

Biopharma firms with negative enterprise value

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Abstract

“Enterprise Value” of a public company is the difference between its market capitalization and net cash. When a biopharma firm announces negative trial results, its stock price plummets, and its market cap can drop below its net cash balance, implying a negative enterprise value. While roughly 100 US biopharma firms went public in 2020, half of them ended up with negative enterprise value due to scientific failures. Motivated by this empirical observation, this paper investigates the cause of the negative enterprise value puzzle and further examines whether the biopharma boom during the pandemic was fundamentally justified. The first part of the paper uses manually collected data to examine the performance of biopharma firms that went public. The descriptive analysis shows evidence of inefficient continuation due to agency conflicts and suggests that investors might have provided too much capital at the time of IPO. To study whether venture capital investors would have behaved differently with the possibility of staging capital injections, the second part of the paper uses the equilibrium model of VC financing to solve for the optimal contract that trades off the cost of inefficient continuation against the risk of early termination. Preliminary results show that upfront financing is indeed preferred, since the biopharma project characteristics imply large value loss from early termination.

1 Introduction

“Enterprise Value” of a public company is the difference between its market capitalization and the net cash held by the firm. In the context of the biopharma firms, it measures the value of intangible assets such as patents, partnerships, drug development programs, and managerial capabilities. While a firm with promising projects certainly has positive enterprise value, a biopharma firm that experiences scientific failure might end up with a negative enterprise value. For example, on June 6, 2022, Praxis Precision Medicines, INC. announced the discontinuation of its lead drug candidate after the phase II trial, and its stock price dropped from \$8.59 to \$1.88 per share on the date of the news release. Its market cap fell to \$85.55 million, even though it had net cash of \$174.05 million according to the last quarterly balance sheet data prior to the event.

This paper is motivated by the recent increase in the number of US public biopharma firms with negative enterprise value. Over the past ten years, we have had more public firms with negative enterprise value in the biopharma sector than in the other sectors combined (Figure 1). The count peaked in 2022, totaling more than 120 biopharma firms with negative enterprise value. For other sectors, the count peaked during the Internet Bubble period (2000-2002) and the 2008 financial crisis. As shown in Figures 2 and 3, nearly one in five public biopharma firms had negative enterprise value in 2022, and many of them went public during the COVID stock market boom of 2020-2021. For the 2020 IPO cohort, for example, 97 biopharma firms went public, and nearly half of them ended up with negative enterprise value.

Based on these empirical observations, this paper investigates the cause of the negative enterprise value puzzle and raises the question of whether the biopharma boom during the pandemic was fundamentally justified. In addressing the research question, the first part of the paper uses manually collected data to document the performance of biopharma firms that went public. The descriptive analysis shows the widespread incidence of agency conflicts in the aftermath of scientific failures. Investors prefer liquidation, given that substantial cash remains at the time of scientific failure.¹ However, among the 54 firms that had negative enterprise value in the 2020 IPO cohort, only 1 firm liquidated, and 15 firms did M&A.² All other firms are still in operation, might be actively seeking strategic alternatives, or are simply burning shareholders’ money to meet the managers’ own goals.

One might ask whether these biopharma firms should have remained financed by venture capital (VC) rather than going public so early. Instead of providing all the capital needed at once, VCs typically stage capital injection in multiple periods to reduce their exposure

¹This is also why stock prices jump when a company announces liquidation following news of a scientific failure.

²Some were acquired by big pharmaceutical companies, but many reverse mergers faced shareholder investigations.

to agency problems. Studying whether VCs would have behaved differently from the public market helps answer whether the biopharma boom during the pandemic was fundamentally justified or speculative.

Thus, the second part of the paper uses the equilibrium model of VC financing developed by Parry (2025) to determine the optimal contract (upfront or staged financing) in the context of biopharma firms. In the model, VCs endogenously stage capital injections over time to limit losses from committing too much capital to entrepreneurs who conceal project failures. While staged financing helps reduce the cost of inefficient continuation, entrepreneurs face the risk of early termination, which is modeled by the probability of failing to renew their previous funding contracts. The risk of early termination is a real concern, as VCs may face various constraints in practice, and subsequent funding may not always be readily available. Preliminary results show that upfront financing is indeed preferred, since the underlying project characteristics of biopharma firms imply large value loss from early termination. Given that staying private is not an effective solution to the negative enterprise value puzzle, more effort should be devoted to the better “recycling” of biopharma firms in the aftermath of scientific failures.

The problem of firms with negative enterprise value is not new. Nevertheless, it is widely regarded as a market inefficiency, with various frictions preventing arbitrage opportunities, as in the Palm-3Com case in 2000. This paper focuses on the biopharma sector and tries to identify the specific type of friction underlying the phenomenon. It is crucial to investigate the problem to protect investors and ultimately to help address underinvestment in the biopharma sector.

This research contributes to the literature on financing medical innovation, especially the drug development process and its associated costs and risks. Lo and Thakor (2022) give an overview of market frictions to which drug development firms are exposed and discuss how these frictions affect their incentives to invest in developing new drugs. A growing body of literature studies the market value of drug development programs. Aryal et al. (2022) take a similar approach to this paper, analyzing stock market responses to drug development announcements to infer drug values. There are also discussions of the market value of cash in the biopharma industry. A related paper by Xu (2009) investigates whether the rate of R&D innovation contributes to the market pricing of an additional dollar of cash in the biotech industry. This paper will fill in the gap between these studies by focusing on the sample of firms with failed projects.

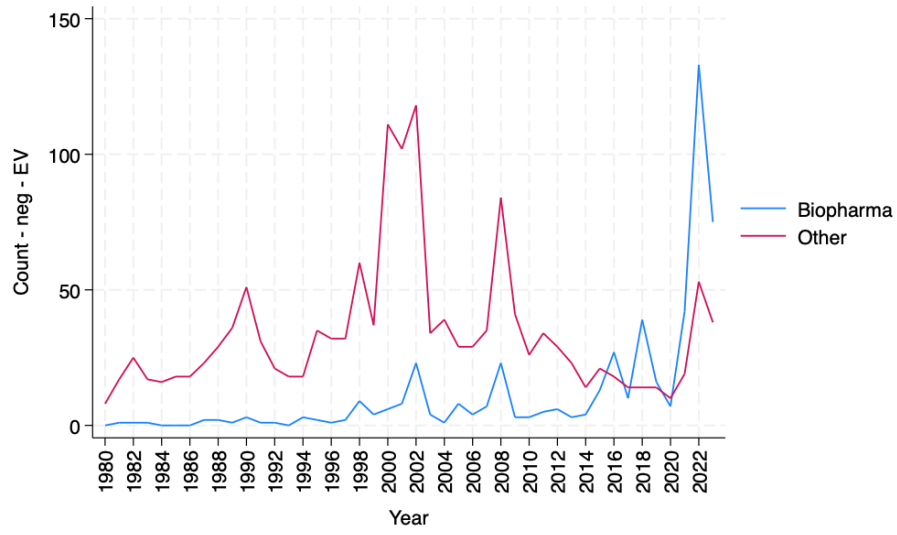


Figure 1: Number of public firms with negative enterprise value for biopharma vs other sectors

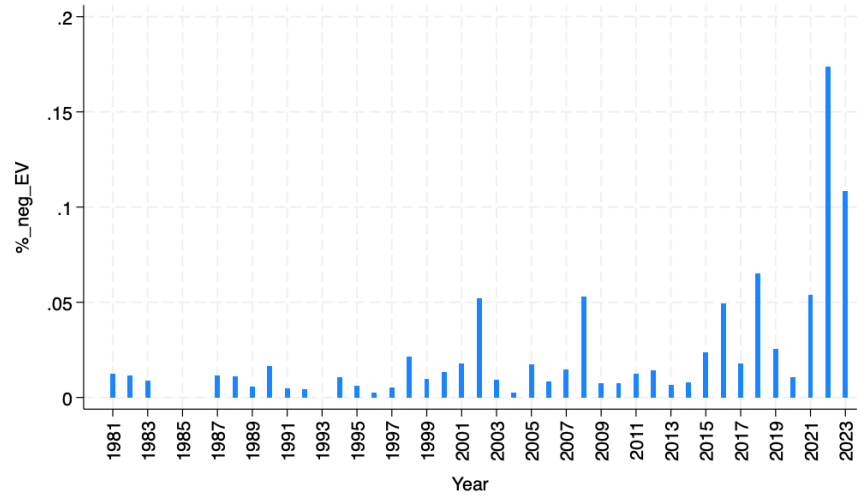


Figure 2: Share of firms with negative enterprise value among US public biopharma firms

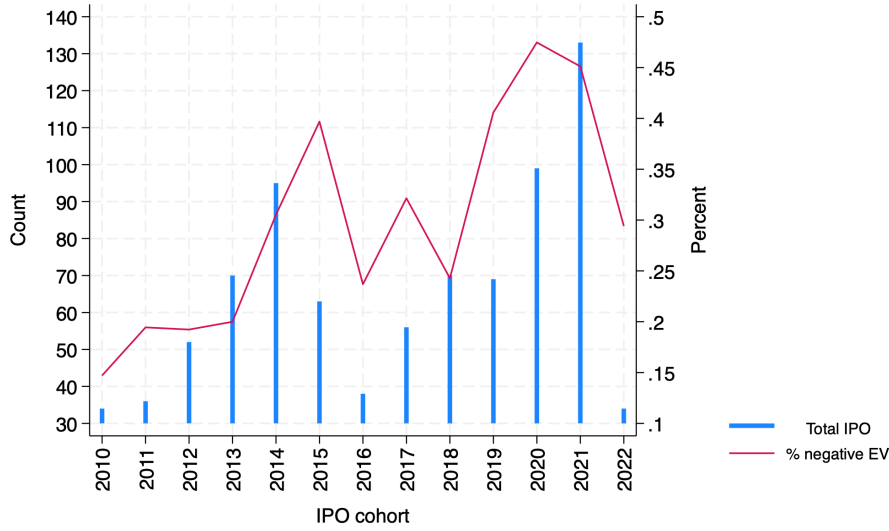


Figure 3: Biopharma firms with negative enterprise value by IPO cohort

More broadly, this research is relevant to the discussions on financing innovation. Nanda and Rhodes-Kropf (2017) study the impact of shifts in capital supply on start-up innovation, showing that increased capital supply helps finance more innovative firms with larger real option value. Parry (2025) focuses on the risk of early termination due to the staged financing of venture capital and shows that a significant portion of start-ups shut down prematurely despite having positive continuation value. This paper tests these predictions in the context of the biopharma sector, where the discussion of real option value is particularly relevant. The trade-off between inefficient continuation and early termination applies to other sectors as well. As the market anticipates more AI-related IPOs, one needs to question whether too much money is flowing into pre-revenue AI firms.

The remainder of the paper is organized as follows. Section 2 shows the descriptive analysis using manually collected data, and Section 3 presents the counterfactual analysis using the equilibrium model of VC financing. Section 4 concludes and provides future research plans.

2 Descriptive analysis

2.1 Comparison of biopharma firms with negative enterprise value and tech firms with negative enterprise value during the Internet Bubble period

As shown in Figure 1, numerous public firms in other sectors also held negative enterprise value during the Internet Bubble period. This section provides a brief discussion of how biopharma firms with negative enterprise value differ from tech firms that also had negative enterprise value during the Internet Bubble period.

The main sample for the analysis is the 112 tech firms that had negative enterprise value from 2000 to 2002 and 173 biopharma firms that have had negative enterprise value since 2020. Using Compustat yearly balance sheet data, I show below the summary statistics for their net cash, net income, and, most importantly, the magnitude of the negative enterprise value – that is, the difference between net cash and market capitalization (Table 1).

The common feature between these two groups of firms is the high cash burn rate implied by the net cash and net income. However, the net cash held by biopharma firms with negative enterprise value is generally much larger than that held by tech firms, and the magnitude of negative enterprise value also tends to be greater for the biopharma group. Interestingly, of the 112 tech firms with negative enterprise value from 2000 to 2002, only 68 were active in 2003, suggesting the negative enterprise value of tech firms might have been related to the high bankruptcy rate as the Internet Bubble burst. However, as I show in the rest of this paper, most biopharma firms continue to operate after scientific failures thanks to the significant cash remaining at the time of failure. Thus, the biopharma negative enterprise value puzzle is likely driven by the expected loss of shareholder value from inefficient continuation and the difficulty of forcing liquidation and getting the cash distribution.

Table 1: Summary statistics of biopharma and tech firms with negative enterprise value

<i>(a) Net Cash</i>		
Statistics	Biopharma	Technology
P25	25.88	8.93
P50	57.08	21.92
P75	113.84	57.47
<i>(b) Net Income</i>		
Statistics	Biopharma	Technology
P25	-78.65	-41.64
P50	-43.56	-20.42
P75	-18.50	-7.22
<i>(c) Difference between net cash and market cap</i>		
Statistics	Biopharma	Technology
P25	5.47	1.97
P50	16.58	6.50
P75	34.36	14.86

2.2 The ex-ante rationale for the market to allow the entry of early-stage biopharma firms

Investors have been rather supportive of biopharma firms’ IPOs over the past decade. Figure 4 shows the shares of the healthcare and technology sectors, respectively, among new entries (IPOs) since 1980. The shares of healthcare and tech firms were comparable from 1980 to 2012, apart from the Internet Bubble period, but we have had more healthcare firms in firms doing IPOs since 2012.

At first glance, it is puzzling to see investors supporting the biopharma sector that is full of scientific uncertainties. However, Fagnan, Fernandez, Lo, and Stein (2013) argue in their influential paper “Can financial engineering cure cancer?” that one could apply portfolio theory to mix a large number of drug development projects in a single “megafund” portfolio. In a word, investors might lose money if they invest in individual projects due to high scientific uncertainty, but they can greatly improve the risk-return profile by holding a well-diversified portfolio of biopharma firms.

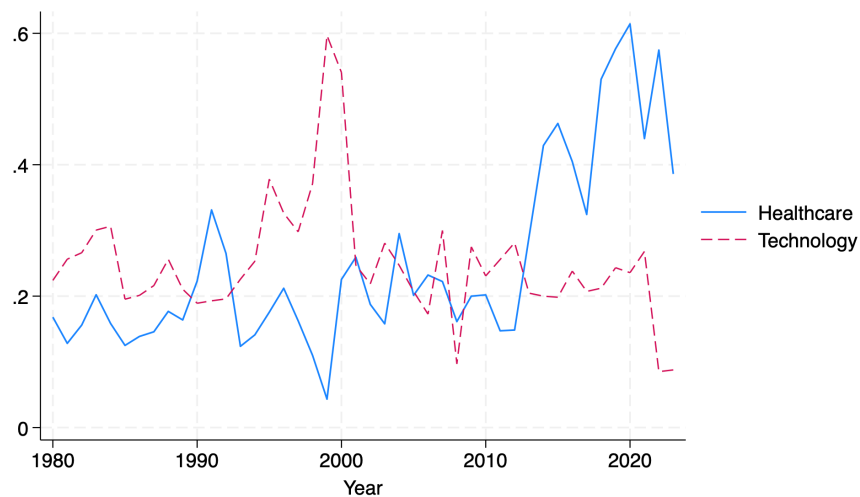


Figure 4: Share of healthcare and tech firms in IPOs

To see if their arguments hold in practice, I computed the returns to a hypothetical investor who has invested in biopharma IPOs since 2001 and plotted them in Figure 5. By focusing on new entries and applying the portfolio theory proposed in Fagnan, Fernandez, Lo, and Stein (2013), I examine whether stock returns can explain investors’ continued support for biopharma firms’ IPOs over the past decade.

Here, I assume the investor seeks to construct an equally-weighted market portfolio of biopharma firms that went public starting from 2001. At the end of each month, the investor

realizes the returns and purchases a new portfolio to account for the entry and exit. Figure 5 shows the monthly-compounded cumulative returns for the investor and for a market portfolio of tech firms used as a benchmark, assuming the same strategy. Interestingly, the portfolio of biopharma firms started generating higher returns than the portfolio of tech firms roughly from 2010, and the spread has become considerably larger since then until the end of the COVID biotech boom.

The analysis shows that the higher returns generated by the biopharma market portfolio could very well justify the increased entry of biopharma firms since 2012 and during the COVID boom. But the significant downturn in biopharma stocks during the 2022-2023 period could already hint at heavy losses for investors who entered the market during the COVID boom. The next section provides more details on the performance of biopharma firms that went public.

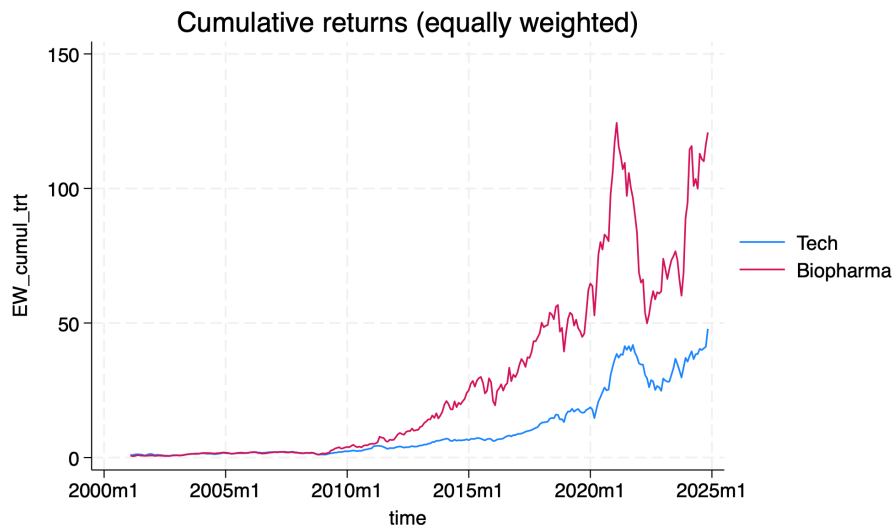


Figure 5: Cumulative returns to investors, by sector

2.3 The performance of early-stage biopharma firms that went public

Drug development is a risky, costly, and lengthy process. Starting from the pre-clinical stage (evaluation of drug candidates before testing on humans), a drug candidate needs to go through phase I (testing the toxicity of the drug candidate on healthy people), phase II (testing the efficacy of the drug candidate on patients with the target diseases), phase III (randomized controlled trial to test the safety and efficacy of the drug candidate compared to the current standard treatment), and finally application for the FDA approval. Firms with their lead drug candidate in phase II or earlier clinical trials are typically called early-stage biopharma firms, while those in phase III or later are called late-stage biopharma firms.

Most biopharma firms go public with their lead drug candidate in phase I and phase II. Given that the transition probability from phase II to phase III is around 50 percent, a large share of those firms fail in their phase II trials within 2-3 years after the IPO and discontinue their drug development program. As already described in the introduction, of the 97 biopharma firms that went public in 2020, 68 experienced major scientific failures, and 54 firms have had negative enterprise value since then. In this section, I expand the main sample of analysis to all public biopharma firms that experienced negative enterprise value due to scientific failures since 2020. I first filtered 173 firms with negative enterprise value using Compustat balance sheet data, and manually collected scientific failure events for these firms from SEC 8-K filings and the LSEG (Refinitiv) news database. After a close examination, only 153 firms are included in the main sample for analysis. The enterprise value of the remaining firms was temporarily negative due to heavy equity issuance or other scandals irrelevant to scientific development. In total, 234 events of scientific failure are identified, as some firms had multiple lead drug candidates under development that later failed.

As one could imagine, the stock prices of the firms were greatly affected by the scientific failure events. To identify the exact impact of the scientific failure, the dates on which firms announced scientific failures are linked to stock price data from the LSEG (Refinitiv) database to track stock price changes.

Figure 6 below is a box plot that shows the impact of scientific failure on the enterprise value of 153 firms in the main sample. The blue boxes show the ratio of market capitalization to each firm's net cash for the previous quarter on the date before the announcement of scientific failures, and the red boxes show the same ratio on the date the firms announced the news. The black reference line at value 1 indicates that firms have a negative enterprise value if their observations fall below it. The sample is split into three groups to show the time variation of the impact of scientific failure on enterprise value. While market capitalization decreased sharply across all groups after the news, the impact of scientific failure was most detrimental to enterprise value when the pandemic biotech boom ended in 2022. Over the 2022-2023 sample period, the median market capitalization-to-net cash ratio following news of a scientific failure was 0.77, representing a 23 percent discount to the value of cash.

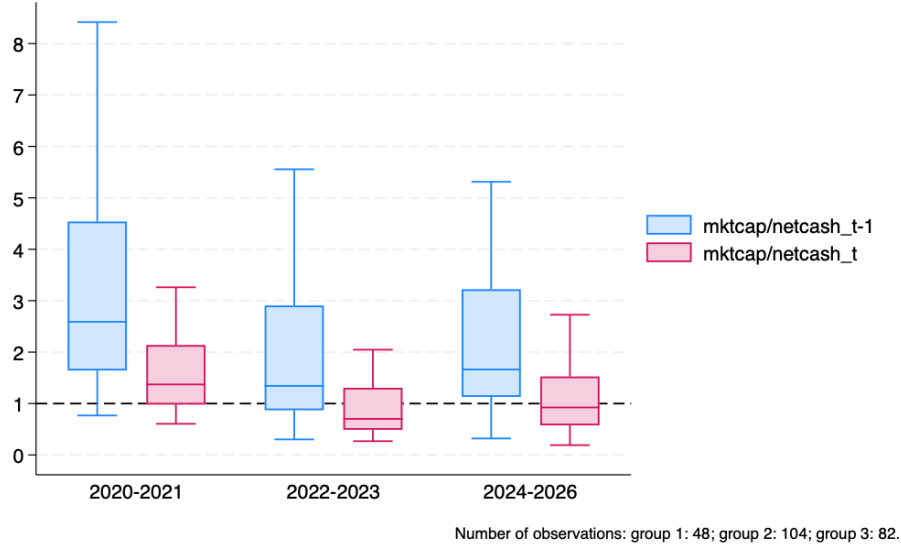


Figure 6: The impact of scientific failure on enterprise value

After a firm decides to discontinue its lead drug candidate due to a lack of efficacy, it generally has three strategic options. The firm can continue exploring a new drug candidate, pursue mergers and acquisitions, or liquidate and return the remaining cash to shareholders.

For the main sample of 153 firms with negative enterprise value, 86 firms continued, 31 were acquired by big pharma or activist firms targeting their cash, 24 merged with other biopharma firms, and only 12 were liquidated. The implications of these strategic alternatives to shareholders' value are detailed in the next section. For completeness of the analysis, below I first present the performance of the firms that continued, measured by returns to their shareholders.

With the standard formula below, annualized returns are computed using the stock price on the announcement date of the scientific failure (P_{event}), the stock price on the recent date 31/12/2025 ($P_{current}$), and the holding period (t) in months between the two dates.

$$\text{Annualized Return} = \left(\frac{P_{current}}{P_{event}} \right)^{\frac{12}{t}} - 1$$

From the mean shareholder return of -6.1 percent, one could infer inefficient continuation, as the continued operation did not deliver value to the shareholders. Managers may have private incentives to choose continuation, as inferred from the low incidence of voluntary liquidation. Continuation could give managers the opportunity to extract benefits from significant cash reserves or to avoid reputational harm when a firm liquidates. In some cases, managers are also the company's founders, in which case they wish to use the cash to pursue their own goal of scientific achievement, even if it goes against other shareholders' interests.

2.4 The strategic alternatives for biopharma firms that have discontinued product development while holding substantial cash balances

While shareholders would like to liquidate the firm and return cash, managers prefer continuation, as the data show. To address this agency problem, the current practice in the biopharma sector is for investors to use golden parachutes to induce managers' exits through change-of-control events such as M&A. The severance payment could easily exceed a lump-sum payment of \$1 million, and managers could receive additional monetary gains from the accelerated vesting of equity options.

However, since a biopharma firm without any promising projects has only its public company status and cash, just like a special purpose acquisition company (SPAC), it has few potential M&A partners. Reverse mergers with startups have been a popular option because market valuations have been high until the end of the biopharma boom in 2022, and thus merging with startups could create value for existing shareholders, despite heavy share dilution. In a word, as long as high market valuations persist, investors (and also managers) of biopharma firms would still have a valid exit option after scientific failures.

Unfortunately, the stock market was bearish during 2022-2023, and merging with startups did not deliver value to existing shareholders. Using data on 70 reverse merger cases that occurred during 2020-2024, I computed the changes in shareholder wealth due to reverse mergers. Specifically, changes in the wealth of legacy shareholders can be computed by $\frac{A*B}{C}$, where A is the existing shareholders' ownership of the combined company, B is the market capitalization of the combined company (data of first quarter-end post-merger), and C is the net cash of the public company pre-merger. The pre-merger net cash is used for the denominator, assuming that investors still have the option to liquidate the firm and get the cash distribution right before the merger.

While existing shareholders of the public shell company typically gained during the hot market (2020-2021), the median shareholder value loss from a reverse merger was -52% in 2022. This is because, following a reverse merger, existing shareholders receive a small stake in the combined entity due to the significantly higher valuations for startups, yet market capitalization increases only modestly following the business combination when the stock market is bearish.

The above analysis shows that reverse mergers could be a solution for biopharma firms that have experienced scientific failures, but existing shareholders need better protection. The SEC adopted a new set of rules effective from July 2024, targeting SPACs and shell companies to enhance investor protection from business combinations, including reverse mergers. The new rules set additional filing requirements for reverse mergers, making it more complicated for public shell companies to combine with private firms. But there is more room for government regulation to specifically address the concerns of legacy shareholders, which will help investors

feel more confident investing in early-stage biopharma firms.

3 Counterfactual analysis using a structural model

Evidence of significant funds remaining after scientific failure suggests that investors may have provided early-stage biopharma firms with too much capital at the time of IPO. But the firms that achieved scientific success might have benefited from such upfront financing, since they did not face the risk of early termination due to a lack of follow-up funding. To formalize the analysis, the following sections of the paper study the counterfactual scenario in which biopharma firms are financed by venture capital investors. The analysis is based on the equilibrium model of start-up financing developed by Parry (2025), in which VCs endogenously stage capital injections over time to limit losses from committing too much capital to entrepreneurs who conceal project failures.³ The trade-off here is that VCs can reduce the committed capital remaining at the time of scientific failure by choosing a shorter funding horizon, at the risk of not being able to renew the funding contract and thus shutting down promising projects.

3.1 An equilibrium model of venture capital (Parry, 2025)

3.1.1 Entrepreneurs' problem in the frictionless benchmark

Each start-up has a drug development project that is ex-ante homogeneous. That is, projects share the same characteristics (k, κ, p, π) . Here, k is the flow investment cost. The result of a drug development project is realized on an uncertain future date $T_\kappa \sim \text{Exp}(\kappa)$, where κ is the arrival rate of the results. The outcome is a success with probability p , and π is the payoff in case of a success, while the payoff is 0 in case of a failure. Entrepreneurs are risk-neutral and have a time discount rate ρ .

Suppose an entrepreneur can self-finance the project. The project NPV is then given by

$$\bar{V} = E \left[e^{-\rho T_\kappa} p \pi - \int_0^{T_\kappa} e^{-\rho t} k dt \right] = \frac{\kappa p \pi - k}{\rho + \kappa} \quad (1)$$

and the project will be financed if $\bar{V}$ is positive.

Alternatively, suppose an entrepreneur seeks funding from VCs, but the realization of the project outcome can be publicly observed. The optimal contract then specifies the capital commitment K and VCs' equity share ς . With the perfect information, VCs will provide the

³The model developed here is a simplified version of Parry (2025) without matching and acquisition. In Parry (2025), entrepreneurs search for VCs in a frictional matching market following the entry or exhaustion of previous funding. I model entry as start-ups that are financed by VCs, and entrepreneurs face the risk of failing to renew their previous funding contract. I also removed the acquisition as an exit option since such a complication is not helpful in the current setting.

flow investment k until the results are realized. Thus, the expected capital commitment is

$$K = \frac{k}{\rho + \kappa} \quad (2)$$

and VCs' equity share ς is given by the binding participation constraint

$$\varsigma * \frac{\kappa p \pi}{\rho + \kappa} = K. \quad (3)$$

3.1.2 The model with asymmetric information and agency conflicts

Below, I assume entrepreneurs have no wealth and must seek funding from VCs. Each VC can finance at most one project at a time, and the total measure of VCs is normalized to be 1. At any instant, a measure Γ of projects is newly financed and enters the drug development state.

Contrary to the frictionless benchmark, the realization of the project outcomes is private information to entrepreneurs. I further assume that entrepreneurs get a non-pecuniary flow benefit x whenever their projects are actively funded. Given the private benefit x , entrepreneurs never report failures. Because of this risk of inefficient continuation, VCs might choose to inject capital in multiple rounds.

The incomplete contract then specifies the VCs' equity stake ς and the hazard rate ω that governs the funding termination date. In other words, VCs commit to pay the flow investment k until an unknown time T_ω , where $T_\omega \sim \text{Exp}(\omega)$. A lower contract rate ω corresponds to a longer expected funding horizon and VCs' increased exposure to entrepreneurs' inefficient continuation.

Upon exhaustion of prior funding, VCs can review the project data, and failed projects cannot seek additional funding. In other words, only start-ups that have exhausted their capital but have not yet failed can raise follow-up funding. These start-ups can successfully renew their contracts with probability q , which is exogenous. Failure to raise follow-up funding leads to early termination of viable projects ex-post.

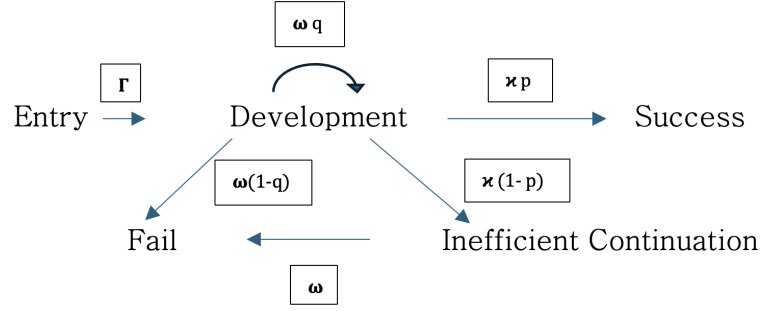


Figure 7: State transitions

3.1.3 The optimal contract with agency conflicts

With the state transitions illustrated in Figure 7, I can further write the value functions. The value of a start-up in the development stage is

$$\rho V = \kappa(p\pi - V) - \omega(V - qV) \quad (4)$$

which gives

$$V(\omega) = \frac{\kappa p \pi}{(\rho + \kappa) + \omega(1 - q)}. \quad (5)$$

Assuming the entrepreneur has the full bargaining power, the optimal contract rate ω maximizes the surplus to the entrepreneur

$$\omega = \arg \max_{\omega \in [0, \infty)} \{(1 - \varsigma)V(\omega)\} \quad (6)$$

where VC' equity share ς is given by the binding participation constraint

$$\varsigma V(\omega) = K(\omega) \quad (7)$$

and $K(\omega)$ is the expected capital commitment of VC

$$K(\omega) = \underbrace{\frac{k}{\rho + \kappa + \omega}}_{\text{Frictionless expected capital cost}} + \underbrace{\frac{\kappa(1-p)}{\kappa + \omega}}_{\text{Pr(Negative result arrives before funding termination)}} \underbrace{\frac{k\kappa}{(\rho + \omega)(\rho + \kappa + \omega)}}_{\text{Remaining commitment}}. \quad (8)$$

The trade-off is clear from equations (5) and (8). A lower ω (more upfront financing) reduces the value loss from early termination, while a higher ω (more staging) reduces the cost due to inefficient continuation.

3.1.4 Steady-state

In the steady-state equilibrium, the measures of start-ups in the development state (μ^p) and inefficient continuation (μ^u) should remain constant.

The steady-state conditions are therefore:

$$\Delta\mu^p = 0 : \Gamma + \omega\mu^p q = (\kappa + \omega)\mu^p \quad (9)$$

$$\Delta\mu^u = 0 : \kappa(1 - p)\mu^p = \omega\mu^u \quad (10)$$

Since the total measure of VCs is 1, the flow of entry Γ guarantees the equilibrium total measure of actively funded start-ups $\mu^p + \mu^u = 1$.

3.1.5 Extension: two-stages

To better reflect the biopharma setting, below I extend the model to include early- and late-stage drug development. The empirical counterparts of early- and late-stage are phase II and phase III, respectively. The state transitions are illustrated in Figure 8. The key ingredients are the transition probability from the early to the late stage, p_e , and the success probability conditional on reaching the late stage, p_l . While the arrival rate of project outcomes, κ , and the probability of successfully renewing the contract, q , are the same for early- and late-stage development, the flow capital costs are stage-specific (k_e and k_l). Given the stage-specific project characteristics, the optimal contract rate ω will also be stage-specific and will be solved separately for each development stage.

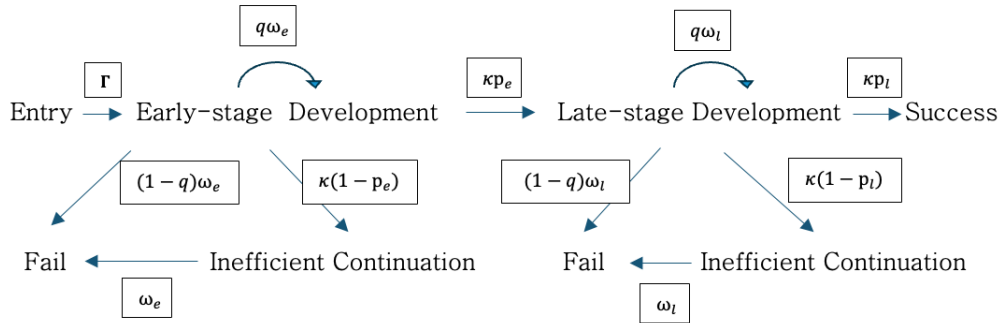


Figure 8: State transitions in two-stage model

As in the case of a single development stage, the value of a start-up in the late-stage development is

$$\rho V_l = \kappa(p_l\pi - V_l) - \omega_l(V_l - qV_l) \quad (11)$$

Assuming the entrepreneur has the full bargaining power, the optimal contract rate ω_l

maximizes the surplus to the entrepreneur

$$\omega_l = \arg \max_{\omega_l \in [0, \infty)} \{(1 - \varsigma_l)V_l(\omega_l)\} \quad (12)$$

where VC's equity share ς_l is given by the binding participation constraint for the VC

$$\varsigma_l V_l(\omega_l) = K_l(\omega_l). \quad (13)$$

and the expected capital commitment $K_l(\omega_l)$ is analogous to the one in the single development stage (equation (8)).

Since an early-stage firm enters the late-stage development upon the arrival of positive news, the value of a start-up in the early-stage development is

$$\rho V_e = \kappa(p_e V_l - V_e) - \omega_e(V_e - qV_e) \quad (14)$$

The optimal contract rate ω_e solves the same maximization problem subject to the constraint as in equations (12) and (13), where the expected capital commitment $K_e(\omega_e)$ is again analogous to equation (8).

In the steady-state, the measures of start-ups in the early-stage development (μ_e^p), in the late-stage development (μ_l^p), and in the inefficient continuation (μ_e^u and μ_l^u) remain constant. The corresponding steady-state conditions are:

$$\Delta \mu_e^p = 0 : \Gamma + \omega_e q \mu_e^p = (\kappa + \omega_e) \mu_e^p \quad (15)$$

$$\Delta \mu_e^u = 0 : \kappa(1 - p_e) \mu_e^p = \omega_e \mu_e^u \quad (16)$$

$$\Delta \mu_l^p = 0 : \kappa p_e \mu_e^p + \omega_l q \mu_l^p = (\kappa + \omega_l) \mu_l^p \quad (17)$$

$$\Delta \mu_l^u = 0 : \kappa(1 - p_l) \mu_l^p = \omega_l \mu_l^u \quad (18)$$

I assume the total measure of VC that finances early-stage development is 1. Thus, the flow of entry Γ guarantees the steady-state total measure of early-stage firms ($\mu_e^p + \mu_e^u$) equals 1.

The underlying project characteristics $(\kappa, k_e, k_l, p_e, p_l, \pi)$ as well as the funding environment q determine the optimal contract rate – in other words, the duration of funding – that trades off the risk of early termination against the cost of inefficient continuation. For example, the chance of inefficient continuation decreases with the probability of success p_e and p_l , while the risk of early termination decreases with the probability of successfully renewing the contract q .

3.2 Counterfactual analysis

The counterfactual analysis intends to study the optimal financing contract when investors have the option to stage capital injection. Below, I first solve for the optimal contract rate if VCs were to use the project characteristics $(\kappa, k_e, k_l, p_e, p_l, \pi)$ documented in the biopharma literature. Then, I study how the optimal contract rate and the steady-state measure of firms in the inefficient continuation differ from what I observe in the data.

3.2.1 Calibration

The parameter estimates for the project characteristics and the corresponding sources of literature are provided in Table 2. The unit of time is 1 year. The arrival rate of project outcome $\kappa = 0.33$ means the expected full horizon of project development in the current model (from phase II to commercialization) is $2 \times \frac{1}{\kappa} \approx 6$ years. This is within the reasonable range as the average time from the start of clinical trials to the marketing approval was 96.8 months in the survey conducted by DiMasi et al. (2016).⁴ The success probability in the early-stage p_e is 0.36, which corresponds to the transition probability from phase II to phase III, and the success probability in the late-stage p_l is 0.56, which corresponds to the probability that a drug entering phase III will eventually be approved. Finally, the success payoff π is \$1.5 billion, which is within the range given by Aryal et al. (2024).⁵

I refer to Parry (2025) for the discount rate $\rho = 0.08$ as well as the probability of successfully renewing the contract $q = 0.8$ in the VC context.⁶

Table 2: Parameter estimates: project characteristics

Parameters	Symbol	Value	Source
Arrival rate of project outcome	κ	0.33	DiMasi et al. (2016)
Flow investment: early-stage (\$ Mn USD/year)	k_e	20	DiMasi et al. (2016)
Flow investment: late-stage (\$ Mn USD/year)	k_l	80	DiMasi et al. (2016)
Success probability: early-stage	p_e	0.36	DiMasi et al. (2016)
Success probability: late-stage	p_l	0.56	DiMasi et al. (2016)
Success payoff (\$ Mn USD)	π	1500	Aryal et al. (2024)

⁴DiMasi et al. (2016) examined the dataset of 1442 self-originated compounds of the top 50 pharmaceutical firms first tested in humans anywhere from 1995 to 2007.

⁵Using the Cortellis Competitive Intelligence database, Aryal et al. (2024) find that the average ten-year and fifteen-year discounted sales revenues are \$1.40 and \$1.99 billion per drug.

⁶The probability of successfully renewing the contract in my model (q) corresponds to $1 - \frac{\lambda}{\lambda + \nu_e}$ which is the probability that a firm in search for funding successfully meets a VC in Parry (2025). In his model, a VC cannot provide subsequent funding for the project that she financed before and thus entrepreneurs must find a new VC when the earlier funding contracts are terminated. This type of search friction does not serve the purpose of this paper and thus replaced with the simple financing friction.

Using the above parameter estimates, the optimal contract rate and the steady-state measures of firms in each state are computed and shown in Table 3.

Table 3: Steady-state Equilibrium

Contract rate: early-stage	ω_e	0.4
Contract rate: late-stage	ω_l	0.3
Share of early-stage start-ups in development	μ_e^p	0.65
Share of early-stage start-ups in inefficient continuation	μ_e^u	0.35
Share of late-stage start-ups in inefficient continuation	$\frac{\mu_l^u}{\mu_l^p + \mu_l^u}$	0.33

3.2.2 Discussion

Given the parameter estimates from the literature, the optimal contract rates for the early and late stages are 0.4 and 0.3, respectively. This translates into the expected funding horizon of 2.5 years for the early stage and 3.33 years for the late stage. Since the value of a start-up is higher as it approaches final success, VCs would try to guarantee a longer funding horizon in the late stage to reduce the risk of shutting down a late-stage firm due to financial constraints. But interestingly, the expected funding horizons, ω_e and ω_l , are very close to the expected product development horizon, κ , meaning that VCs find it optimal to commit all the necessary funding rather upfront even when there is the possibility of smoothing capital injections over time. Again, the optimal contract rates are determined by the characteristics of the biopharma projects that we are considering.

In the steady-state equilibrium, the shares of firms in inefficient continuation are 0.35 and 0.33 for the early and the late stages. These values are close to the mean share of biopharma firms with negative enterprise value for the five years (2015-2019) prior to the biopharma boom (2020-2021). The significantly higher incidence of biopharma firms with negative enterprise value in the 2020 IPO cohort could be explained by investors' preference for more innovative projects during the bullish stock market, suggesting lower success probabilities p_e and p_l and a higher success payoff π than the estimates given by the literature. This hypothesis can be tested using the collected data, and the result will be available soon.

4 Conclusion and future research directions

This paper studies the negative enterprise value problem faced by biopharma firms that experience scientific failures. By examining the performance of early-stage biopharma firms that went public, this paper ultimately raises the question of whether the biotech boom during the pandemic was fundamentally justified. Although the increased number of biopharma firms with negative enterprise value in the 2020 IPO cohort suggests that investors were

giving too much capital to the premature firms during the bullish market, the counterfactual analysis shows that providing the capital needed upfront is optimal given the characteristics of biopharma projects. Given that staying private is not an effective solution to the negative enterprise value puzzle, more effort should be devoted to the better “recycling” of biopharma firms in the aftermath of scientific failures. The analysis in this paper showed that reverse mergers could be a solution, as these firms look a lot like SPACs, but more regulatory efforts should be directed toward protecting existing shareholders of the public “shell” company.

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