548-1555.
Ozmel, U., & Guler, I. (2015). Small fish, big fish: The performance effects of the relative standing in partners' affiliate portfolios. *Strategic Management Journal*, *36*(13), 2039-2057.
Ozmel, U., Yavuz, D., Reuer, J. J., & Zenger, T. (2017). Network prominence, bargaining power, and the allocation of value capturing rights in high-tech alliance contracts. *Organization Science*, *28*(5), 947-964.

Pennings, E., & Sereno, L., (2011). Evaluating pharmaceutical R&D under technical and economic uncertainty. *European Journal of Operational Research* 212, 374-385.
Phene, A., & Tallman, S. (2012). Complexity, context and governance in biotechnology alliances. *Journal of International Business Studies*, *43*(1), 61-83.
Pisano, G. P. (1991). The governance of innovation: vertical integration and collaborative arrangements in the biotechnology industry. *Research Policy*, *20*(3), 237-249.
Pisano, G. P., & Teece, D. J. (2007). How to capture value from innovation: Shaping intellectual property and industry architecture. *California Management Review*, *50*(1), 278-296.
Poppo, L., & Zenger, T. (2002). Do formal contracts and relational governance function as substitutes or complements?. *Strategic Management Journal*, *23*(8), 707-725.
Reuer, J. J., & Arino, A. (2007). Strategic alliance contracts: Dimensions and determinants of contractual complexity. *Strategic Management Journal*, *28*(3), 313-330.
Ruback, R.S., & Krieger, D.B., 2000. Merck & Co.: evaluating a drug licensing opportunity. *Case 9-201-023*. Harvard Business School Publishing, Boston, MA.
Sakakibara, M. (2010). An empirical analysis of pricing in patent licensing contracts. *Industrial and Corporate Change*, *19*(3), 927-945.
Santos, F. M., & Eisenhardt, K. M. (2005). Organizational boundaries and theories of organization. *Organization Science*, *16*(5), 491-508.
Shepard, A. (1987). Licensing to enhance demand for new technologies. *The RAND Journal of Economics*, 360-368.
Shockley, R., Curtis, S, Jafari, J., & Tibbs, K. (2003). The option value of an early-stage biotechnology investment. *Journal of Applied Corporate Finance* 15, 44-55.
Smit, H.T.J., & Trigeorgis, L., (2017). Strategic NPV: real options and strategic games under different information structures. *Strategic Management Journal*. 8(13): 2555-2578.
Somaya, D. (2012). Patent strategy and management: An integrative review and research agenda. *Journal of Management*, *38*(4), 1084-1114.
Somaya, D., Kim, Y., & Vonortas, N. S. (2011). Exclusivity in licensing alliances: using hostages to support technology commercialization. *Strategic Management Journal*, *32*(2), 159-186.
Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy*, *15*(6), 285-305.
Thompson, L. (1990). The influence of experience on negotiation performance. *Journal of Experimental Social Psychology*, *26*(6), 528-544.
Trigeorgis, L. (1996). *Real options: Managerial flexibility and strategy in resource allocation*. MIT press.
Trigeorgis, L., & Reuer, J. J. (2017). Real options theory in strategic management. *Strategic Management Journal*, *38*(1), 42-63.
Vassolo, R. S., Anand, J., & Folta, T. B. (2004). Non-additivity in portfolios of exploration activities: A real options-based analysis of equity alliances in biotechnology. *Strategic Management Journal*, 25(11), 1045-1061.
Veer, T., Lorenz, A., & Blind, K. (2016). How open is too open? The mitigating role of appropriation mechanisms in R&D cooperation settings. *R&D Management*, *46*(S3), 1113-1128.
Wadhwa, A., Bodas Freitas, I. M., & Sarkar, M. B. (2017). The paradox of openness and value protection strategies: effect of extramural R&D on innovative performance. *Organization Science*, *28*(5), 873-893.
Wang, Y., Guo, B., & Yin, Y. (2017). Open innovation search in manufacturing firms: the role of organizational slack and absorptive capacity. *Journal of Knowledge Management*, *21*(3), 656-674.
Ziedonis, A. A. (2007). Real options in technology licensing. *Management Science*, 53(10), 1618-1633.
Zobel, A. K., Balsmeier, B., & Chesbrough, H. (2016). Does patenting help or hinder open innovation? Evidence from new entrants in the solar industry. *Industrial and Corporate Change*, *25*(2), 307-331.

TABLE 1. Number of deals, median upfront fee, milestones and royalty rates by stage.

Stage at deal signing	Number of Deals	Upfront Fee ($m)	R&D Milestones ($m)	Sales Milestones ($m)	Royalty Rate
Preclinical	77	9.5	54.5	110.0	5.0%
Phase I	48	8.5	70.0	95.0	8.0%
Phase II	66	10.0	101.0	100.0	10.0%
Phase III	39	15.0	111.8	103.8	14.5%
Approval	27	9.8	20.4	75.0	13.0%
Total	*257*	*10.0*	*57.5*	*100.0*	*10.0%*

TABLE 2. Classification of licensing schemes and number (%) of deals per scheme.

	Licensing contract scheme	Who controls development	# Deals	%
I	Licensee controls development and pays development costs (D)	LE	193	75%
II	Licensor controls development and pays development costs (D)	LR	36	14%
III	Licensor & Licensee co-develop (share development costs, D)	LR/LE	28	11%
		Total	***257***	***100%***

Note: LE denotes the Licensee (typically big pharma), LR the Licensor (small biotech).

TABLE 3. Definitions and sources of main variables.

VARIABLE	DEFINITION	SOURCE
%LR	Logarithm of the fraction (in %) of total Expanded Net Present Value (E-NPV) of the licensing deal accruing to the licensor	Medtrack; Recap IQ; SEC
AGE_LR	Logarithm of number of years since the licensor's incorporation date until 2013 (most recent year in the sample)	Medtrack; Osiris
FINACCESS_LR	Dummy with value: 1 if the licensor had access to external equity capital through an IPO or VC financing; 0 otherwise	Medtrack
%ROYALTY	Logarithm of [1 + royalty rate (in %)]	Medtrack; Recap IQ; SEC

ROYALTIES-TO-FIXED	Logarithm of the ratio of royalties on future drug sales to fixed payments (milestones + upfront fee). Royalties on sales are obtained by multiplying the royalty rate times the peak sales of each drug by therapy area	Medtrack; Recap IQ; SEC
LATESTAGE	Dummy with value: 1 if the licensor has signed a deal on a candidate drug in late stages (Phase II, Phase III or Approval); 0 in early stages (Preclinical or Phase I)	Recap IQ
LICENSED-IN_LE	Logarithm of the number of drugs licensed-in from third parties divided by the total assets of the licensee	Medtrack; Osiris
CODEV	Dummy variable with value: 1 when the licensing deal is structured as co-development based on contractual scheme III; 0 otherwise	Recap IQ
SCHEME_LE	Dummy variable with value: 1 when the licensing deal is structured based on contractual scheme I (licensee controls development); 0 otherwise	Recap IQ

TABLE 4. Summary statistics.

Panel A. Descriptive Statistics.

	N	**Min**	**Max**	**Mean**	**Std. Dev.**
%LR	201	0.09	0.89	0.46	0.17
AGE_LR	193	3.00	150.00	34.88	30.90
FINACCESS_LR	201	0.00	1.00	0.42	0.49
%ROYALTY	201	0.02	0.25	0.09	0.05
ROYALTIES-TO-FIXED	199	0.02	79.35	3.45	8.61
LATESTAGE	201	0.00	1.00	0.56	0.50
LICENSED-IN_LE	181	0.00	10.00	0.18	0.90
CODEV	201	0.00	1.00	0.10	0.31
SCHEME_LE	201	0.00	1.00	0.77	0.42
N	*175*				

Panel B. Correlations.

	%LR	AGE_LR	FINACCESS_ LR	%ROYALTY	ROYALTIES-TO-FIXED	LATESTAGE	LICENSED-IN_LE	CODEV	SCHEME_LE
%LR	1.000	0.160	0.063	0.609	-0.259	0.369	-0.126	0.021	-0.047
AGE_LR	0.160	1.000	-0.137	0.118	0.048	0.159	-0.071	0.002	-0.014
FINACCES_LR	0.063	-0.137	1.000	-0.104	-0.090	-0.106	0.042	0.073	-0.032
%ROYALTY	0.609	0.118	-0.104	1.000	0.209	0.632	-0.080	0.023	-0.161
ROYALTIES-TO-FIXED	-0.259	0.048	-0.090	0.209	1.000	-0.014	-0.042	-0.108	0.108
LATESTAGE	0.369	0.159	-0.106	0.632	-0.014	1.000	0.051	-0.092	-0.108
LICENSED-IN_LE	-0.126	-0.071	0.042	-0.080	-0.042	0.051	1.000	-0.096	0.091
CODEV	0.021	0.002	0.073	0.023	-0.108	-0.092	-0.096	1.000	-0.618
SCHEME_LE	-0.047	-0.014	-0.032	-0.161	0.108	-0.108	0.091	-0.618	1.000

TABLE 5. Main OLS and Tobit regression results

Panel A. Results of OLS regressions

Dependent variable: % of total value of licensing deal accruing to licensor (%LR)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
AGE_LR	0.017* (1.885)	0.017** (2.231)	0.019** (2.478)	0.021*** (2.693)	0.021*** (2.709)	0.021*** (2.730)
FINACCESS_LR	0.033** (2.470)	0.026** (2.265)	0.024** (2.115)	0.027** (2.236)	0.028** (2.312)	0.028** (2.418)
%ROYALTY	1.689*** (10.550)	1.962*** (13.607)	2.226*** (11.997)	2.233*** (11.385)	2.260*** (11.410)	2.301*** (11.711)
ROYALTIES-TO-FIXED		-0.054*** (-7.731)	-0.057*** (-8.097)	-0.056*** (-7.870)	-0.057*** (-7.928)	-0.058*** (-8.157)
LATESTAGE			-0.033** (-2.225)	-0.029* (-1.850)	-0.031** (-1.973)	-0.028* (-1.775)
LICENSED-IN_LE				-0.031 (-1.602)	-0.033* (-1.674)	-0.035* (-1.795)
CODEV					-0.018 (-0.982)	0.015 (0.649)
SCHEME_LE						0.040** (2.280)
CONSTANT	0.156*** (4.728)	0.179*** (6.199)	0.172*** (5.969)	0.162*** (5.329)	0.163*** (5.363)	0.125*** (3.625)
Adj R2	0.382	0.529	0.538	0.564	0.564	0.575
Model F	40.547***	54.806***	45.756***	38.573***	33.193***	30.423***

Panel B. Results of Tobit regressions.

Dependent variable: % of total value of licensing deal accruing to licensor (%LR)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
AGE_LR	0.026** (2.05)	0.027** (2.42)	0.030*** (2.69)	0.033*** (2.90)	0.033*** (2.93)	0.033*** (2.96)
FINACCESS_LR	0.051*** (2.64)	0.042** (2.46)	0.039** (2.31)	0.042** (2.44)	0.043** (2.55)	0.045*** (2.66)
%ROYALTY	2.484*** (10.65)	2.882*** (13.70)	3.284*** (12.18)	3.299*** (11.67)	3.345*** (11.76)	3.403*** (12.09)
ROYALTIES-TO-FIXED		-0.078*** (-7.72)	-0.083*** (-8.13)	-0.081*** (-7.98)	-0.083*** (-8.09)	-0.085*** (-8.35)
LATESTAGE			-0.051** (-2.33)	-0.044* (-1.96)	-0.048** (-2.12)	-0.043* (-1.93)
LICENSED-IN_LE				-0.047* (-1.67)	-0.049* (-1.76)	-0.052* (-1.89)
CODEV					-0.314 (-1.17)	0.017 (0.51)
SCHEME_LE						0.058** (2.30)
CONSTANT	0.134*** (2.80)	0.169*** (4.00)	0.157*** (3.77)	0.144*** (3.28)	0.146*** (3.28)	0.091* (1.84)
Loglikelihood	118.089	144.031	146.718	137.737	138.421	141.017

FIGURE 1. Product development and market life cycle for representative drug.

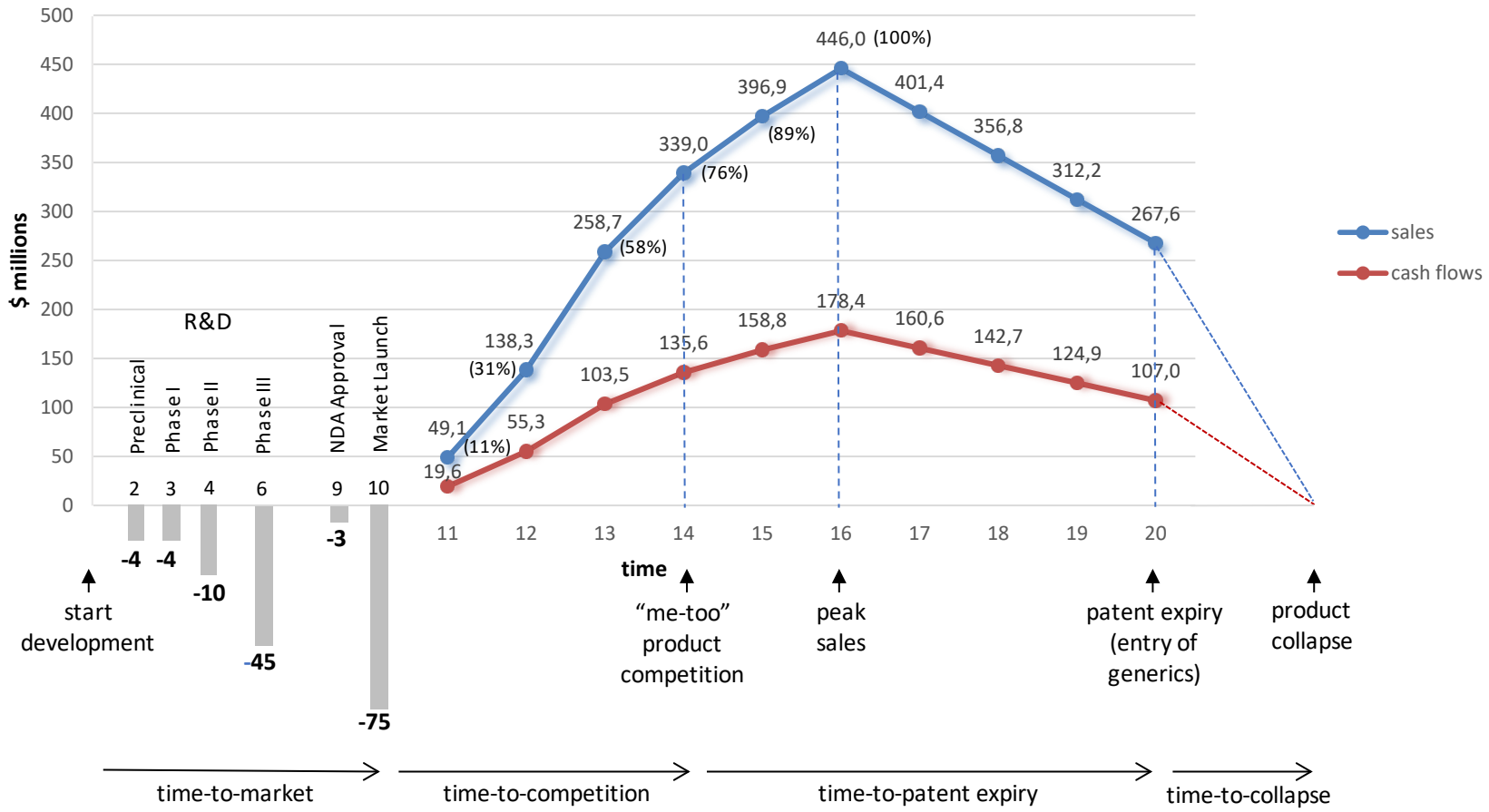
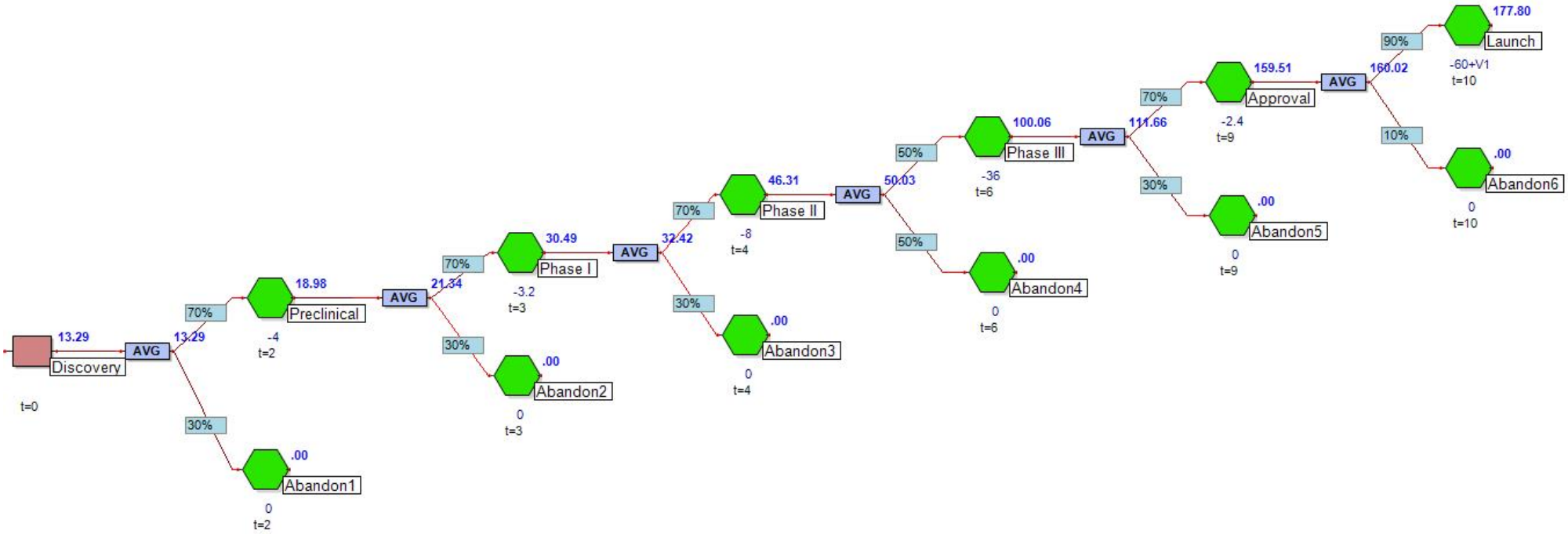


FIGURE 2. Compound-option R&D valuation of a typical drug at discovery stage.



APPENDIX 1. Drug development inputs, peak sales and success probabilities by stage and therapy.

	Discovery	Preclinical	Phase I	Phase II	Phase III	NDA Approval	Market Launch	*Total/ Cumul.*
Time (year)	0	2	3	4	6	9	10	
Duration (years)	2	1	1	2	3	1		*10*
Cost (US $ mln)	-4	-4	-4	-10	-45	-3	-75	*-145*
Biotech	*-3*	*-3*	*-3*	*-7*	*-30*	*-3*		
Pharma	*-6*	*-7*	*-5*	*-12*	*-68*	*-3*		
Success Prob.	70%	70%	70%	50%	70%	90%	100%	*11%*

Source: DiMasi et al. (2003, 2016), Bogdan and Villiger (2010).

#	Therapy Area	Mean Peak Sales (US $ mln)	Median Peak Sales (US $ mln)	Peak Sales Used (US $ mln)	Success Probabilities by Stage				
					Phase I	Phase II	Phase III	Approval	*Cumulative*
1	Cardiovascular	466	145	306	68%	48%	76%	89%	*22.3%*
2	Central Nervous System	746	422	584	71%	51%	62%	83%	*18.5%*
3	Endocrine, Metabolic & Genetic Disorders	803	371	587	53%	57%	79%	98%	*23.2%*
4	Gastroenterology	792	299	546	72%	54%	71%	91%	*25.1%*
5	Immunology & Inflammation	571	349	460	70%	50%	65%	87%	*19.5%*
6	Infectious Diseases	385	265	325	76%	56%	80%	102%	*34.7%*
7	Oncology & Hematology	735	323	529	69%	47%	65%	95%	*20.1%*
8	Respiratory	646	213	430	68%	46%	60%	82%	*15.5%*
9	Osteo-arthritis & Musculoskeletal	127	127	127	82%	43%	78%	94%	*25.9%*
10	Urology & Women's Health	602	535	569	50%	45%	58%	74%	*9.5%*
11	*Average/Other* (*)	***587***	***305***	***446***	***70%***	***50%***	***70%***	***90%***	***21.9%***

(*) Other includes dermatology, ophthalmology and miscellaneous.
Main Source: Bogdan and Villiger (2010), pp. 75, 78.

APPENDIX 2. Binomial valuation of a Phase II drug for licensee for Scheme I deal: LE controls development.

	Phase II			Phase III			NDA	Launch
Year	0	1	2	3	4	5	6	7
Prob	*0,47*		*0,65*			*0,95*	*1*	
Fee (F)	10							
Devel (D)	10		45			3		
Milest (M)			28			56	28	42
Launch (C)								75
Inv (I)			73			59	28	117

Launch/Commercialization (t = 6)

Year	0	1	2	3	4	5	6
0	233,75	737,83	2.202,27	6.398,92	18.309,17	51.960,11	147.021,74
1		61,03	238,91	776,79	2.360,61	6.910,59	19.771,46
2			-0,96	54,10	236,18	813,80	2.550,01
3				-21,11	-9,76	36,72	219,34
4					-26,28	-27,21	-28,18
5						-27,21	-28,18
6							-28,18

NDA Stage (t = 5)

Year	0	1	2	3	4	5
0	185,92	654,32	2.032,10	6.004,43	17.281,46	49.146,86
1		23,91	182,98	680,27	2.178,18	6.484,97
2			-33,02	10,28	166,34	711,31
3				-50,43	-46,22	-24,59
4					-54,43	-56,36
5						-56,36

Phase III (t = 2)

Year	0	1	2
0	86,67	357,26	1.255,81
1		-7,93	46,49
2			-28,18

$- M_{II} + \max(P_{III} * C_{III} - D_{III}, 0)$

Phase II (t = 0)

Year	0
	20,56

$- F_{II} + \max(P_{II} * C_{II} - D_{II}, 0)$