Evolutionary Game Theory and Time Series Returns Rank Strategy: a Quantitative Approach Tested in Chinese Stock Market

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ABSTRACT

This comprehensive study applies Evolutionary Game Theory (EGT) in the context of stock market investment, with particular emphasis on the Chinese stock market. We use the 000300 index, a representation of the most significant stocks traded in the country, spanning from 2018 to 2022. In this research, we leverage the financial data API 'tushare', a robust tool for extracting and analyzing Chinese market data. In total, we analyze 166 stocks out of the 300 incorporated in the 000300 index, with data persistently available throughout the study period. Our model takes an evolutionary approach to investment, distributing funds across a selection of top and bottom stocks in an attempt to balance profit generation and risk management. Through rigorous data analysis and model testing, we identify that an optimal balance is achieved with a delay of 20 days and a portfolio comprising 12 stocks. This approach proved resilient even during volatile market periods, such as the Covid-19 pandem. Further research can extend and refine these methods to further harness the potential of EGT in the complex and rapidly changing landscape of stock market investment.

Key Words: Evolutionary Game Theory, Stock Market Investment, Chinese Stock Market, Portfolio Management, Sharpe Ratio, Sortino Ratio.

BACKGROUND

The Chinese stock market offers a fascinating context for investment analysis due to its rich history and dynamic traits. Despite its relatively brief existence compared to Western counterparts, the Shanghai and Shenzhen stock exchanges have experienced significant growth in size, liquidity, and regulatory procedures. However, the complexity of the Chinese stock market necessitates innovative models for precise predictions. Evolutionary game theory, originally designed to understand biological behaviors, provides a promising approach. Unlike traditional game theory, it considers the bounded rationality of market participants and explores dynamic processes leading to equilibrium or persistent oscillations. This theoretical framework is fitting for modeling the intricacies of the stock market, where actors constantly adjust their strategies based on historical performance.

In this study, we conducted a comprehensive investigation of existing research on the application of evolutionary game theory to predict the Chinese stock market. Our search across esteemed academic databases revealed a surprising scarcity of relevant works in this area. By employing a strategic research methodology, including carefully curated keywords and refined selection processes, we identified a narrow set of 11 papers that satisfied our rigorous criteria. These papers, along with additional tangentially related sources, were meticulously analyzed to uncover their potential relevance to our research topic.

Our research aims to make a novel contribution to the field by applying evolutionary game theory to predict the Chinese stock market. By doing so, we seek to introduce new methodologies and insights that could expand the boundaries of knowledge and understanding in this specific area of financial economics.

MODEL & METHODS

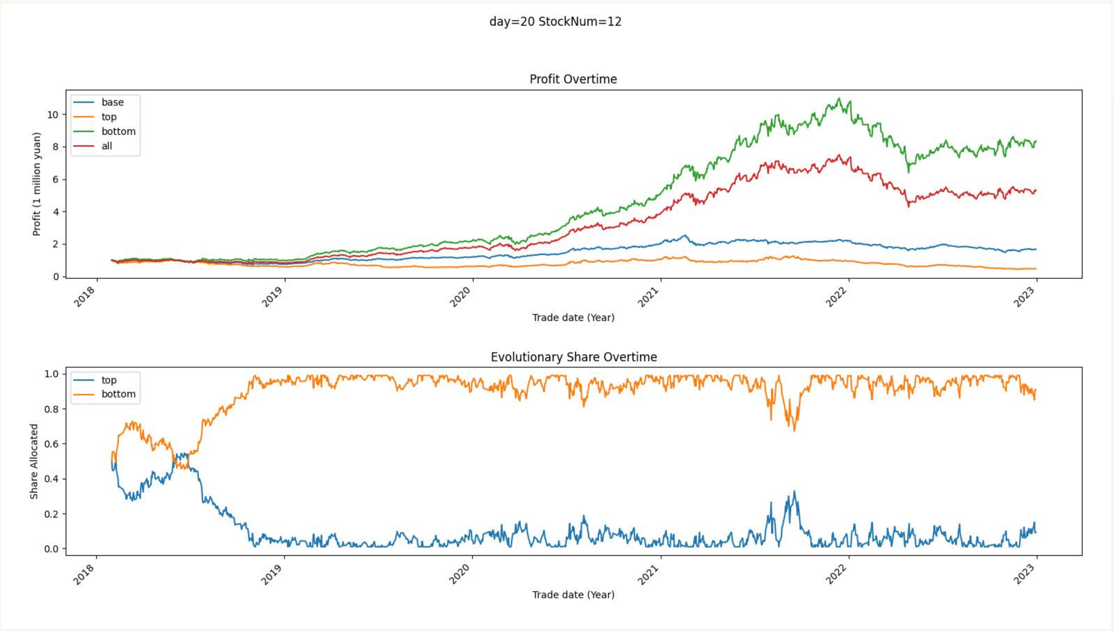
Multi-factor quantitative strategy

- Delay: the number of days we trace back to compute the time series returns rank
- StockNum: number of top/bottom stocks

Evolutionary game theory

- Begin with 50% of the initial asset for top vs. Bottom strategy
- Returns of both strategies to reallocate the percentage of hold (or share) according to the returns by adding the absolute value of returns difference to the preferable strategy.

We have also tested the model with two varying parameters and determined an optimal pair: (20, 12). This means that we pick delay to be 20 days and 12 to be the number of stocks for each round of game.



There are two other aspects that are also of interest. Namely, we examined evolutionary share overtime and profitability overtime.

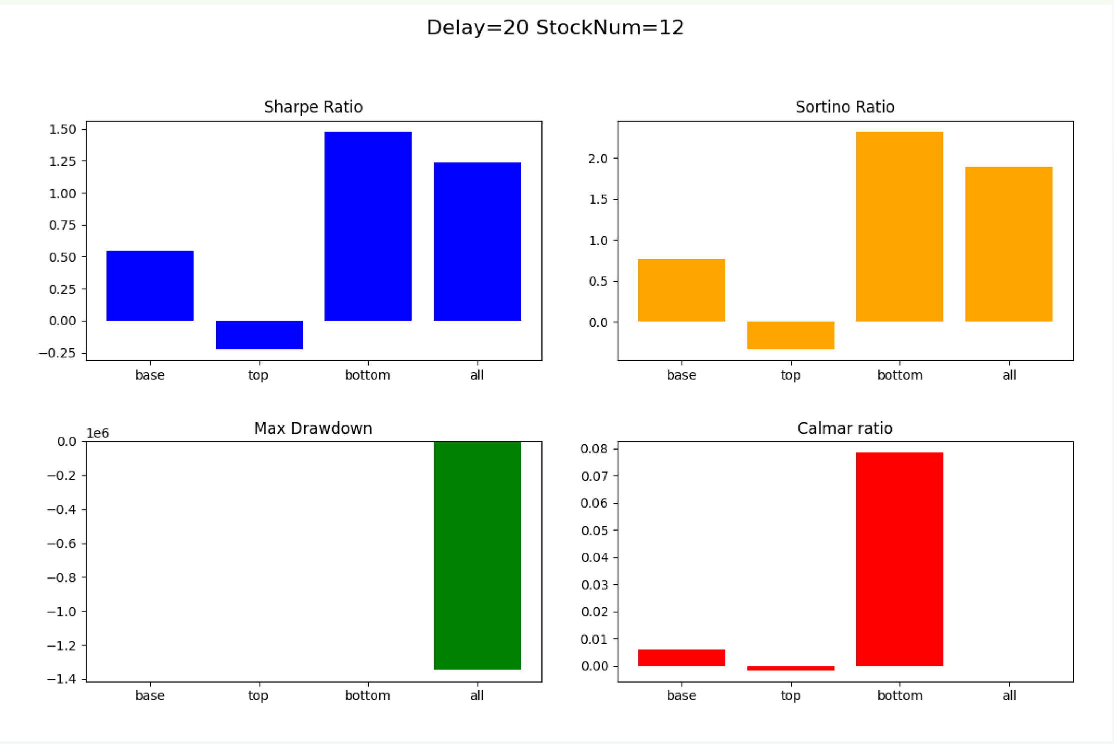
For evolutionary share overtime, we observed that the investment shares for top and bottom stocks tend to evolve to a fixed result: bottom stocks take up most of the share and only a tiny portion is allocated to the top stocks. In general, the outcome is unified.

For profitability overtime, we observed that the top ranking stocks' profitability (yellow line) has more uncertainty and fluctuations compared to the bottom ranking stocks, but also has higher peaks (spikes). This is reasonable since considering a combination of a variety of stocks gives us a less biased and more omnipotent view of the stock market and its possible changes.

Side note: intensive programming was included in this project, so forgive our briefness of the model explanation, since much of the content is built on Python code.

RESULTS

There are several measures we use to understand the performance of the model. This includes the relation of delay and stock number to overall profit and the two common financial modeling ratios (Sharpe Ratio and Sortino Ratio); in addition to that is an overview of evolutionary shares to top and bottom stocks and profitability overtime.



From our observations of the data, we can say that the evolutionary strategy seems to work well in the investment of stocks. Although it does not generate the highest profit (like the bottom stocks), it well balances risk and return: return is second highest when other parameters are optimized, but variation is much smaller than the "bottom" line and the trends seem to be less prone to events like Covid-19.

Through intensive experimentation with data, we have pinned down an ideal set of parameters to use in the modeling code assuming no large fluctuations in the stock market other than shocks from Covid-19 in 2020-2022.

We have observed that for each delay value, when stock number is 12, the profits and the Sharpe and Sortino ratios reach peak values; stock number = 12 seems to be some sort of optimal value for this model.

We have observed that for each stock number, when delay is 20, the profits and the Sharpe and Sortino ratios reach peak values; delay = 20 seems to be some sort of optimal value for this model. Even when stock numbers increases to as large as 88, delay = 20 still seems to be a local maximum in graphs that depict change in Sharpe and Sortino ratios.

CONCLUSIONS

In conclusion, this study applies Evolutionary Game Theory (EGT) to the Chinese stock market. Using financial data from the 000300 index, a multi-factor quantitative strategy is developed, distributing funds across top and bottom stocks based on historical returns. The optimal strategy comprises a 20-day delay and a portfolio of 12 stocks, generating high returns with stability even during volatile periods like the COVID-19 pandemic. This research contributes to game theory in financial decision-making and offers insights into optimizing stock market investment using EGT. Further research can expand these methods to other markets and factors. Overall, it represents a significant advancement in applying EGT to stock market investment.

REFERENCES

Al-Awadhi, A. M., Alsaifi, K., Al-Awadhi, A., & Alhammadi, S. (2020). Death and contagious infectious diseases: Impact of the COVID-19 virus on stock market returns. *Journal of Behavioral and Experimental Finance*, *27*, 100326. https://doi.org/10.1016/j.jbef.2020.100326

Bailey, W. (1994). Risk and return on China's new stock markets: Some preliminary evidence. *Pacific-Basin Finance Journal*, *2*(2–3), 243–260. Scopus. https://doi.org/10.1016/0927-538X(94)90019-1

Chen, L., Li, T., Jia, F., & Schoenherr, T. (2023). The impact of governmental COVID-19 measures on manufacturers' stock market valuations: The role of labor intensity and operational slack. *Journal of Operations Management*, *69*(3), 404–425. https://doi.org/10.1002/joom.1207

Chen, X., & Chiang, T. C. (2016). Stock returns and economic forces-An empirical investigation of Chinese markets. *Global Finance Journal*, *30*, 45–65. https://doi.org/10.1016/j.gfj.2016.01.001

Fernald, J., & Rogers, J. H. (2002). Puzzles in the Chinese Stock Market. *The Review of Economics and Statistics*, *84*(3), 416–432. https://doi.org/10.1162/003465302320259448

Liu, W., Ma, Q., & Liu, X. (2022). Research on the dynamic evolution and its influencing factors of stock correlation network in the Chinese new energy market. Finance Research Letters, 45, 102138. https://doi.org/10.1016/j.frl.2021.102138

Shanghai Stock Exchange. (2018). Trading rules of shanghai stock exchange - ENGLISH.SSE.COM.CN. http://english.sse.com.cn/start/sserules/stocks/trading/mainboard/c/5613747.pdf

Zhou, X., Zhang, W., & Zhang, J. (2012). Volatility spillovers between the Chinese and world equity markets. *Pacific-Basin Finance Journal*, *20*(2), 247–270. https://doi.org/10.1016/j.pacfin.2011.08.002

Amir, R., Evstigneev, I.V., Hens, T. *et al*. Evolutionary finance and dynamic games. *Math Finan Econ* **5**, 161–184 (2011). https://doi.org/10.1007/s11579-011-0053-2

Amir, R., Belkov, S., Evstigneev, I.V. *et al*. An evolutionary finance model with short selling and endogenous asset supply. *Econ Theory* **73**, 655–677 (2022). https://doi.org/10.1007/s00199-020-01269-x

Belkov, S., Evstigneev, I.V., Hens, T. *et al*. Nash equilibrium strategies and survival portfolio rules in evolutionary models of asset markets. *Math Finan Econ* **14**, 249–262 (2020). https://doi.org/10.1007/s11579-019-00254-w

Zhitlukhin, M. A continuous-time asset market game with short-lived assets. *Finance Stoch* **26**, 587–630 (2022). https://doi.org/10.1007/s00780-022-00479-6

ACKNOWLEDGEMENT

We acknowledge the help and patient guidance of Prof. Fu throughout the project.