

Financing and the Market for Ideas

Evidence from the Biopharma Industry

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Nov 6th 2015

Outline

Background and Research Question

Empirical Specification

Data and Descriptives

Regression Results

Discussion and Implications

Appendix

Motivation

- ▶ Market for ideas is important for innovation
 - ▶ Complementary assets, specialization of labor,
 - ▶ Productive efficiency: time to market, success rate, cost
- ▶ Sellers may have strategic incentive to delay sale
 - ▶ Increased bargaining power
 - ▶ Asymmetric information
- ▶ Efficient stage of transfer vs. seller's optimal stage of transfer, and role of financing

Background: Biopharma Industry

- ▶ Market of ideas in drug development
- ▶ Which stage to sell is strategically important
- ▶ Financing is a key constraint

Research Question

- ▶ Effect of a biotech startup's financial resources on the decision to develop independently or to sell to a downstream firm at each phase of clinical trials.

Preview of Results

- ▶ Conditional correlation: positive for phase I and II, negative for III
- ▶ Causal effect: positive for phase I and II, negative for III
- ▶ Coefficients in IV: larger magnitude, but not precisely estimated
- ▶ Weak evidence of incentive to develop to phase II ?

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Thought Experiment

- ▶ Two identical projects endowed with different amounts of funding – which one progresses further on its own before a sale?

Identification Challenges

- ▶ Reverse causation: financial environment as instrument
- ▶ Hidden type or quality: financial environment as instrument
- ▶ Missing expected price: control for buyer appetite and year, stage, area, location dummies
- ▶ Measurement of financial resource: n-year funding window
- ▶ Anticipated funding: n-year funding window
- ▶ Effect is mechanic: no effect is informative

Decision to Self Develop

- ▶ Sell: expected current price
- ▶ Self develop: expected cost, success probability, duration, and future price

Decision to Self Develop

$$D_{is} = \beta \Sigma f_{is} + \gamma_1 X_{is} + \mu_{b1} Z_{ij}^b + \pi_{11} X_s + \pi_{12} X_t + \pi_{13} X_j + \pi_{14} X_{sj} + \pi_{15} X_l + \nu_{is} \quad (1)$$

Funding is Endogenous

- ▶ Reverse causation
- ▶ Hidden type or quality

Financing Equation

$$\Sigma f_{is} = \gamma_0 X_{is} + \mu Z_{it}^f + \mu_{b0} Z_{it}^b + \pi_{01} X_s + \pi_{02} X_t + \pi_{03} X_j + \pi_{14} X_{sj} + \pi_{15} X_l + \xi_{is} \quad (2)$$

Validity of Instruments

- ▶ Year-location funding environment Z_{tl}^f has a clear effect on project-phase level funding raised Σf_{is}
- ▶ Year-location funding environment Z_{tl}^f does not affect project-phase level decision of self development D_{is} other than through funding raised by project i for phase s Σf_{is} .
 - ▶ The instruments are orthogonal to ν_{is} , a project-phase level error term after controlling for year, therapeutic area by stage, and location.
 - ▶ Variation in funding environment is not caused by idiosyncratic quality of drugs, conditional on all controls.

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Data Sources

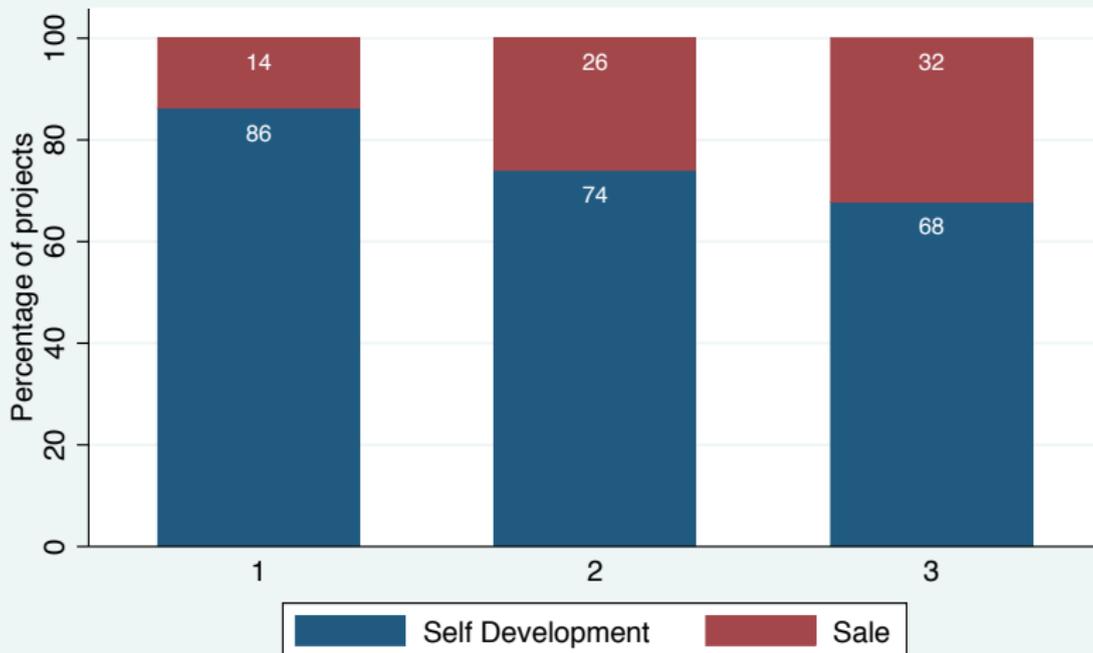
- ▶ Thomson Cortellis
 - ▶ Drug development
 - ▶ Transactions
 - ▶ 52k drugs, 10k companies
 - ▶ 1970-2013
- ▶ Strategic Transactions
 - ▶ Funding events
 - ▶ 500 deals annually
 - ▶ 1991-2012
- ▶ Supplemental Data Source
 - ▶ ThomsonOne: Financial Environment
 - ▶ Drugs@FDA: Buyer Appetite

Sample

- ▶ Sample construction
 - ▶ Exclude universities and pharmaceuticals
 - ▶ Focus on phase I to phase III of clinical
 - ▶ For sales, focus on development licensing or transfer of exclusive patent rights
 - ▶ Trials conducted in the U.S.
 - ▶ Company-years with one project in the clinical trial phase
- ▶ Sample size
 - ▶ Before: 52062 drugs (86413 projects), 10643 companies.
 - ▶ After: 3005 drugs (4926 projects), 2263 companies
 - ▶ 6598 observations.

Outcome Variable: Sale

Percentage of projects sold in each stage of drug development



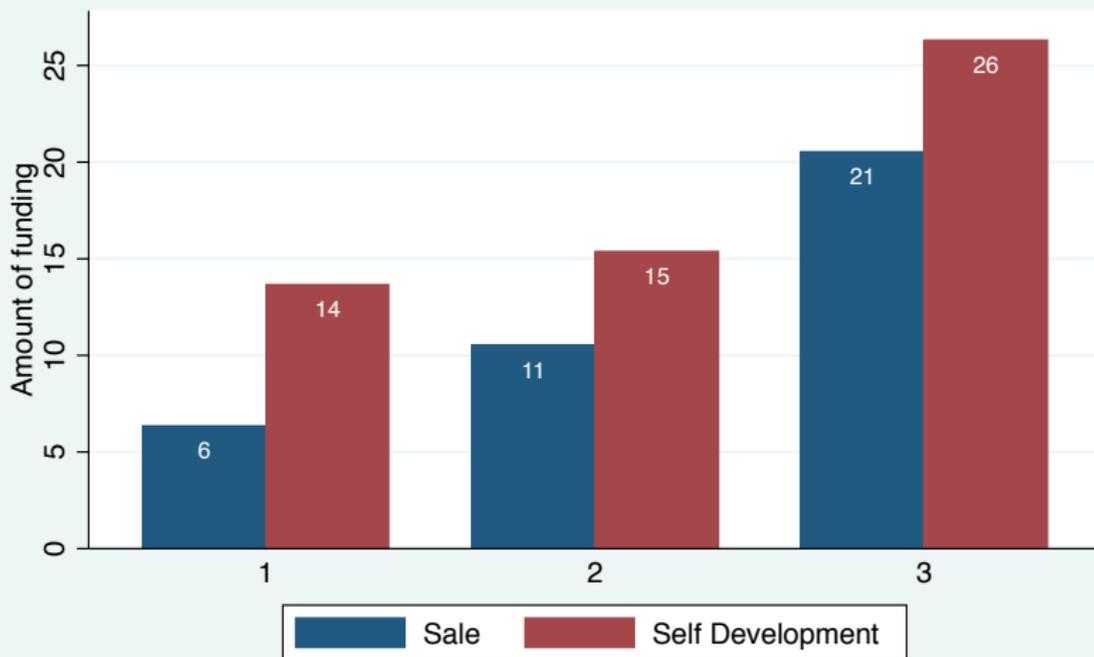
Source: ThomsonPharma

Explanatory Variable: Funding

- ▶ Matched by company name and date of funding
 - ▶ 2 year funding window prior to start of a stage
 - ▶ Start and end dates
-
- ▶ 4926 projects. 55% matched to at least one funding events
 - ▶ 11775 funding events. 46% matched to sample

Funding by Stage and Decision

Amount of funding raised by stage and sale decision

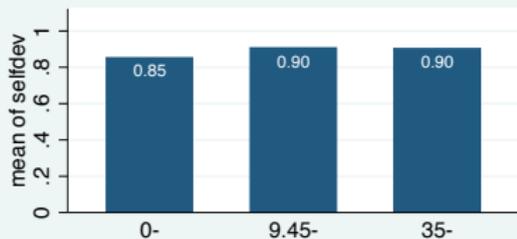


Source: ThomsonPharma

Self Development Probability by Funding

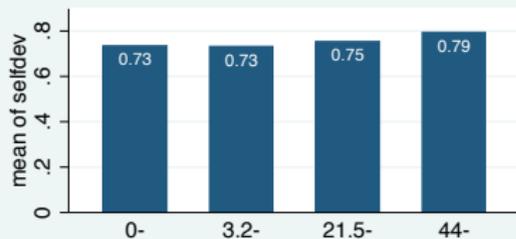
Probability of Self Development and Funding

Stage 1



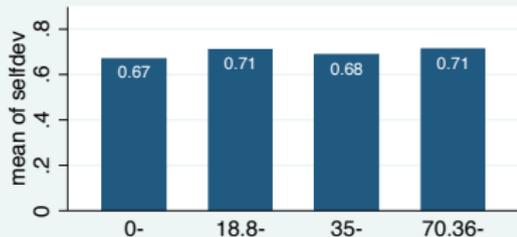
Source: ThomsonPharma

Stage 2



Source: ThomsonPharma

Stage 3



Source: ThomsonPharma

Instrumental Variable 1

- ▶ Dollar amount (\$m) available for VC investment for a given state- year
- ▶ Capture the overall financial environment
- ▶ Source: ThomsonOne
- ▶ Advantage: exogenous
- ▶ Disadvantage: info only available for half of the observations

Instrumental Variable 2

- ▶ Dollar amount (\$m) invested in biotech firms for a given therapeutic area- year
- ▶ Source: Strategic Transaction
- ▶ Advantage: no missing data
- ▶ Disadvantage: less exogenous

Control Variables

- ▶ Buyer appetite
 - ▶ Number of potential buyers
 - ▶ Fraction facing patent cliff

- ▶ Fixed Effects
 - ▶ 3 stages
 - ▶ 24 years: 1990 to 2013
 - ▶ 20 therapeutic Areas: oncology, infectious diseases, and neurology, etc.
 - ▶ 40 states in the U.S. : CA, MA, NY
 - ▶ 25 other countries: China, UK, and Canada

 - ▶ Capture cost, duration, risk of development

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Effect of Funding on Likelihood of Self Development

	Base	Year	Year and Area	Stage Area Interacted	Location
funding_phase1	0.0000428 (0.000138)	0.0000343 (0.000137)	0.0000343 (0.000142)	0.0000768 (0.000146)	0.0000961 (0.000200)
funding_phase2	0.000630* (0.000232)	0.000650* (0.000232)	0.000617* (0.000247)	0.000527* (0.000253)	0.00101* (0.000256)
funding_phase3	-0.0000903 (0.000188)	-0.0000892 (0.000187)	-0.0000873 (0.000196)	-0.0000153 (0.000202)	-0.000149 (0.000197)
funding_info	0.0758* (0.0117)	0.0757* (0.0117)	0.0758* (0.0128)	0.0719* (0.0131)	
stage dummies	Yes	Yes	Yes	Yes	Yes
year dummies	No	Yes	Yes	Yes	Yes
area dummies	No	No	Yes	Yes	Yes
location dummies	No	No	No	No	Yes
stage area interacted	No	No	No	Yes	No
N	5684	5684	4921	4921	2678

Standard errors in parentheses

Source: Thomson and Strategic Transactions

+ $p < 0.10$, * $p < 0.05$

Effect of Funding on Likelihood of Self Development, Continued

	Base	Year	Year and Area	Stage Area Interacted	Location
firm_n_proj	0.00915* (0.00104)	0.00903* (0.00104)	0.00901* (0.00114)	0.00208+ (0.00107)	
firm_n_sold	-0.0420* (0.00252)	-0.0422* (0.00252)	-0.0409* (0.00272)		-0.0256* (0.00306)
firm_n_bought	-0.000804 (0.00257)	-0.000176 (0.00256)	-0.000958 (0.00278)	-0.0105* (0.00277)	-0.00169 (0.00327)
n_pot_buyer	-0.000438* (0.000185)	-0.000138 (0.000195)	0.000795 (0.000838)	0.000814 (0.000860)	0.00233* (0.00111)
patentcliff_phase1	0.153* (0.0587)	0.0444 (0.0761)	-0.0760 (0.103)	-0.0873 (0.106)	-0.0638 (0.132)
patentcliff_phase2	0.128* (0.0614)	0.0277 (0.0799)	-0.0916 (0.107)	-0.100 (0.110)	0.0770 (0.141)
patentcliff_phase3	-0.220* (0.104)	-0.299* (0.116)	-0.385* (0.144)	-0.385* (0.153)	-0.104 (0.186)
<i>N</i>	5684	5684	4921	4921	2678

Standard errors in parentheses

Source: Thomson and Strategic Transactions

+ $p < 0.10$, * $p < 0.05$

Effect of Local VC Fund Creation on Amount of Funding Raised

	Base	Year	Year and Area	Stage Area Interacted	Location
IV_localVCfund	0.00113* (0.000234)	0.00102* (0.000252)	0.00111* (0.000270)	0.00111* (0.000271)	0.000449 (0.000506)
company characteristics	Yes	Yes	Yes	Yes	Yes
buyer appetite	Yes	Yes	Yes	Yes	Yes
stage dummies	Yes	No	Yes	Yes	Yes
year dummies	No	Yes	Yes	Yes	Yes
area dummies	No	No	Yes	Yes	Yes
location dummies	No	No	No	No	Yes
stage area interacted	No	No	No	Yes	No
<i>N</i>	2901	2901	2678	2678	2678

Standard errors in parentheses

Source: Thomson and Strategic Transactions

+ $p < 0.10$, * $p < 0.05$

Effect of Funding on Likelihood of Self Development, with Local Fund Creation as IV

	Base	Year	Year and Area	Stage Area Interacted	Location
funding_phase1	0.000707 (0.00125)	0.000641 (0.00130)	0.000249 (0.00135)	0.000113 (0.00141)	0.0530 (0.151)
funding_phase2	0.000962 (0.00371)	0.00274 (0.00437)	0.00281 (0.00421)	0.00239 (0.00446)	0.0528 (0.150)
funding_phase3	-0.00337 (0.00264)	-0.00253 (0.00284)	-0.00422 (0.00332)	-0.00597 ⁺ (0.00359)	0.0192 (0.0565)
stage dummies	Yes	Yes	Yes	Yes	Yes
year dummies	No	Yes	Yes	Yes	Yes
area dummies	No	No	Yes	Yes	Yes
location dummies	No	No	No	No	Yes
stage area interacted	No	No	No	Yes	No
<i>N</i>	2901	2901	2678	2678	2678

Standard errors in parentheses

Source: Thomson and Strategic Transactions

⁺ $p < 0.10$, * $p < 0.05$

Effect of Funding on Likelihood of Self Development, with Local Fund Creation as IV, Continued

	Base	Year	Year and Area	Stage Area Interacted	Location
firm_n_proj	0.00547* (0.00268)	0.00403 (0.00326)	0.00511 (0.00327)	0.00613+ (0.00348)	-0.0425 (0.135)
firm_n_sold	-0.0325* (0.00396)	-0.0319* (0.00420)	-0.0328* (0.00443)	-0.0337* (0.00461)	-0.0158 (0.0501)
firm_n_bought	-0.00327 (0.00431)	-0.00477 (0.00468)	-0.00557 (0.00438)	-0.00450 (0.00482)	-0.0211 (0.0538)
n_pot_buyer	-0.0000609 (0.000333)	-0.0000104 (0.000341)	0.00179 (0.00125)	0.00163 (0.00133)	-0.00368 (0.0187)
patentcliff_phase1	0.0970 (0.0879)	-0.000175 (0.112)	-0.0373 (0.152)	-0.00946 (0.165)	-0.365 (1.280)
patentcliff_phase2	0.240* (0.117)	0.148 (0.140)	0.118 (0.167)	0.125 (0.185)	0.166 (1.078)
patentcliff_phase3	-0.0974 (0.146)	-0.222 (0.167)	-0.128 (0.218)	-0.150 (0.231)	-0.919 (2.645)
<i>N</i>	2901	2901	2678	2678	2678

Standard errors in parentheses

Source: Thomson and Strategic Transactions

+ $p < 0.10$, * $p < 0.05$

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Interpretation of Results

- ▶ Treatment effect vs. selection effect
- ▶ Suggestion for better IV
- ▶ Weak evidence that biotech has incentive to develop to phase II

Thank You!

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Summary Stata of Variables in Regressions

Variable	Mean	Std. Dev.	N
Self Development	0.786	0.41	6598
Funding amount in 2 years prior to start of phase I	12.632	69.085	2961
Funding amount in 2 years prior to start of phase II	14.099	34.682	2716
Funding amount in 2 years prior to start of phase III	24.441	75.245	921
number of projects	7.562	6.686	6598
number of sold projects	2.379	2.602	6598
number of bought projects	2.034	2.396	6598
Number of potential buyers in the therapeutic area this year	52.602	29.718	6217
Fraction of buyers facing patent cliff in this area-year, phase I	0.155	0.136	2542
Fraction of buyers facing patent cliff in this area-year, phase II	0.148	0.135	2345
Fraction of buyers facing patent cliff in this area-year, phase III	0.148	0.135	797
Funding available for this location this year, phase I	4074.875	5574.432	1387
Funding available for this location this year, phase II	4078.218	5263.527	1386
Funding available for this location this year, phase III	3501.138	5204.391	508
Million dollars invested in this area-year, phase I	1106.121	1116.108	2426
Million dollars invested in this area-year, phase II	1015.736	1070.356	2251
Million dollars invested in this area-year, phase III	842.616	868.670	726

First Stage of IV regression, investments by therapeutic area

Table : Effect of investments in the therapeutic area on project-level funding raised

	Base	Year	Year and Area	Stage Area Interacted	Location
IV_areaVCinvest	0.00162 (0.00116)	0.000113 (0.00133)	0.000558 (0.00216)	0.000745 (0.00251)	-0.000711 (0.00439)
company characteristics	Yes	Yes	Yes	Yes	Yes
buyer appetite	Yes	Yes	Yes	Yes	Yes
stage dummies	Yes	Yes	Yes	Yes	Yes
year dummies	No	Yes	Yes	Yes	Yes
area dummies	No	No	Yes	Yes	Yes
location dummies	No	No	No	No	Yes
stage area interacted	No	No	No	Yes	No
<i>N</i>	4921	4921	4921	4921	2901

Standard errors in parentheses

Source: Thomson and Strategic Transactions

+ $p < 0.10$, * $p < 0.05$

IV regression, investments by therapeutic area

Table : Effect of funding on Likelihood of self development and sale, with investment by area IV

	Base	Year	Year and Area	Stage Area Interacted	Location
funding_phase1	-0.00209 (0.00682)	-0.0198 (0.0409)	0.000678 (0.0117)	0.00101 (0.00909)	-0.231 (44.21)
funding_phase2	0.00250 (0.00565)	-0.0154 (0.0408)	0.00387 (0.0136)	0.00262 (0.00896)	-0.295 (56.48)
funding_phase3	0.0000661 (0.00648)	-0.0167 (0.0432)	0.00213 (0.0153)	0.00366 (0.0104)	-0.294 (56.34)
funding_info	0.0868 (0.129)	0.496 (0.940)	0.0323 (0.297)	0.0330 (0.207)	0 (.)
stage dummies	Yes	Yes	Yes	Yes	Yes
year dummies	No	Yes	Yes	Yes	Yes
area dummies	No	No	Yes	Yes	Yes
location dummies	No	No	No	No	Yes
stage area interacted	No	No	No	Yes	No
N	4921	4921	4921	4921	2678

Standard errors in parentheses

Funding Patterns

- ▶ 50% VC, 30% public
- ▶ Typical: 3 fundings (25% 1 95% 10-15)
- ▶ Typical fund raising: 1-4 private placement, then maybe IPO
- ▶ Typical gap between funding: under one year
- ▶ Typical number of drugs under pipeline: 1

Compare characteristics by IV

	mean1	mean2	diff	p
terminated	0.18	0.21	-0.03*	0.02
projectterm	0.31	0.31	-0.01	0.58
mduration	904.82	907.78	-2.96	0.78
nprj	9.66	10.38	-0.72***	0.00
nbuy	3.43	3.42	0.01	0.92
nsell	4.02	4.00	0.02	0.80