

A Review on Adaptability Controversies and Optimization Paths of Valuation Methods for Unprofitable Technological Enterprises: A Comparison Based on DCF, Real Options, Relative Valuation and Venture Capital Valuation Method

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Abstract. In spite of substantial R&D expenditures, extended development timelines, and high uncertainty, unprofitable technology companies in biotechnology, semiconductors, and artificial intelligence (AI) have become important drivers of global innovation. As such, this paper explores these three industries and examines the adaptability and optimization paths of four mainstream valuation approaches, including discounted cash flow (DCF) valuation, real options valuation (ROV), relative valuation, and venture capital (VC) valuation. Using a core-and-supplementary structure, with biotechnology as the core focus and the other two industries as supporting cases, this study explores targeted improvements for each valuation method and verifies their applicability through theoretical analysis and empirical evidence. The results show that the four methods have significant differences in industry adaptability, thereby leading to the proposal of a stage-differentiated valuation framework. In particular, early-stage enterprises should prioritize the improved VC and ROV methods, mid-stage enterprises should focus on optimized real options valuation and risk-adjusted discounted cash flow valuation, while late-stage pre-IPO enterprises should adopt improved discounted cash flow valuation as the primary approach supplemented by improved relative valuation. This study enriches the valuation theory for unprofitable technology firms and provides practical insights for investors and enterprises.

Keywords: Unprofitable Technology Companies, Valuation Method, Discounted Cash Flow (DCF), Real Options Valuation, Venture Capital (VC) Method

1. Introduction

In recent years, unprofitable technology companies have emerged as major catalysts for global innovation, particularly in the fields of biotechnology, semiconductors, and artificial intelligence (AI). In this context, supported by favorable capital market policies like China's STAR Market, these high-growth enterprises continue to expand despite prolonged losses. Nevertheless, their high R&D input, long development cycles, negative cash flows, and extreme uncertainty create severe valuation challenges. In this context, traditional methods including discounted cash flow (DCF)

valuation, real options valuation (ROV), and relative valuation often fail to capture their true value, while the venture capital (VC) method, as a classic and widely adopted tool in practice, has rarely been systematically compared with the three mainstream approaches in existing literature. Existing research primarily focuses on valuation issues within individual industries and lacks cross-industry comparative analysis as well as comprehensive valuation selection frameworks. This paper reviews adaptability disputes and optimization paths of DCF, real options, relative valuation, and the VC method. To achieve this, it adopts a core-and-supplementary structure, focusing on biotechnology as the core industry while also using semiconductors and artificial intelligence as supporting sectors. Theoretically, this study enriches valuation theory for unprofitable tech firms by clarifying method applicability across sectors. From a practical perspective, it provides clear guidance for investors, analysts, and enterprises.

2. Features and valuation of loss-making tech firms

2.1. Firm definition and core features

Unprofitable tech firms refer to enterprises suffering continuous net losses mainly owing to heavy R&D spending and slow commercialization [1]. In most cases, these firms are in the early or growth stages and lack stable cash flows, yet they possess core technologies and promising development prospects, creating value through long-term innovation rather than short-term profitability [2]. As a result, they exhibit several distinctive characteristics, including persistent losses, massive R&D investment, high operational uncertainty and phased value release. Traditional valuation methods centered on stable earnings and cash flows fail to adapt to such features, incapable of assessing their technological potential and flexible growth value, leading to biased valuation results [3].

2.2. Core principles of the four major valuation methods

Due to the high uncertainty, substantial R&D investment, and unstable cash flows of unprofitable technology enterprises, traditional valuation methods often face significant limitations. DCF is a fundamental income-based valuation method. And its core principle is that the value of an asset equals the present value of its expected future free cash flows discounted at a risk-adjusted rate.

$$\text{Enterprise Value} = \sum \left(\frac{\text{FCFF}_t}{(1+\text{WACC})^t} \right) \quad (1)$$

Where FCFF denotes free cash flow to the firm, WACC is the weighted average cost of capital, and t represents time periods.

In contrast to traditional cash-flow-based approaches, real options valuation (ROV) emphasizes managerial flexibility under uncertainty. ROV regards strategic investments such as R&D, project expansion, and commercialization as options that allow managers to defer, expand, contract, or abandon projects according to market conditions. Accordingly, its core principle is to capture the value of strategic flexibility and growth opportunities under uncertain environments. Common ROV models include the Black-Scholes model, binomial tree model, and Monte Carlo simulation

From a market-oriented perspective, the relative valuation method estimates firm value using market multiples of comparable companies, including P/E, P/B, and EV/Sales ratios. Its underlying principle is that similar assets should have similar market valuations.

$$\text{Enterprise Value} = \text{Comparable Firm's Multiple} \times \text{Target Firm's Financial Indicator} \quad (2)$$

Compared with income-based approaches, relative valuation is simpler and more intuitive, but its effectiveness heavily depends on the availability and comparability of benchmark firms. In addition to these mainstream approaches, the VC method is widely applied to early-stage and high-growth enterprises. It estimates current firm value by discounting expected future exit value to the present using a target rate of return. Rather than focusing on current profitability, it emphasizes future exit potential and growth expectations.

$$\text{Enterprise Value} = \frac{\text{Expected Exit Value}}{(1 + \text{Target Return})^n} \quad (3)$$

As a result, the VC method is particularly suitable for startups and unprofitable firms with strong growth potential but limited historical financial performance.

2.3. Core contradictions and optimization methods

The distinctive characteristics of unprofitable technology firms in biotechnology, semiconductors, and AI often make traditional valuation methods ineffective in accurately capturing their value. First, standard valuation models like DCF valuation and relative valuation rely on stable positive cash flows and profitability [4]. But these firms often sustain losses due to heavy R&D investment, clinical trials, and technological iteration [3]. For instance, biotech firms may have no revenue during long clinical phases, semiconductor firms face high costs and industrial cycles, and AI firms require long-term algorithm investment. Thus, these industries often fail to meet the assumptions underlying traditional valuation models. Second, traditional valuation methods focus primarily on current financial performance, whereas the value of these firms largely depends on intangible assets and R&D potential [5]. As a result, standard valuation approaches often fail to quantify such value accurately, particularly in the biotechnology industry. Third, relative valuation lacks comparable firms due to huge differences in tech paths and stages [4]. These limitations highlight the need for industry-adapted improvements to four major valuation methods.

3. Applicability and improvement of four major valuation methods

3.1. Applicability and improvement of DCF model

Loss-making tech firms conflict with the DCF model, which relies on steady positive cash flows and fixed discount rates. Heavy early R&D keeps these firms cash-negative and mismatches core DCF premises. The model also fails to capture milestone value from technical or clinical progress, leading to potential undervaluation, while static discount rates cannot reflect phased risk profiles, resulting in valuation distortions.

To resolve the poor applicability of traditional DCF to unprofitable technology enterprises, a series of enhanced valuation approaches have been developed. In particular, multi-stage cash flow modeling serves as a basic improvement, dividing corporate development into different phases to reflect staged value realization and enable period-specific financial forecasting [6, 7]. Risk-adjusted Net Present Value (rNPV) is widely used in biotech valuation, weighting future cash flows by success rates to measure R&D risks and prevent unreasonable overvaluation. For biotech assets, rNPV reduces mean absolute valuation error from 71% (standard DCF) to 29%, with 83% of estimates falling within $\pm 20\%$ of actual market values [8]. Besides, staged discount rates are set to match declining enterprise risks across different development stages. Scenario simulation covering

multiple situations is also introduced to cope with various external uncertainties, effectively improving the overall robustness and reliability of valuation results [6, 7].

Empirically, studies consistently show that improved DCF models perform significantly better than the standard model in valuing unprofitable tech companies. To be more precise, multi-stage DCF and rNPV adjustments effectively reduce valuation bias for biotechnology firms by capturing pipeline risks and milestone value, and their estimation errors are significantly lower than those of the traditional model [8]. A case study of CloudWalk Technology (AI, STAR Market) finds that a three-stage DCF with user-growth calibration yields a valuation error of only 0.62%, versus 38.7% for standard DCF [6]. At the industry level, stage-dependent discount rates enhance valuation accuracy for semiconductor and AI companies by reflecting the evolutionary trend of corporate risk, improving alignment with market performance. For pre-revenue enterprises, scenario-improved DCF provides more reasonable and robust estimation results, although it remains less suitable for very early-stage firms compared with real options or the VC method [6, 7]. In general, the improved DCF model achieves the highest reliability for late-stage Pre-IPO enterprises with clear commercial prospects in the three industries, and has been widely recognized in both academic research and practical valuation [7].

3.2. Optimization of real options approach

ROV boasts strong adaptability to unprofitable tech enterprises and makes up for DCF's defects in evaluating milestone value by capturing flexible strategic value amid high uncertainty. It effectively captures the option value embedded in biotech R&D pipelines and reflects valuation changes across key clinical stages. It also accounts for value creation from semiconductor technological iterations and AI algorithm optimization. Without relying on stable cash flow assumptions, it aligns well with the high-risk and stage-dependent development characteristics of such enterprises.

Despite its theoretical advantages, real options valuation is subject to significant controversies and practical limitations. First, the model parameters are highly subjective, especially the estimation of underlying asset volatility, which lacks uniform standards and easily leads to unstable valuation results [9]. For instance, a calibration study of 120 STAR Market tech firms shows that analysts' volatility assumptions (30%-70%) can cause ROV values to vary by up to 128%, compared with 45% for multi-stage DCF valuations [7]. Second, the model structure is complex and difficult to popularize. Most practitioners lack the expertise required to construct binomial trees, Black-Scholes models, or compound option models, leading to a gap between theory and practice. Third, existing ROV mostly adopts a general framework and rarely carries out industry-specific calibration. It does not fully capture cross-sector heterogeneity across the biotechnology, semiconductor, and AI industries [10]. Fourth, ROV may overestimate enterprise value by placing excessive emphasis on growth options while neglecting operational risks and failure costs. For pre-revenue AI startups, ROV produces a mean overvaluation of 37%, versus 11% for scenario-adjusted DCF [6].

To enhance ROV accuracy, standardized parameter calibration and industry volatility databases are required to reduce subjective bias [9]. And compound option models suit multi-stage research features, while simplified binomial tree models balance accuracy and practicability for wider use [6, 10]. It can also combine with risk-adjusted DCF to form a hybrid system, securing rational cash flow prediction while measuring flexible value [9]. Besides, the introduction of industry correction coefficients for option value differentiation and valuation accuracy enhancement.

3.3. Improvement of relative valuation method

Traditional relative valuation is ill-suited for unprofitable tech firms. Its mainstream profit-based multiples fail to apply to loss-making enterprises. Since such companies derive core value from research achievements and technical advantages instead of current profits, these multiples cannot reflect their real intrinsic value. Moreover, huge gaps exist among peer firms in development status and operation modes, making accurate comparison hard. Besides, volatile market sentiment easily distorts relevant valuation indicators and causes biased valuation outcomes.

To fix such drawbacks, practical and academic studies propose targeted refinements for relative valuation. Instead of profit-based ratios, analysts adopt EV/Sales, EV/R&D and per-user value tailored for unprofitable tech firms [6, 9]. Specifically, EV/R&D applies to R&D-intensive sectors like biotech and semiconductors, while user-based multiples are used for user-centric AI platforms, as shown in Table 1 [8]. In addition, comparable firms are selected based on business scope, R&D maturity, and capital scale rather than broad industry classification, and the resulting cross-industry optimization effects are summarized in the referenced table [6, 7]. Moreover, customized industry adjustment coefficients offset biases from divergent growth, risks and innovation competence [8, 9]. The combined use of listed multiples and M&A benchmarks stabilizes valuation outputs.

Table 1. Deviation reduction by industry screening method (%)

Industry	Multi-dimensional screening (Deviation reduction %)	Simple-industry matching (Deviation reduction %)
Semiconductor	28.4	10.1
Biotechnology	31.2	12.5
AI	25.7	9.8

Empirically, improved relative valuation performs better for unprofitable technology firms, as non-profit multiples better reflect their underlying economic conditions [6]. Proper peer selection and multiple adjustment lower valuation deviations, performing well in biotech and AI sectors [8]. In addition, the use of combined multiples helps stabilize cyclical fluctuations in semiconductor valuation. Due to its simplicity and market-oriented nature, relative valuation is well suited to revenue-generating technology firms and serves as a supplementary tool in biotechnology valuation. However, it fails to capture milestone-driven and long-term growth value, and therefore should be used in conjunction with other valuation models [6, 9].

3.4. Optimization of venture capital valuation method

The VC method applies to unprofitable biotech, semiconductor, and AI firms. As an early-stage valuation method, it emphasizes commercialization potential, technological barriers, and exit expectations, capturing growth without positive cash flows across clinical-stage biotechs, iterative semiconductor firms, and scaling AI companies [6, 11]. Besides, its simplicity aligns with primary market practice, thus driving wide adoption in early-stage financing [9, 12].

However, the VC method has critical limitations. Parameters like exit multiples, holding periods, and hurdle rates are highly subjective, causing unstable valuations [9]. A fixed discount rate ignores staged risk reduction and milestone value shifts (e.g., clinical approvals) [11, 13]. It is also sensitive to market sentiment, distorting valuations in volatile conditions [12]. Moreover, it lacks industry

calibration, failing to reflect sectoral differences in exit cycles, success rates, and value drivers, leading to accuracy gaps, as shown in Figure 1 [13].

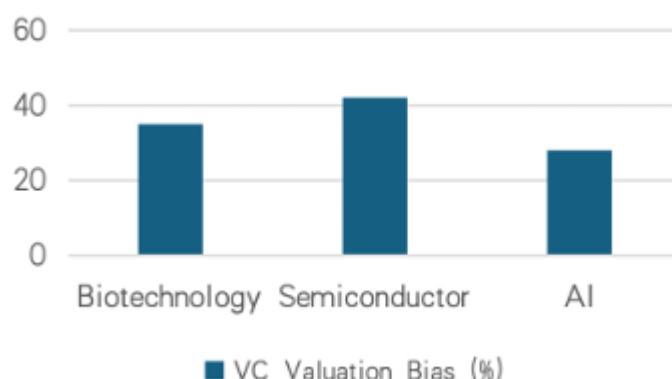


Figure 1. Valuation bias of the VC method across three tech sectors

To improve reliability and industry fit, targeted optimization is needed for unprofitable tech firms. The use of differentiated return rates is necessary to match dynamic risk profiles. In addition, the construction of industry exit multiple databases from real transaction data improves parameter optimization and reduces subjectivity [11]. In parallel, milestone discount mechanisms capture staged value growth arising from research and business progress [12]. Integration of the VC method with risk-adjusted DCF or real options forms a hybrid model combining practicality and theoretical rationality [9, 13]. Furthermore, the setting of industry correction coefficients differentiates sector characteristics and improves valuation accuracy.

4. Industry and stage-based valuation paths

4.1. Industry applicability of the four methods

In biotech industry, improved DCF can reflect post-commercialization cash flow potential and control R&D risks, yet it cannot fully embody milestone value and performs poorly in early periods. ROV fits its high uncertainty well by measuring flexible value, while it suffers from subjective parameters and complex calculation. In contrast, revised relative valuation is easy to apply to assess R&D value, but is constrained by insufficient comparable firms and market sentiment interference. Improved VC method suits early financing regardless of current profits, though its parameters rely too much on market exit conditions. For cyclical and capital-intensive semiconductor enterprises, staged DCF adapts to long-term cash flow evaluation, revenue-oriented relative multiples fit mature firms, and VC method suits early-stage technological iteration enterprises [5, 14]. As for data-driven AI enterprises, sales and user-based relative valuation is most practical, VC method matches user expansion period, and ROV can further assess algorithmic growth value [9].

4.2. Valuation selection in different stages

In the seed stage of biotechnology firms, where cash flows are absent and uncertainty is high, an improved VC method based on staged return rates is prioritized, with real options valuation used as a complementary tool to assess R&D option value [6]. At clinical-oriented growth stage, optimized compound real options serve as the core approach, alongside risk-adjusted DCF to evaluate pipeline value [6, 15]. When entering Pre-IPO stage with steady prospects and initial cash flows, improved

DCF takes the lead, while revised relative valuation verifies final results [14]. Meanwhile, cyclical and capital-intensive semiconductor enterprises adopt risk-adjusted VC and simplified real options in early periods. They combine staged discount rate DCF and R&D-based relative multiples during growth, and apply DCF matched with sales multiples for verification before listing. For asset-light AI enterprises, potential-adjusted VC and user-oriented valuation fit their seed-stage evaluation. As firms move into the growth stage, valuation mainly adopts sales and user multiples, with real options used to measure algorithmic value. In Pre-IPO period, relative valuation acts as the main method, supported by improved DCF to enhance valuation reliability.

5. Conclusion

This study focuses on unprofitable technology companies in biotechnology, semiconductors, and AI, and analyzes the adaptability and optimization paths of four valuation methods, including DCF, real options, relative valuation, and the VC method, and draws two core conclusions. First, the four valuation approaches exhibit significant differences in adaptability across the three industries. The real options and VC methods are more suitable for biotechnology firms characterized by high uncertainty and milestone-driven value creation. DCF and relative valuation are more applicable to semiconductor firms with pronounced cyclicalities and high capital intensity. And relative valuation is the most practical for artificial intelligence firms driven by data and algorithms, while the VC and real options methods serve as complementary approaches. Second, a unified valuation framework is developed for unprofitable tech firms. And this framework is grounded in industry characteristics, guided by development stages, and centered on method optimization. Early-stage firms primarily rely on the improved VC method and real options method. Mid-stage firms emphasize the improved real options method and risk-adjusted DCF. Late-stage Pre-IPO firms adopt the improved DCF method as the core, supplemented by improved relative valuation for validation, thereby achieving more accurate and robust valuation results. However, the findings are limited to three technology industries and may not be fully generalizable. Besides, the analysis lacks empirical case validation and does not sufficiently incorporate macroeconomic factors. Future research may employ machine learning techniques to optimize valuation parameters, incorporate ESG indicators to enrich the evaluation framework, and undertake cross-country comparative analyses to further enhance the valuation system.

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