Project Number 653413

Interim Empirical Analysis Report on Licensing (D4.1)

This report is a progress report toward Working Paper –Theme II (second, empirical part) on

(2) ***Multi-stage R&D and IP licensing: theoretical analysis and empirical investigation.*** The first part (theory) would examine R&D and licensing as multi-stage compound options, also accounting for the probability of success at each stage, focusing on how to design optimal and fair licensing terms and value sharing rules accounting for who controls innovation development and commercialization options. The second part (empirical) tests the theoretical predictions and analyzes licensing deals and terms using the Medtrack and RECAP IQ databases on biotech/pharma licensing deals and terms (e.g. upfront payment, milestones, royalties).

The first part of the licensing deal analysis uses theory of valuing multi-stage innovation options in the context of R&D and biopharma licensing agreements to theoretically determine the % of the total value (Expanded NPV including option or flexibility value) accruing to the innovator/licensor (LR). The valuation of multi-stage options explicitly accounts for the technical probabilities of success by stage. The second, empirical part uses the Medtrack and RECAP IQ databases of pharma/biotech deals to empirically test the developed theoretical real option predictions. For this part I collaborated with LUISS faculty R. Oriani and F. Baldi.

Data Description

We make an integrated use of three databases. The main dataset comes from Medtrack database of licensing deals (Life Science Analytics) and Recap IQ –Deal Builder (Thomson Reuters). Recap IQ provided data on deal size, milestones and royalties, number of molecules, therapy area, phase at deal signing, and type of deal. Medtrack provided data about the companies involved in each deal and various characteristics like the pipeline of drugs, number of licensed-in drugs, licensing deal terms, and funds raised via IPO and VC investments. [1]

[1] The Medtrack database on biotech/pharma licensing deals compiled by the Politecnico of Milan contains data on each licensing deal by product name, therapeutic area, stage of R&D development, and licensing deal terms such

IMS Health Inc. was used for obtaining consensus inputs for an NPV analysis of drugs by therapy area. Supplementary data were used based on drug characteristics in the literature (e.g., DiMasi et al. (2003, 2016), Bogdan and Villiger (2010)), using public press releases and SEC filings. The deals were categorized by scheme type (three main types: the licensor controls development, the licensee controls, both co-develop), stage at deal signing, therapy area, royalty rates, milestone payments and so on. The collected data and y-variable construction allowed testing the multi-stage compound option model (adjusted to account for success probabilities by R&D stage) underlying biotech-pharma licensing deals and confirm its validity and explanatory power in explaining the value sharing among the parties (accounting for which party controls development) as observed in actual licensing deals.

The Recap IQ and Medtrack databases contained 257 licensing deals between a specified licensor (LR) and a licensee (LE) with complete licensing terms and other financial data over the period 2003-2013 that enabled compound option pricing of the licensing deal. Of these, 26 deals were excluded due to missing data needed for estimation of the y-variable (%LE) or key independent variables of the econometric model of eq. (1), and 56 deals were excluded due to containing outliers (e.g., unreasonably high reported royalties in some cases). The final data set contains complete data enabling to construct our dependent and explanatory variables and run our regressions with the full set of variables with valid listwise observations on 175 licensing deals.

Licensing Deal Characteristics and Summary Statistics

The number of observations on each variable and summary statistics on the 253 deals with complete data are given in Table 8 panel A. The 256 licensing deals with complete data are classified into three main licensing schemes, depending on whether the licensee (LE), the licensor (LR) or both parties (LE&LR jointly) control the development and hence the continuation or abandonment option. The

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 is 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.

number of deals distributed by each of the licensing schemes (with subcategories a. and b.) are given in Table 6.

Table 1 reports the number of licensing deals by therapy area. It also gives the typical (median) upfront fee, as well as the R&D and sales milestones by therapy area based on available deal data. Table 2 shows the median upfront fee as well as R&D and sales milestones by stage at deal signing. Table 3 provides representative percentage royalty rates by therapy area as well as by stage of signing. It is noteworthy that the agreed royalty rate tends to increase toward the later stages of deal signing (from 5% at preclinical to 8% at Phase I, 10% at Phase II and 14.5% at Phase III of clinical trials) as the innovator-licensor is making a higher commitment and relative contribution the later the deal is signed. Nonetheless, upon NDA approval and market launch, the balance of power and contribution shifts in favor of the licensor (typically large pharmaceutical or larger biotech) who is better able to commercialize the drug.

Table 4 presents representative (average) drug development parameters, such as stage duration, typical development costs by stage and average technical probabilities of success by stage. Table 5 provides detail of stage success probabilities by therapy area. It also provides mean and median peak sales by therapy area. Mean (average) peak sales tend to be biased upward as they include infrequent blockbuster drugs while media sales represent better smaller or more typical drugs. We have used the average of the two peak sales estimates in our projections of expected cash flows of each drug depending on the stage and therapy area as per Table 5 (partly also to update somewhat dated estimates available in the literature). A typical S-shaped sales curve following "me-too" product competition during the first 6 years from drug market launch (assumed at year 10) until reaching peak sales (estimated at $446 million for the average drug as per Table 5), followed by a smooth decline of sales as patent expiry approaches and a subsequent rapid product collapse with the entry of generics is used to estimate each drug's expected cash flows as shown in Figure 1.

Methodology

The basic econometric model used in the empirical analysis is the following:

% of total value to Licensor (notation %LR) or (1)

(Ratio of) compound option value (E-NPV) to Licensor (LR)-innovator/total E-NPV to both parties

= f (% royalty accruing to LR, %ROYALTY; the % of variable sales royalties to total fixed payments (upfront fee and milestones), ROYALTIES-TO-FIXED; late stage in lifecycle, LATESTAGE; license scheme & control of development option, LICSCHEME; control variables)

The control variables include: Licensor (biotech) age and experience, AGE_LR; Licensor prior access to financing (e.g., via IPO or venture capital funding), FINACCESS_LR; Licensee pipeline composition and broader/open innovation strategy capturing the degree of licensing-in external drugs, LICENSE-IN_LE).

The stage when the deal was signed (and hence the # 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 accounted for in the theoretical estimation of the depended variable (%LR).

The base analysis follows standard OLS regression. For robustness, due to the dependent variable being a ratio and censored (between 0 and 1), we also use Tobit regressions. Both sets of regressions follow the econometric model of eq. (1) above. When the OLS regression is used, the dependent variable (%LR based on the E-NPV of the licensor to the total E-NPV of both parties) is log-transformed to more closely satisfy the OLS normality assumption. Results are similar if the Ln version is used or not. All independent variables (except for the dummies) are in Ln form. The Tobit regressions were run without the log transformation. Results are comparable and are robust. A more detailed description of the estimation of the dependent and independent variables is given next.

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

When the expected cash flows obtained as described above are discounted at the cost of capital (assumed 11% for the typical drug) back to the beginning of deal signing, the underlying (gross) project value (Vo) for each drug is obtained. These estimates differ depending on the drug's therapy area (which result in different peak sales used rather than the $446 m average as per the therapy area in Table 5) and by

stage (which involves a different discounting horizon). Then each drug is valued as a multi-stage compound option using binomial tree valuation, properly adjusted for technical probabilities of success by stage, to obtain the drug's total or Expected Net present Value (E-NPV) that besides the standard NPV of cash flows also includes the value of embedded options (i.e., the real option value).[2] In estimating the compound option value of the multistage development process, the typical development costs by stage of Table 4 are used (each serving as the exercise price of the option to proceed to the next stage), also accounting for the probabilities of success by stage and therapy shown in Table 5. Depending on the therapy area, each drug is assessed into a volatility range based on recent average industry volatility estimates for the biotechnology sector obtained from Damodaran's public website: low volatility (70%), medium volatility (85%), high volatility (100%).[3] Figure 2 Illustrates the compound-option valuation of a typical R&D drug at the discovery stage (t = 0) (based on the typical parameters given in the tables above) whose development is controlled by the innovator-licensor (LR). The Expanded-NPV to the licensor (E-NPV_LR) at t = 0 is shown at the left-most node ($13.29m).

When the option-based valuation for a licensing deal is adjusted to account for the additional stipulated lease payments (upfront fee, R&D milestones and sales milestones, and sales royalties) for the innovator-licensor LR (who is stipulated to receive these payments) and the licensee LE (who makes these payments), then the net total value (including the value of the options to develop or abandon the drug and the option to launch) to the licensor (E-NPV_LR) and to the licensee (E-NPV_LR) are obtained.[4] Care is taken in these estimations to account for the contingency that if in certain "bad"

[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 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. For the last launch option, for example, the option payoff for the licensee (LE) is of the form: $-MIL_{FDA} + MAX(P_L*V_T*(1-R) - I_{LE} ; 0)$. MIL_{FDA} 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 launch (P_L) and reduced by the fraction of royalties to value (R%) paid to the licensor.

[3] 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.

[4] Table 7 shows ranges where the value shares for Licensor (E-NPV_LR) as % of total value are contained based on stage of deal signing based on E-NPV analysis compared to ranges used in practice based on standard NPV.

demand states (in the binomial option tree) the party who controls development and market launch (typically the pharmaceutical firm or 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 milestone or sales royalty payments. The dependent variable %LR is then obtained as[5]

$$\%LR = \text{E-NPV\_LR} / (\text{E-NPV\_LR} + \text{E-NPV\_LE}) \quad (2)$$

The dependent variable, %LR, being the E-NPV of the licensor divided by the sum of E-NPVs of the licensor and licensee, shows what percent of the total value of the licensing deal from a real options perspective goes to the licensor (LR). This is the analogue of the "profit split ratio" commonly used in negotiations of licensing deals in the biopharma industry but from a real options perspective. The ratio is between 0 and 1.

Independent Variables

Licensor's age (AGE_LR). This is defined as Ln of the age of the licensor (LR), computed from the licensor's incorporation date to 2013 (the most recent year covered in the dataset). It is a proxy for the survivability, size and experience of the licensor, testing whether a more experienced licensor can obtain more value in a deal. The older the licensor (typically a small biotech start-up) is, the more its survivability and accumulated experience and the higher its perceived contribution to drug development in a deal.

Licensor's access to financing (FINACCESS_LR). This is a dummy that takes the value 1 if the licensor has previously raised funding through an IPO or received VC financing, proxying for the LR's access to external financing and financial viability resulting in stronger negotiating position. When the dummy

[5] The simple ratio for %LR of eq. (2) is used in summary statistics and in the Tobit regressions, while its logarithmic version is used in all OLS regressions.

takes value 0 it likely reflects financial constraints. The dummy also partly accounts for the biotech IPO wave.

Licensee's degree of drugs licensed-in (LICENSED_IN_LE). This is defined as (Ln of) external drugs licensed-in divided by the total assets of the licensee (LE). It represents greater innovation breath and propensity (e.g., reflecting a broader or more open innovation strategy) on the part of the LE, indicating a broader or more holistic innovation-driven portfolio strategy. Along with more experience with licensing transactions, it reflects greater bargaining power for the licensee. Hence, the higher the portion of the LE's portfolio based on licensed-in drugs (past experience in licensing activity), the lower the value obtained by the licensor as the LE can use its bargaining power at the expense of the LR. Thus, it tests if a more powerful licensee reduces the value of the deal for the licensor.

Percentage royalty rate on sales (% ROYALTY). Since 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 constant. Along with fixed payments, this is a key variable for value appropriation although there is an inherent tradeoff that needs to be accounted for, discussed next.

Ratio of royalties to fixed payments (ROYALTIES_TO_FIXED). This ratio (in Ln) captures the inherent tradeoff between variable royalty payments and fixed payments, with higher variable royalties benefiting the licensor directly but generally coming at the expense of lower fixed payments in a negotiation. Royalties on sales here are computed by multiplying the royalty rates times the peak sales of each drug by therapy area. Fixed fees are the sum of upfront fee and various milestones. If the latter adverse effect in the ratio dominates, this ratio (which captures the interaction between the two payment components) will have a negative sign resulting in a lower value share for the licensor.

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). Its inclusion aims to shed light if the value obtained by the licensor increases or decreases in late stages. Other things constant, the later the stage of deal signing the more value share one might expect to accrue to the licensor as he might be in a stronger position. However, by the later stage the licensor

will also have incurred a heavier financial commitment in terms of incurring R&D costs and, although it theoretically controls development, it typically has little incentive to abandon the project midstream as it may put its very survival at stake. Upon approval, the balance shifts in favor of the licensee (typically large pharma) who controls the launch option and brings more value during the commercialization phase. Dominance of the latter effect would be at the expense of the licensor and result in a negative sign on %LR.

Co-development (CODEV). This is a dummy that takes value 1 for those deals involving co-development and 0 otherwise. Co-development has mixed effects. On one hand, it is beneficial to the licensor as the licensee can not 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, though it may be insignificant if the opposite effects partially offset each other. A negative sign on CODEV would suggest that co-development makes the licensor worse off in net.

Licensing scheme type (LICSCHEME). Motivated by the practical observation in the data and the realization that co-development may be the worst scheme for the licensor while licensee (LE) control of development may be preferable in many cases as it would result in more fixed payments to the licensor (LR), LICSCHEME is defined as the Ln of a licensing scheme variable that takes value 0 when there is co-development, value 1 when the licensor controls development, and value 2 when the licensee controls development. Co-development may be worse for the licensor as it would still have to pay part of the R&D costs but it would not receive milestone payments during the co-development period. The option to control development is typically more valuable in the hands of the licensee than the licensor. If the licensee is in control of development, it has strong incentives to discontinue further development in certain bad states and not pay future milestones and royalties in those states. If the licensor is in control, it would be less likely to exercise the option to discontinue development as this may risk the very survival of the biotech company. A positive sign on the LICSCHEME variable would be in line with

this practical reality concerning different licensing schemes observed in the data, suggesting that the licensor is worse off in net when it agrees to co-development and better off in terms of fixed payments that matter the most when the licensee controls development.

Hypotheses

Based on the above analysis, we develop and test the following hypotheses:

Ho (baseline): The share of total value (total E-NPV) accruing to the licensor (LR), %LR, will be greater the greater the LR's age, survivability and experience (AGE_LR) and the greater the access to financing of the LR (FINACCESS_LR), and it will be lower the greater the experience and bargaining power of the licensee (LE) as evidenced by the degree of licensed-in drugs (LICENSE-IN_LE).

H1a: The share of total value accruing to the licensor (%LR) will be greater the greater the royalty rate (%) to be received by the licensor, other things constant; but it will be less at the margin if higher royalty rate is traded off resulting in less fixed payments (upfront fee plus milestones).

H1b: the above tradeoff between variable royalties and fixed payments is more pronounced the later the stage of deal signing. Although anecdotal industry experience suggests the licensor can get a higher % royalty when the deal is signed later, the marginal effect on %LR reflecting the tradeoff with negotiated fixed payments will be negative (while the real commercialization power shifts in favor of the licensee as market launch approaches).

H2a: The value share to the licensor (%LR) is less under co-development.

H2b: The value share to the licensor (%LR) is generally influenced by the licensing scheme and who controls development (LICSCHEME) recognizing that the licensor may be worse off under co-development and better off under a scheme where the licensee pays for development.

Main Results

Table 8 Panel A provides summary statistics on the independent variables, and Panel B shows the correlation matrix among all independent variables. Correlations are generally low, with no concerns

for any serious collinearity problem (VIF scores in Table 9 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 seen in practice (see also Table 2 last column and Table 3).

Table 9 (panel A using OLS and panel B using Tobit regressions) presents our results testing Hypotheses Ho, H1a/b and H2a/b via 5 models (Models 1-5). It is based on 175 observations with complete data on all regression variables. The dependent variable, %LR, is the E-NPV of the licensor divided by the sum of E-NPVs of licensor and licensee, showing how much of the total value of the deal goes to the licensor. The regression analysis in Table 9 starts with some of the variables (controls) to test the baseline hypothesis (Ho) and incrementally adds more key explanatory variables, one at a time, showing the incremental effect of each key variable (the last comprehensive Model 5 includes all variables combined).

Model 1 of Table 9 (panels A and B) tests our baseline hypothesis (Ho) running a regression with only the first 3 independent variables (controls), namely AGE_LR, FINACCESS_LR, and LICENSED-IN_LE. In accordance with Ho, the share of total value accruing to the licensor (% LR) is greater the greater the LR's age, size and experience (AGE_LR) and access to financing (FINACCESS_LR), and is lower the greater the experience and bargaining power of the licensee (LE) as evidenced by the degree of licensed-in drugs (LICENSE-IN_LE). The positive impact of access to financing represents relaxation of financing constraints for licensors that had access to IPO and VC funds and hence a broader range of investors, resulting in more negotiating power and value share appropriation.

To test H1a, Model 2 adds (to the first 3 variables) the %ROYALTY and ROYALTIES-TO-FIXED. As hypothesized, %ROYALTY has a positive coefficient, of about 2 (significant at 1% with t-stat 13.47) confirming that the licensor is better off when it receives higher royalty rate, other things the same. However, in reality this comes at the expense of receiving significantly less fixed payments, being worse off in net. The coefficient of ROYALTIES-TO-FIXED capturing the marginal effect on %LR is negative (-0.053) and significant at 1% (t-stat 7.6), providing evidence of a binding tradeoff between negotiated variable and fixed payments at the detriment of the licensor. If the licensor negotiates higher % royalties, it would typically give up more share in fixed payments.

Model 3 tests H1b by adding LATESTAGE to the above variables (of Model 2). The late stage dummy's negative coefficient suggests a net loss of value for the licensor in later stages at the margin (confirming a negative marginal effect). The negative and significant coefficient (at 10% or 5%) confirms that although signing a deal in later stages enables the LR to negotiate a higher % royalty rate, the resulting tradeoff involving sacrifice of commensurably more valuable fixed payments leaves the LR worse off, making the marginal impact of LATESTAGE on %LR negative.[6] Besides foregoing interim milestone payments, the later the stage the deal is signed the more the licensor has already invested for drug development (in terms of money, effort and risk undertaken) in all previous stages leading up to the stage of deal signing. Signing a deal earlier would attain a lower % royalty rate but would involve a lower cumulative fixed commitment of resources by the licensor while receiving more milestones. Further, as the last stage closer to market launch approaches, the relative contribution (in terms of sales and distribution) and bargaining power of the licensee increases at the expense of the licensor.

Model 4 adds co-development (CODEV) to the above variables (of Model 3) to test H2a. The coefficient of CODEV is negative in line with the licensor being worse off in a co-development scheme as suggested, though not statistically significant.

Model 5 tests H2b by adding add LICSCHEME to previous variables of Model 3 (without CODEV), confirming the conjectured impact of the type of licensing scheme on value appropriation among the parties, with the licensor being worse off under co-development and better off when the licensee controls development. This is so for several reasons. In the latter case the LR would receive more fixed payments which are less risky and more valuable than royalties. The LR would also be less likely to exercise the option not to continue development as it may be the end of the startup and so the option to control development is less valuable to the LR than the LE. As noted, co-development is worse the LR would pay part of the R&D costs and would forego milestone payments during the co-development period.

[6] This seems contrary to industry wisdom and royalty data by stage suggesting that the licensor can negotiate a higher royalty rate at the later stages. As noted, LATESTAGE and %ROYALTY have a high positive correlation, in line with royalty rates increasing toward the later stages. The opposite than expected sign is partly due to the inherent tradeoff with negotiated fixed costs (represented by ROYALTIES_TO_FIXED variable).

The coefficients and significance of all other variables remain as in previous model regressions, confirming the robustness of the estimates. Model 5 in the OLS regressions (Panel of Table 9) has an Adjusted R^2 of 57%, with model F-stat of 33.85 (significant at 1%). The results of the Tobit regressions (in Panel B) are very similar to those of the OLS regressions, with significant Model 5 Log-likelihood of 139.65.[7]

Conclusion

In structuring licensing deals we have shown the importance in value share appropriation between the parties of the type of licensing scheme and which party controls the development option. Besides confirming the key roles of prior experience and negotiating power of the parties to a licensing deal, we also highlight an important adverse tradeoff for the innovator-licensor of negotiating a higher % royalty in terms of realizing lower fixed upfront and milestone payments, which gets more severe if the deal is signed at a later stage.

[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 two-star level of significance, and the license scheme variable a one-star significance. The co-development variable has a negative coefficient but is not significant in either regression as well. The economic interpretation of the coefficients of the Tobit regression is similar to that of the OLS regression.

TABLE 1. Number of licensing deals, median upfront fee and milestones by therapy area (based on available deal data).

Therapy Area	# Deals	Upfront Fee ($m) (**)	R&D Milestones ($m) (***)	Sales Milestones ($m) (****)
Cardiovascular	17	2.0	42.5	43.5
Central Nervous System	42	6.3	35.0	55.0
Endocrine, Metabolic and Genetic Disorders	24	22.7	30.0	120.0
Gastroenterology	16	10.0	65.0	78.8
Immunology and Inflammation	17	13.5	74.0	100.0
Infectious Deseases	28	14.0	151.5	747.5
Oncology and Hematology	75	6.7	138.0	87.8
Osteo-arthritis & Musculoskeletal	9	10.0	60.0	200.0
Respiratory	8	10.0	24.5	
Urology & Women's Health	6	7.5		
Other (*)	15	6.8	40.0	135.0
Overall	**257**	**10.0**	**57.5**	**92.5**

(*) Other includes dermatology, ophthalmology and miscellaneous.

(**) Based on 190 deals with available upfront fee data.

(***) Based on 88 deals with available breakdown data on R&D milestones.

(****) Based on 24 deals with available sales milestone data.

TABLE 2. Number of deals, median upfront fee, milestones and royalty rates by stage of deal signing.

Phase 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 3. Representative percentage royalty rates by therapy area and by stage of deal signing.

Therapy Area	Preclinical	Phase I	Phase II	Phase III	Approval
Cardiovascular	4.5%	7.5%	7.7%	10.0%	12.5%
Central Nervous System	5.0%	8.0%	9.3%	11.3%	11.2%
Endocrine, Metabolic and Genetic Disorders	5.0%	7.0%	10.0%	10.8%	15.0%
Gastroenterology	5.0%	8.6%	10.3%	14.0%	
Immunology and Inflammation	5.7%	7.5%	11.5%	14.5%	14.0%
Infectious Deseases	8.0%	10.0%	13.1%	14.0%	14.0%
Oncology and Hematology	5.0%	8.0%	10.0%	12.1%	13.4%
Osteo-arthritis & Musculoskeletal	5.6%	8.0%	10.0%	12.1%	13.4%
Respiratory	6.3%	11.5%	10.4%	10.0%	13.8%
Urology & Women's Health	5.6%	8.8%	7.5%	12.1%	13.4%
Other/Avg	5.6%	8.5%	10.0%	12.1%	13.4%
Overall (based on 256 deals)	**5.0%**	**8.0%**	**10.0%**	**14.5%**	**13.0%**

TABLE 4. Representative (typical) drug development parameters: duration, development costs, and success probabilities by R&D stage.

	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).

TABLE 5. Peak sales by therapy area and probabilities of success by therapy area and stage.

#	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%***

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

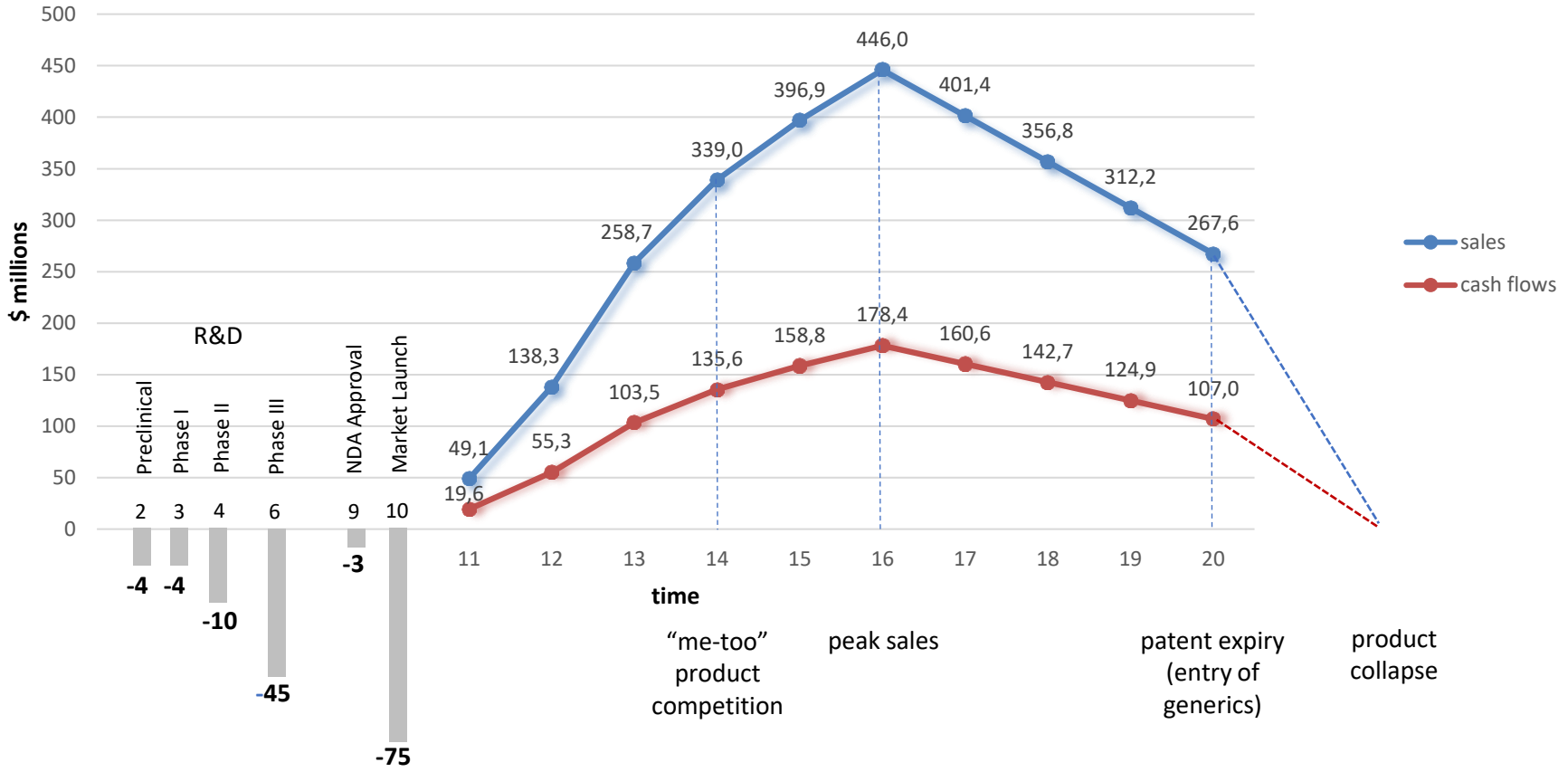

FIGURE 2. Compound-option valuation of a typical drug at discovery stage for the innovator-licensor (LR).

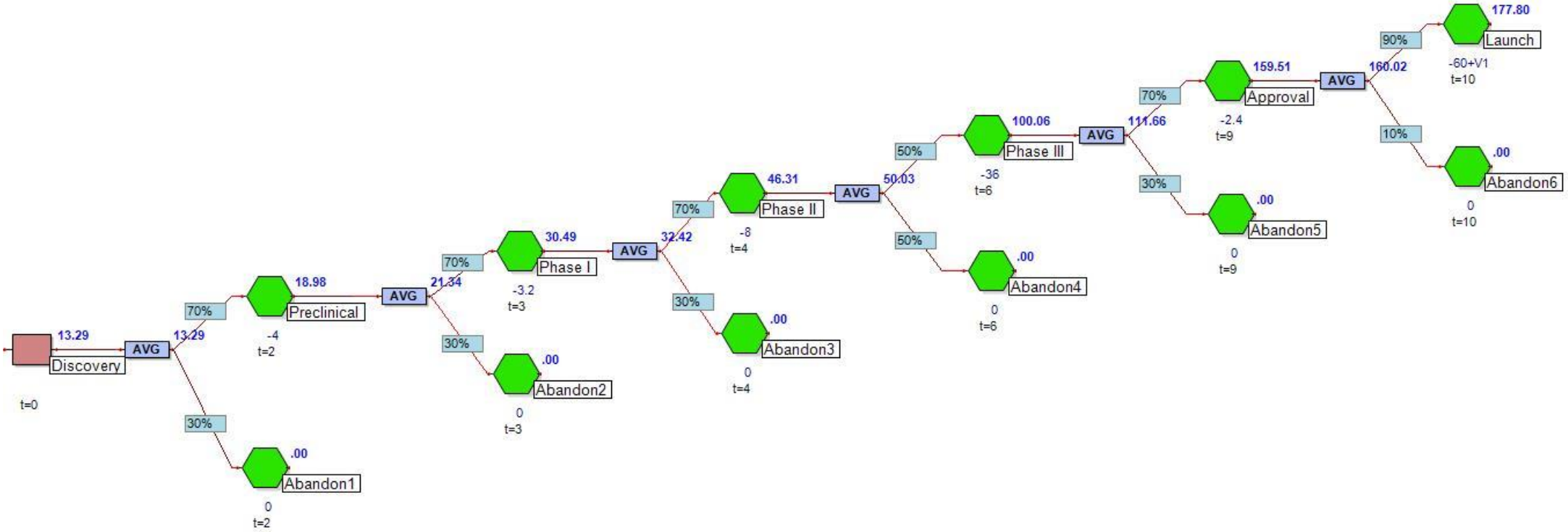

TABLE 6. Classification of licensing schemes and deals per scheme.

	Licensing contract scheme	**Who controls development**	**# Deals**	**%**
I	a) Licensee controls development and pays development costs (D)	LR	180	70%
	b) Licensor starts development (D) but Licensee has option to take over midstream		13	5%
II	a) Licensor controls development and pays development costs (D)	LE	3	1%
	b) Licensor pays development costs (D) but gets reimbursed by Licensee		33	13%
III	a) Licensor & Licensee co-develop (share development costs, D) from start	LR/LE	23	9%
	b) Licensor starts development (D) but Licensee has option to switch to co-development		5	2%
		Total	***257***	***100%***

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

TABLE 7. Value share for Licensor (E-NPV_LR) as % of total value (with range).

	Based on	
Stage at deal signing	**% E-NPV LR ***	**% NPV/Practice ****
Preclinical	40% (20-50%)	15% (10-20%)
Phase I (IND)	35% (25-45%)	30% (20-40%)
Phase II	45% (35-55%)	50% (40-60%)
Phase III	60% (50-70%)	
Approval	55% (40-80%)	70% (60-80%)

Sources:

(*) Authors' option-based estimates using Medtrack & RECAP IQ databases.

(**) Bogdan and Villiger (2010), pp. 152.

TABLE 8. Summary statistics.

Panel A. Descriptive Statistics.

	N	Min	Max	Mean	Std. Dev
%LR	201	0.09	0.64	0.3699	0.11835
AGE_LR	193	1.39	5.02	3.2865	0.75040
FINACCESS-LR	201	0.00	1.00	0.4179	0.49445
LICENSE-IN_LR (log)	181	0.00	2.40	0.0878	0.29716
%ROYALTY	201	0.02	0.22	0.0894	0.04119
ROYALTIES-TO-FIXED (log)	199	0.02	4.39	0.9036	0.86537
LATESTAGE	201	0.00	1.00	0.5622	0.49736
CODEV	201	0.00	1.00	0.1045	0.30664
LICSCHEME	201	0.00	1.10	0.9320	0.34721
Valid N (listwise)	175				

Panel B. Correlations.

		1	2	3	4	5	6	7
1	AGE_LR	1						
2	FINACCES_LR	-0.137	1					
3	LICENSE-IN_LE	-0.071	0.042	1				
4	%ROYALTY	0.118	-0.104	-0.080	1			
5	ROYALTIES-TO-FIXED	0.048	-0.090	-0.042	.209**	1		
6	LATESTAGE	.159*	-0.106	0.051	.632**	-0.014	1	
7	CODEV	0.002	0.073	-0.096	0.023	-0.108	-0.092	1

TABLE 9. Main OLS and Tobit regression results.

Panel A. OLS regression results.

Dependent variable: % LR					
	Model 1	Model 2	Model 3	Model 4	Model 5
AGE_LR	0.026** (2.27)	0.02** (2.50)	0.021*** (2.69)	0.021*** (2.71)	0.021*** (2.73)
FINACCES_LR	0.026 (1.48)	0.027** (2.26)	0.027** (2.24)	0.028** (2.31)	0.028** (2.41)
LICENSE-IN_LE	-0.053* (-1.84)	-0.036* (-1.87)	-0.31 (-1.60)	-0.033* (-1.67)	-0.034* (-1.77)
%ROYALTY		1.993*** (13.47)	2.233*** (11.38)	2.26*** (11.41)	2.291*** (11.60)
ROYALTIES-TO-FIXED		-0.053*** (-7.60)	-0.56*** (-7.87)	-0.057*** (-7.93)	-0.058*** (-8.11)
LATESTAGE			-0.29* (-1.85)	-0.031* (-1.97)	-0.032** (-2.03)
CODEV				-0.018 (-0.98)	
LICSCHEME					0.029* (1.78)
Adj. R2	0.041	0.558	0.564	0.564	0.57
Model F	3.467**	44.959***	38.573***	33.193***	33.947***

Panel B. Results of Tobit regressions.

Dependent variable: % LR					
	Model 1	Model 2	Model 3	Model 4	Model 5
AGE_LR	0.041** (2.40)	0.031** (2.68)	0.033*** (2.90)	0.033*** (2.93)	0.033*** (2.96)
FINACCES_LR	0.041 (1.61)	0.043** (2.46)	0.042** (2.44)	0.044** (2.55)	0.045*** (2.64)
LICENSE-IN_LE	-0.079* (-1.90)	-0.055* (-1.95)	-0.047* (-1.67)	-0.05* (-1.76)	-0.052* (-1.86)
%ROYALTY		2.931*** (13.69)	3.30*** (11.67)	3.35*** (11.76)	3.39*** (11.96)
ROYALTIES-TO-FIXED		-0.077*** (-7.65)	-0.081*** (-7.98)	-0.083*** (-9.09)	-0.085*** (-8.28)
LATESTAGE			-0.044* (-1.96)	-0.048** (-2.12)	-0.049** (-2.17)
CODEV				-0.031 (-1.17)	
LICSCHEME					0.047* (1.97)
Log-likelihood	67.243	135.833	137.737	138.421	139.648