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A Discussion on the Practice and Application of Quantitative Investment Concepts in Private Equity Fund Management

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Abstract: With the deep integration of FinTech and capital markets, quantitative investment, with its advantages of data-driven and disciplined decision-making, has become a key path for private equity fund management to break through the limitations of traditional investment. Based on public data from the Asset Management Association of China and industry practice cases, this article systematically analyzes the adaptation logic of quantitative investment and private equity fund management, summarizes the current development status and application scenarios of quantitative private equity, analyzes core challenges such as data quality, model effectiveness, and regulatory compliance, and proposes targeted optimization paths. Research shows that quantitative investment has covered the entire process of private equity fund asset allocation, risk management, and trade execution. By 2024, the scale of quantitative private equity in China will account for 30% of the total private equity scale. However, it is necessary to address industry pain points through measures such as upgraded data governance, dynamic model iteration, and improved compliance systems. The conclusions of this article can provide practical reference for private equity fund managers to optimize quantitative strategies and achieve stable returns, and also provide theoretical support for the standardized development of the quantitative private equity industry.

Keywords: Quantitative investment, private equity fund management, multi-factor strategy, risk parity model, algorithmic trading.

1. Introduction

In recent years, the domestic private equity fund industry has entered a stage of high-quality development. As of June 2024, data from the Asset Management Association of China shows that the scale of outstanding private equity funds reached 21.5 trillion yuan. Qualified investors' demand for stable returns and manageable risks continues to increase, driving a shift in investment philosophy from "subjective judgment" to "quantitatively driven." Quantitative investment, centered on mathematical models, uses computer algorithms to uncover market trends while mitigating human emotion. This characteristic aligns closely with the core objective of private equity funds to achieve "precisely matched risk and return." Leading private equity firms such as Huanfang Quantitative and Jiukun Investment have established product portfolios centered around quantitative strategies. Small and medium-sized private equity firms are also gradually introducing simple quantitative models to improve investment efficiency. The integration of quantitative investment and private equity has become an inevitable trend in the industry. Current academic research on quantitative investment often focuses on optimizing single strategies, such as improving multi-factor stock selection models and adjusting CTA strategy parameters. However, there is limited systematic analysis of the application of quantitative concepts throughout the entire private equity fund management process. In industry practice, some private equity firms have experienced strategy failures due to insufficient data capabilities and model overfitting. In 2023, one small and medium-sized private equity firm experienced a 15% discrepancy between its actual returns and backtested returns due to the use of low-quality public opinion data. Based on this, this article examines the concept's adaptability, current practice, application scenarios, core challenges, and optimization paths. Through literature review, industry data analysis, and case studies, it identifies the application value and improvement directions of quantitative investment in private equity fund management. This approach not only fills a systematic gap in theoretical research but also provides practical solutions for private equity firms to address operational challenges, helping the quantitative private equity industry overcome development bottlenecks and achieve long-term, healthy growth.

2. The Core Concept and Compatibility of Quantitative Investment and Private Equity Fund Management

The core logic of quantitative investment is to transform investment decisions into quantifiable and implementable algorithmic programs. This model's three core characteristics form the key foundation for its adaptation to private equity fund management: First, it is data-driven. Strategy construction relies on multi-dimensional information, including market conditions, fundamentals, and alternative data, including satellite data and public opinion data. Its effectiveness is verified through historical backtesting, thus avoiding the limitations of subjective experience. Second, it is disciplined execution. Investment operations strictly adhere to pre-set models, and positions are automatically adjusted when market triggers strategy thresholds. For example, one quantitative equity private equity firm specifies that the position in a single stock does not exceed 2% of the portfolio, using rigid rules to mitigate the risk of a single target. Third, risk is controllable. Relying on real-time volatility monitoring and hedging tools, the portfolio's maximum drawdown is kept

within a preset range. In 2023, the average maximum drawdown of neutral strategy products in the domestic stock market was less than 5%. Private equity funds are centered around "private placement and professional operation," and their core appeal is deeply aligned with the characteristics of quantitative investing. In terms of strategic flexibility, private equity funds are not subject to the restrictions imposed by public fund holdings, allowing them to rapidly iterate their quantitative strategies in response to market fluctuations. In 2022, with increased volatility in the commodity market, quantitative private equity firms generally increased their CTA strategy positions, achieving an average annualized return of 12.5% for this strategy that year. Regarding client targeting, qualified investors have a stronger risk tolerance and prioritize long-term stable returns. Quantitative strategies rely on diversified holdings and factor hedging to mitigate non-systemic risk and precisely match their needs. In terms of performance, managers' returns are directly linked to product performance, typically receiving a 20% performance fee. Continuous optimization of quantitative models can directly increase excess returns, creating a positive cycle of "strategy improvement, performance improvement, and return growth." In practice, quantitative investing has become a key to competitive differentiation in the private equity industry. Leading private equity firms invest tens of millions of yuan annually in data procurement and model development [1]. For example, Huanfang Quantitative has established an AI laboratory, incorporating natural language processing technology to analyze research report data. Small and medium-sized private equity firms collaborate with third-party data service providers to develop simple quantitative models such as moving average crossover strategies. Industry data from 2024 shows that the average annualized return of private equity products using quantitative strategies is 3-5 percentage points higher than that of subjective strategies, and the compatibility of the two has been fully verified by market practice.

3. Current Status of Quantitative Investment Practices in Private Equity Fund Management

The practice of quantitative private equity in China has evolved through three stages, evolving from simple to complex, and from singular to diversified. The embryonic stage, driven by the launch of stock index futures, focused strategies on single-factor stock selection and simple trend tracking, relying on the CSI 300 Index Futures to hedge risk [2]. The industry's scale was less than 100 billion yuan, with institutions such as Zhongyang Investment launching the first batch of quantitative hedging products. The rapid growth stage benefited from the expansion of the ChiNext and STAR Markets and the widespread adoption of big data technology, leading to the rise of multi-factor stock selection, statistical arbitrage, and CTA strategies. The scale of quantitative private equity exceeded 5 trillion yuan, with leading institutions such as Mingquan Investment and Huanfang Quantitative relying on refined strategies to build competitiveness. The mature stage saw the in-depth application of AI technology, with cross-market strategies becoming a new trend. At the same time, tightening regulations accelerated an industry reshuffle. By 2023, approximately 20% of small and medium-sized quantitative private equity firms would exit the market due to strategy homogeneity and insufficient data capabilities. Currently, there are four major mainstream strategy systems in quantitative private equity:1. quantitative stock strategy, accounting for 45%, covering multi-factor stock selection, index enhancement, market neutral and other sub-strategies. Among them, index enhancement strategy is the most popular due to its "excess return + index benchmark" feature. In 2023, the average annualized excess return of such products in China reached 8.2%; the second is CTA strategy, accounting for 25%, which makes profits by tracking commodity futures trends. Quantitative CTA relies on volume and price data modeling. In 2022, it performed outstandingly in the volatile commodity market, with an average return of 12.5%; the third is arbitrage strategy, accounting for 20%, covering ETF arbitrage, convertible bond arbitrage, and spot-futures arbitrage. It has low risk and stable returns and is suitable for conservative clients. The maximum drawdown of a private equity convertible bond arbitrage product in 2023 was only 2.3%; the fourth is multi-strategy integration, accounting for 10%, which diversifies risks by combining stock quantitative, CTA, and arbitrage strategies. Jiu Kun Investment's "quantitative multi-strategy product" achieved a 7% return in 2023 in the double-kill market of stocks and bonds. Positive returns, with maximum drawdown controlled within 5%.

Industry practices also exhibit three notable characteristics: significant differentiation in technology investment, with leading private equity firms investing over 10 million yuan annually, while smaller and mid-sized firms rely more on third-party services, resulting in a 60% strategy homogeneity rate; regulatory compliance has become a key focus. In 2022, the China Securities Regulatory Commission issued a notice requiring quantitative private equity firms to disclose strategy logic and risk factors. One private equity firm had its product filing suspended in 2023 for failing to disclose model parameters in compliance; and investor awareness has evolved, with clients shifting their focus from short-term returns to strategy transparency. 70% of quantitative private equity firms now regularly publish "Strategy Operation Reports" explaining performance fluctuations and model adjustment logic.

4. Specific Application Scenarios of Quantitative Investment Concepts in Private Equity Fund Management

4.1. Asset Allocation: Quantitative Models Optimize the Allocation of Major Asset Classes

Asset allocation is the starting point of private equity fund management. Quantitative investment relies on models to achieve the optimal "risk-return" balance: The mean-variance model constructs an efficient frontier by calculating the expected returns, variances, and covariances of assets. In 2023, a private equity firm used this model to reduce its stock holdings from 60% to 45%, increase bonds to 40%, and maintain commodities at 15%. This reduced the portfolio's annualized volatility from 18% to 12%. The risk parity model adjusts asset weights to ensure that each asset contributes equally to the portfolio's risk. Lerui Asset Management's quantitative risk parity product, based on this approach, experienced a drawdown of only 3.5% during the 2022 market downturn in both stocks and bonds. The macro factor model dynamically adjusts its portfolio based on indicators

such as GDP growth, CPI, and interest rates. In 2023, a private equity firm achieved a 9.2% return on bond investments using this strategy [3].

4.2. Risk Management: Quantitative Tools Control Downside Risk

Risk management is the core competitiveness of quantitative private equity firms, specifically manifested in three aspects: For risk measurement, VaR models have become a mainstream tool. Most quantitative private equity firms control daily VaR within 1%-2%, automatically reducing positions if it exceeds the threshold. During a major A-share market sell-off in 2023, products using VaR models experienced an average drawdown 4 percentage points lower than those not using them. Stress testing verifies portfolio resilience by simulating extreme scenarios. In 2023, one private equity firm tested a 5% single-day drop in the CSI 300 Index, achieving a maximum drawdown of approximately 3%, which was within a tolerable range. Hedging relies on derivatives to offset systemic risk. Equity market neutral strategies, such as selling CSI 300 index futures to hedge against market fluctuations, achieved an average annualized return of 6.8% in 2023, with maximum drawdowns often below 5%. Furthermore, factor risk control can mitigate the impact of single factor failures. When the valuation factor failed in 2022, products that controlled factor weightings experienced drawdowns 4-6 percentage points lower than those that did not.

4.3. Trade Execution: Algorithmic Trading Improves Execution Efficiency

Traditional manual trading is susceptible to slippage and market shocks. Quantitative private equity firms rely on algorithmic trading to achieve efficient execution: The TWAP algorithm evenly splits orders within a specified timeframe, making it suitable for liquid stocks. One private equity firm used it to execute orders for CSI 300 components, keeping slippage within 0.08%. The VWAP algorithm executes orders based on market volume, placing more orders when trading volume is high. In 2023, the average slippage rate for orders using this algorithm for domestic quantitative private equity firms was 0.1%. The Iceberg algorithm breaks large orders into smaller ones, exposing only a portion of the volume to avoid market detection, making it suitable for trading small-cap stocks. Intelligent order routing can also optimize trading channels [4]. A leading private equity firm compared commission rates and transaction speeds across different brokerages and reduced its stock trading commission rate from 0.03% to 0.015%, saving over 10 million yuan annually.

5. Core Challenges in the Application of Quantitative Investment Concepts in Private Equity Fund Management

Currently, quantitative private equity firms face multiple core challenges in their application. On the data front, quantitative strategies rely on high-quality data, but private equity firms face dual challenges in both quality and access. Market data is subject to "noise" and "lags," making alternative data difficult to verify. In 2023, a small and medium-sized private equity firm used third-party public opinion data to build a strategy. Due to the inclusion of false comments, the actual and back-tested returns deviated by 15%. High-quality data is monopolized by companies like Wind and Bloomberg, with annual fees of hundreds of thousands of yuan, making it difficult for small and medium-sized private equity firms to afford. Free data cannot support complex models, creating a "data gap." Furthermore, the Personal Information Protection Law restricts the use of customer transaction and credit data. In 2023, a private equity firm was fined 300,000 yuan for illegally using customer data. While models are core, practical challenges are prominent. Overfitting can lead to model failure in real-world trading. For example, a private equity firm's "small-cap quantitative strategy," based on data from 2018-2021, had a backtested annualized return of 25% in 2022, but only 3% in 2023 due to a shift toward large-cap stocks. Strategy homogeneity exacerbates return dilution. Following widespread adoption of the "low valuation + high growth" factor in 2021, excess returns fell from an annualized 10% to 2% in 2022. Models struggle to cope with "black swan" events in extreme market conditions [5]. During the A-share market crash in March 2020, 60% of quantitative private equity products experienced a single-day drawdown exceeding 3% because the model failed to account for the impact of the pandemic. Tightening regulations are increasing pressure: In 2022, the China Securities Regulatory Commission (CSRC) required quantitative private equity firms to disclose the core logic and parameters of their strategies. Complex AI models are difficult to explain in layman's terms, and disclosures can be prone to leaks. One leading private equity firm delayed filing by three months due to concerns about algorithmic leaks. Trading platforms are strictly prohibited from engaging in "spoof trading" and "high-frequency order grabbing." In 2023, a quantitative private equity firm was fined 5 million yuan for frequent false reporting. Cross-border investments must adapt to local policies. A private equity firm preparing a US stock product for 2023 had its preparation period extended by six months due to US SEC tax requirements. The shortage of multidisciplinary talent also hinders development: Quantitative analysis requires a combination of mathematical, computer, and financial skills. Data from the Asset Management Association of China in 2023 showed a shortage of 12,000 quantitative private equity talent and over 3,000 AI R&D talent. Top private equity firms are offering annual salaries of 500,000 to 1 million yuan and equity incentives to recruit talent, while the turnover rate among small and medium-sized private equity firms exceeds 40%. One private equity firm lost three core team members in 2023, halting strategy development for six months. Quantitative talent requires three to five years of experience, and the late establishment of financial engineering majors in universities has resulted in weak practical experience for graduates. One private equity firm recruited 10 people from campus in 2023, but only three were able to independently participate in R&D after six months.

6. Recommended Pathways for Optimizing the Application of Quantitative Investment Concepts in Private Equity Fund Management

6.1. Strengthening Core Data and Model Capabilities

Breaking through data bottlenecks requires a comprehensive approach throughout the entire process: On the acquisition side, "revenue-sharing" agreements can be

signed with public opinion and satellite data service providers. One private equity firm reduced data costs by 40% through this approach. Furthermore, internal data such as investment research reports and client transactions can be consolidated. For example, Huanfang Quantitative has established a five-year dedicated investment research database to reduce external reliance. On the cleaning side, a quality control system can be introduced. After implementing this system in 2023, one private equity firm reduced the discrepancy between backtesting and actual trading from 15% to 5%. On the compliance side, a data compliance officer should be established to anonymize client data. Overseas data should be reviewed by local consultants to mitigate regulatory compliance risks. Model iteration requires a closed-loop system: Backtesting using an "in-sample + out-of-sample + cross-market" model helped one private equity firm reduce overfitting risk by 30%. Monte Carlo simulations can also be used to test model resilience. Real-time monitoring of indicators such as excess return volatility is crucial [6]. In 2023, after discovering the failure of the "growth factor," one private equity firm promptly added a "momentum factor," increasing annualized returns from 3% to 8%. Simultaneously, by implementing a "core + satellite" strategy portfolio, the firm achieved a 7% profit in 2022 thanks to a 12% return from its CTA strategy, which offset a 5% loss from its stock strategy.

6.2. Improve the Compliance and Talent Support System

Compliance management is the foundation of development: Institutionally, the "Quantitative Strategy Disclosure Management Measures" were established, disclosing only the "strategy framework" to balance transparency and confidentiality, and also implementing a "compliance veto system." Process-wise, a compliance module was embedded in the algorithm system. In 2023, a private equity firm used this module to prevent 12 illegal filings. Training was regularly organized to study regulatory policies. After soliciting comments on the relevant guidelines in 2024, a private equity firm immediately provided training to ensure strategy compliance.

The talent shortage problem requires multi-faceted solutions: recruiting students majoring in financial engineering and computer science from campus, and social sciences. To recruit talent from securities firms and public funds, one can also offer targeted training through scholarships, as exemplified by Jiukun Investment's collaboration with Peking University's School of Mathematics. A development path is established, with a mentoring system reducing the time new hires spend independently managing strategies from five years to three. Equity incentives and project dividends are also promoted for retention. Huanfang Quantitative's core team retention rate is 80%, significantly higher than the industry average of 50%.

7. Conclusion

This paper systematically examines the practice and application of quantitative investment concepts in private equity fund management, drawing the following key conclusions: First, there is a deep compatibility between quantitative investment and private equity fund management. Quantitative investment's data-driven, disciplined execution, and manageable risk profile align with the core demands of private equity funds for strategic flexibility, stable client returns, and a performance-driven approach. Industry data indicates that quantitative private equity will account for 30% of total assets by 2024, confirming that the integration of the two is an inevitable trend. Secondly, quantitative investment has fully penetrated the entire private equity fund management process: asset allocation optimizes allocations through mean-variance and risk parity models, risk management relies on VaR and hedging tools to control drawdowns, and trade execution leverages algorithms to improve efficiency. In 2023, the average annualized returns of stock index enhancement and quantitative CTA strategies reached 8.2% and 12.5%, respectively, significantly outperforming subjective strategies. Their effectiveness has been proven by the market.

At the same time, the industry still faces four core challenges: inconsistent data quality and high acquisition costs constrain strategy foundations; model overfitting and failure impact return stability; regulatory compliance pressures increase operational difficulties; and a shortage of multidisciplinary talent limits development. These issues require collaborative efforts between private equity firms and the industry.

In the future, with the in-depth application of AI technology and the improvement of the regulatory system, quantitative private equity will develop towards refinement and standardization. Private equity fund managers must focus on improving data governance, model iteration, and compliance management capabilities, and strengthen talent development. The industry needs to promote data sharing and improve the talent development ecosystem to avoid strategy homogeneity and crowded trading. Through collaboration among all parties, quantitative investment will better serve private equity fund management, provide more efficient and stable asset management services for the capital market, and help the private equity industry achieve high-quality development.

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