Agency Problem in Learning:
Theory and Evidence from Drug Innovation Market

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Abstract

This paper studies the agency problem between venture capitalists and biotech firms in the U.S. pharmaceutical industry.

Present a model of drug development choice where:
- Biotech firms suffer a lower cost from drug R&D failure compared to big pharmaceutical firms
- leading to push low-quality drugs to the next stage in drug development.

Use clinical trials and investor-firm deal information to estimate the effect of negative clinical trial results on trial attrition probability.

Show that upon receiving negative clinical trial results, biotech firms are 12.3% more likely to push the drug to the next trial than big pharmaceutical firms.

Introduction

Pharmaceutical R\&D industry is known for its high innovation intensity and risk:
- Average cost per launch: $1.4 billion
- Average year: 12 years
- % drugs pass all criteria: less than 10

Learning: Cost combined with risk makes strategic attrition crucial to success of firms:
- Scientific Attrition v.s. Strategic Attrition
- Venture capital makes strategic attrition more complicated

Compared to big Pharma, Biotech faces very different cost of failure:
- Big Pharma: Profit fund Cost
- Biotech: VC Investment each round

Agency Problem: Different costs lead to different incentives and in turn, different decisions:
- Big Pharma cares all future cost; Biotech cares next-stage payment
- Facing relative bad news, biotech is more willing to push drug forward

Research Question: How does the agency problem influence the biotech company's attrition decision and its welfare impact?

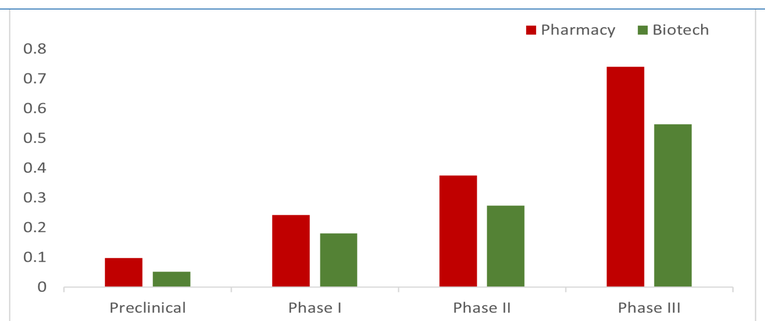

Figure 1. Attrition Rate at Different Phase: Big Pharma vs Biotech

Data

Learning: Clinical Trials from FDA, Drug Events from Citeline
Payment: Deals and financing data from Biocentury & Pitchbook
Revenue: Disability-adjusted life years for diseases

Table 1. Attrition Probability with Negative Signal

	(1)	(2)	(3)
VARIABLES		Attrition	
Negative*BigPharma	0.0736***	0.0571***	0.0957***
	(0.0112)	(0.0114)	(0.0135)
BigPharma	-0.155***	-0.143***	-0.114***
	(0.00685)	(0.00696)	(0.00832)
Negative	0.219***	0.191***	0.202***
	(0.0124)	(0.0128)	(0.0155)
Disease FE	√	√	√
Phase FE		√	√
Year FE			√

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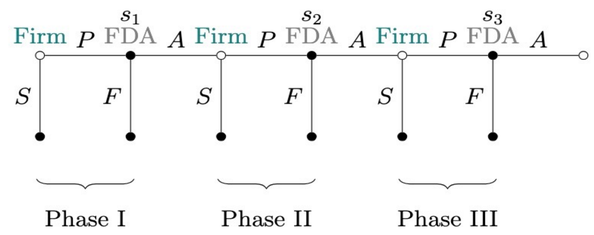
Table 2. Attrition Probability with Positive Signal

	(1)	(2)	(3)
VARIABLES		Attrition	
BigPharma*Positive	-0.292***	-0.278***	-0.277***
	(0.00951)	(0.00978)	(0.00978)
BigPharma	-0.142***	-0.134***	-0.134***
	(0.00754)	(0.00761)	(0.00761)
Positive	-0.143***	-0.146***	-0.146***
	(0.00950)	(0.00962)	(0.00962)
Disease FE	√	√	√
Phase FE		√	√
Year FE			√

Model



- Firm owns a drug with unknown quality $\theta \sim F(\cdot\,|f \in \{Pharma, Bio\})$
- At each stage, firm decide to push(P) or stop (S) the drug (Strategic Attrition).
- Upon push, firm get a public signal indicate the quality of the drug $s_i \sim G(\cdot\,|\theta)$
- Contingent on signal realization, FDA decide whether to approve for next stage (Scientific Attrition).

- Big Pharma gets final revenue R only at last stage, pay all cost $\sum_i c_i$ when failed.
- Biotech gets invest at each round approval $p_i(s_i) - \sum_i c_i$, gets a share of final revenue if succeed δR.

Big Pharma's value function:

$$V_4^P = \max_{\sigma\in[0,1]} \left[\Phi\left(s_{im4} - \tau_{m4}\right) R_m - c_{m4}\right]\sigma - \sum_1^3 c_{mk}$$

$$V_t^P = \max_{\sigma\in[0,1]} \left[\mathbf{E}_{t-1}\left[\Phi\left(s_{imt} - \tau_{mt}\right) V_{t+1}^P\right] - c_{mt}\right]\sigma - \sum_{k=1}^{t-1} c_{mk}$$

Biotech's value function:

$$V_4^B = \max_{\sigma} \left[\Phi\left(s_{im4} - \tau_{m4}\right)\left(\delta R_m - p_3(s_{im3})\right) - c_{m4}\right]\sigma + p_3(s_{im3}) - \Sigma^3 c_{mk}$$

$$V_t^B = \max_{\sigma} \left[E_{t-1}[\Phi\left(s_{imt} - \tau_{mt}\right)\left(V_{t+1}^B - p_{t-1}(s_{imt-1}) + \Sigma^{t-1} c_{mk}\right)] - c_{mt}\right]\sigma + p_{t-1}(s_{imt-1}) - \Sigma^{t-1} c_{mk}$$

Proposition

- When signal is positive, $\sigma_B(s) < \sigma_P(s)$; When signal is negative, $\sigma_B(s) > \sigma_P(s)$

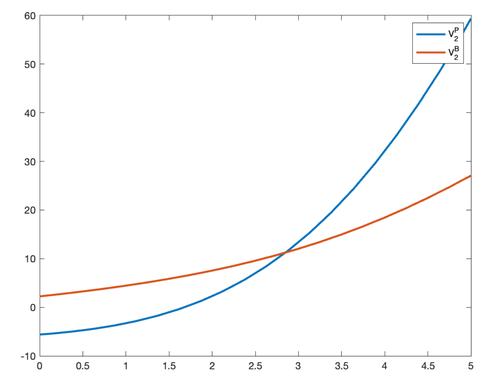


Figure 2. Value function to continue conditional on different signals: Big Pharma vs Biotech

Next Steps

Construct an identification strategy to separate scientific attrition and strategic attrition.
Calibrate the parameter to answer:
- Does Biotech benefit the market by searching for more efficient drugs or wasting money by testing risky drugs?
- Can FDA improve social welfare by setting optimal criteria?
- How can government subsidy improve the cold start problem in innovation?

References

1. Acemoglu, Daron and Joshua Linn (2004) "Market size in innovation: theory and evidence from the pharmaceutical industry," The Quarterly journal of economics, 119 (3), 1049–1090.
2. Cunningham, Colleen, Florian Ederer, and Song Ma (2021) "Killer acquisitions," Journal of Political Economy, 129 (3), 649–702.
3. Halac, Marina, Navin Kartik, and Qingmin Liu (2016) "Optimal contracts for experimentation," The Review of Economic Studies, 83 (3), 1040–1091
4. Khmelnitskaya, Ekaterina (2023) "Competition and Attrition in Drug Development."
5. Krieger, Joshua, Danielle Li, and Dimitris Papanikolaou (2022) "Missing novelty in drug development," The Review of Financial Studies, 35 (2), 636–679.
6. Lo, Andrew W and Richard T Thakor (2022) "Financing biomedical innovation," Annual Review of Financial Economics, 14, 231–270.
7. Rao, Anita (2020) "Strategic research and development investment decisions in the pharma-ceutical industry," Marketing Science, 39 (3), 564–586.