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Evolutionary Stable Portfolio Rule: Requirements and Obstacles

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ABSTRACT

The present study aims to investigate the investment strategies used in stock markets from an evolutionary game theory perspective. Our primary objective is to identify the necessary conditions for achieving an evolutionarily stable equilibrium and to highlight the importance of non-return effects. To achieve a yield-dominant stable investment strategy, investors must focus on profits while remaining cautious of yield disparities. However, to achieve this equilibrium, people must act completely rationally, but as social beings, humans can make mistakes. Therefore, evolutionary theory is ideal for modeling emotional states and non-rational behaviors, such as reciprocity, altruism, and selfishness. We used evolutionary game theory to model how people interact with each other when making investment decisions. Our focus was on how individuals adapt and change their strategies. Our analysis also concentrated on non-interactive strategy changes using signaling mechanisms. We conclude that low-return strategies can persist for extended periods due to non-return effects, conformism, and human-specific emotions.

1. Introduction

This study uses evolutionary game theory to analyze investment strategies in the stock market. Its primary objective is to identify the conditions necessary for stable evolutionary equilibrium and understand the factors contributing to investors' success or failure. The goal is to uncover the reasons behind these outcomes.

The success of an investment is often measured by its return on investment. However, it's important to consider other factors beyond just financial benefits. Humans have emotions such as altruism, reciprocity, skepticism, and shame, which can greatly influence their decision-making. These emotions can lead people to irrational choices or spiritual happiness. This is where evolutionary theory comes in, providing a framework for modeling emotional states and non-rational behaviors, such as reciprocity, altruism, and selfishness. Our use of evolutionary game theory to model how people interact with each other when making investment decisions, and our focus on how people change their strategies.

Evolutionary game theory, a formidable mathematical framework, is often harnessed to model human behavior, particularly

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conformism and non-yield-dominant motives. With the use of replicator dynamics, it offers a powerful tool to simulate how individuals interact with each other and make decisions based on their preferences. One of its most awe-inspiring features is ability to establish emotional relationships across different periods.

We used the principles of evolutionary game theory to create a realistic replicator dynamics model. During the modeling process, we assumed that non-return effects can influence economic agents and make them content with selecting low-return strategies, and agents tend to be risk-averse. Additionally, we acknowledged that individuals could alter their strategies by interacting with other players, receiving new information, making predictions, and influencing their social surroundings.

All these assumptions align with human nature. Moreover, in the last part of our study, the analysis was repeated on the idea that the interaction between two economic agents is not random. If the matches are not random, people prefer environments where people who think like themselves are concentrated, and this prevents opposing strategies from interacting. When pairings are not random, humans tend to gravitate towards environments where people share similar thoughts and ideas. This behavior creates echo chambers where individuals are isolated from opposing strategies and ideas, limiting the opportunity to interact with different viewpoints.

According to our findings, observing a return-oriented investment strategy that captures the entire market is challenging due to various factors, including irrational decision-making by investors, conformism and behavioral dimension, risk premium based on risk aversion, and non-random matchings. We also showed that investors have different degrees of aversion to risk, so they demand varying risk premiums. This makes it difficult to create an investment strategy that satisfies the needs of all investors. Additionally, it's challenging to develop a single investment strategy that can cater to the entire market due to non-random pairings of investors with similar risk preferences. Lastly, our results demonstrate that the low-return effects significantly prevent return-dominant strategies from achieving a decisive victory.

We hope that our study will contribute to the existing literature from various perspectives. It's an important conclusion that low-return investment strategies can be successful in the market, which advances our understanding of decision-making processes in specific contexts. Additionally, the research offers vital insights into the social and emotional factors that impact our preferences and can lead to consistent errors in our decisions. Overall, it provides valuable insights into the complex nature of investment strategies in the stock market and highlights the importance of considering different factors and conditions to achieve evolutionary stable equilibrium. The findings are significant because they demonstrate that individuals who consistently make errors and value non-monetary factors such as kindness, goodwill, and reciprocity, can easily adopt suboptimal investment strategies and continue to stick with them.

2. Literature Review

In this section, we will present a literature review of studies that analyze investment markets and strategies with evolutionary game theory tools. Such studies provide valuable insights into the behavior of the stock market and can inform investment decision-making. Yet, before presenting these critical studies, we will discuss other important studies that do not use evolutionary theory.

In 1953, Milton Friedman, and in 1965, Eugene Fama, argued that financial markets are efficient because they naturally choose rational strategies. According to this theory, the market is self-correcting and considers all publicly available information about a security into its price. This means that even if a group or an individual investor has access to privileged information, they can't use it to consistently outperform the market, as the market will quickly incorporate that information in the security price. The market prices securities based on their intrinsic value, making it challenging for investors to use insider information or other non-public data to capture the market. This theory remains a fundamental concept in modern finance.

Humans are social beings and tend to make systematic errors. Therefore, the idea of rational markets can be viewed with suspicion. For instance, stock prices do not converge to their rational values even in the long term, which is a strong indication against the existence of a rational market (Kogan et al., 2006). This happens because a rational market needs rational investors, but it is not always the case. Evolutionary theory explains why markets can't converge to rational values, even in the long run, due to the existence of irrational investors. It questions the conclusions of Friedman and Fama.

In 1989, De Long and his colleagues conducted a study to assess the impact of noise trading on individuals' well-being and its prevalence in the market. They employed a model to consider investors with short-term horizons. The study's findings were conclusive: The risk created by noise trading could reduce the capital stock and consumption of the entire economy. Therefore, rational investors may have to bear some of this cost. Since, accordingly this research, we know that noise trader is an individual who trades based on incomplete or inaccurate data and often trades irrationally, the existence of rational markets is questionable. In our study, we will explain the behavior of these investors through the signaling mechanism in replicator dynamics.

Another study analyzing investment markets, the discounted cash flow approach, also known as net present value, considers the stock price as the present value of future cash flows. To assess the investment potential, this approach compares the present value of the stock's future return with the return of a different investment instrument (Williams, 1997). One important drawback of analysis is that it relies on assumptions about future events, which may not be accurate. The choice of discount rate is subjective, and an investment's projected cost and returns are merely estimates. Furthermore, it is driven by quantitative inputs and does not consider nonfinancial metrics. Our study can address this shortcoming and model the impact of non-financial metrics on investment decisions.

Important studies that accept the basic principles of evolutionary theory have reached results that can eliminate the deficiencies mentioned above. Dong et al. (2020) developed an evolutionary game model to study stock prices. The model considers factors such as potential revenue or loss, the probability of gain or loss, and the cost of corresponding behavior to analyze the impact of investors' decisions on stock investment. The study found that reducing speculation, increasing access to information, and improving market information disclosure mechanisms can alleviate price synchronicity (volatility) in the stock market. Therefore, the transparency and accessibility of information in markets are more crucial than the rational character of economic agents. This means that having access to accurate information is more important than how individuals behave in the market.

Shleifer's (2000) study suggested that random choice strategies may generate higher profits than rational ones. However, whether randomly selected investment strategies can maintain their stability over time remains uncertain. Similarly, another study that shows fully rational behavior is not essential for a rational investment market is conducted by Brock et al. (2005). Their research indicated that an evolutionary market system may become unstable if investors are overly sensitive to slight differential returns between strategies. These results show that Friedman and Fama's findings are not always valid. Nevertheless, Hens and Hoppe's (2005) research revealed that financial and insurance markets can maintain stability if a dominating strategy increases its market share against another.

In a study conducted by Evstigneev et al. in 2002, the researchers delved into the long-term dynamics of the market selection process within an incomplete asset market with endogenous prices. Through their analysis, they were able to discern a distinct financial trading strategy that emerged as the sole survivor in the market dynamics. It was found that investors who adhered to this particular strategy gradually accumulated total market wealth over time. This significant outcome extended the previous research conducted by Blume and Easley in 1992, as it applied to both complete and incomplete asset markets. In another study, they demonstrated the importance of evaluating stocks based on expected relative dividends to maintain an evolutionary stable stock market. The introduction of any other market can potentially lead to an invasion by a portfolio rule that can increase its market share at the expense of the incumbent. Introducing this portfolio rule can result in a shift in asset valuation over time (Evstigneev et al., 2006).

Blume and Easley's study (2006) analyzed the properties of Pareto optimal consumption allocations in a stochastic general equilibrium model, investigating the market selection hypothesis. The fate of each consumer in any Pareto-optimal allocation is determined solely by their discount factors and beliefs. In complete markets, Pareto optimal equilibrium allocations are achieved. However, in incomplete markets, the long-term survival of the economy may depend on the payoff functions, and the market selection hypothesis may not be applicable. This finding implies that it's uncertain whether the investment market will eventually be controlled by agents whose beliefs are most aligned with reality. If we agree that investors with rational expectations have the most accurate expectations, it underscores that the dominance of rational investors in the market in the long term is not a certitude.

Andrei and Hasler (2015) concluded that investors' attention to news and learning uncertainty are significant determinants of asset prices. These factors lead to an increase in stock return variance and risk premia, which increase quadratically. The study highlights the importance of attention and uncertainty in influencing asset prices, as shown theoretically and empirically. Due to lack of attention and uncertainty about the future, economic agents may make irrational choices, causing markets to move away from efficient equilibrium. An improved version of the information mechanism in this study is included in our study.

In Cheng et al. (2011), the authors explored how macroprudential rules and policies, designed to safeguard financial stability, can inadvertently heighten the risk within the financial system and detrimentally impact investment strategies. Conversely, Rubio and Gallego (2016) demonstrated that similar policies have the potential to stabilize the financial system and diminish risk associated with investment strategies. Additionally, Boz and Mendoza (2014) highlighted that certain financial regulations may create a false sense of security among investors regarding assets like stocks, leading to overconfidence in the market and ultimately causing investment strategies to fail.

In their 2020 research, Craven and Graham introduced a matrix-based evolutionary algorithm tailored to approximate solutions for the simultaneous multiple portfolio optimization problem with cardinality constraints. Their study encompassed a variety of indices, ranging from 31 to 493 assets. The authors scrutinized the algorithm's performance across different cardinality constraint values and concluded that achieving a close approximation of the unconstrained efficient frontier is possible with a small subset of fewer than n assets for a given dataset. Employing this technique has the potential to significantly reduce computation times. Furthermore, by pooling results from multiple independent realizations and utilizing a sifting algorithm, Craven and Graham were able to obtain notably improved estimates of the efficient frontiers for the cardinality-constrained problem.

In their 2023 study, Song et al. introduced the ECMADE algorithm, a co-evolutionary multi-swarm adaptive differential evolution approach designed to address premature convergence and search stagnation. The algorithm employs a parallel distributed framework to divide the population into exploration, development, and auxiliary subpopulations. Additionally, an adaptive information exchange mechanism allows subpopulations to avoid local optima. A multi-operator parallel search strategy and an adaptive adjustment mechanism of control parameters are also utilized to maintain population diversity and optimize for different problems. The adaptive adjustment mechanism leverages a recent elite parameter archive and weight distribution to effectively generate control parameters tailored to the current evolutionary stage. The empirical results indicate that ECMADE demonstrates superior accuracy and efficiency in solving the test functions compared to two classical algorithms. Application of ECMADE also significantly enhances the portfolio's resilience to extreme losses, providing further evidence of its effectiveness and feasibility.

Hens and Naebi (2022) demonstrated how the standard two-period Capital Asset Pricing Model (CAPM), with exogenous wealth and exogenous returns, can be extended over time. The paper presented theoretical and empirical findings on behavioral differences in the CAPM with evolutionary dynamics. The market selection process led to a fundamental-based beta, to which the standard beta tends to converge asymptotically. The model's results were validated using data from the Dow Jones Industrial Average Index.

Evstigneev et al. (2023) proposed a model in which the payoffs are endogenous, meaning they are determined by the proportion of total market wealth allocated to the specific asset.

Ari and Alagoz (2023) introduced a genetic programming-based forecasting model generation algorithm designed to predict daily stock market index trends while optimizing hyperparameters. They used a differential evolution (DE) algorithm to optimize hyperparameters of the genetic programming orthogonal least square (GpOls) algorithm, allowing for the creation of an optimal forecast model from the modeling dataset. By evolving GpOls agents within the hyperparameter search space, they could adapt the GpOls algorithm specifically to the modeling dataset. This evolutionary hyperparameter optimization technique has the potential to improve the data-driven modeling performance of the GpOls algorithm and enable the optimal autotuning of user-defined parameters.

Gulmez (2023) conducted an important study and proposed a new deep network, named LSTM-ARO. The primary goal of this proposed model is to forecast stock market prices, with DJIA index stock price data from 2018.01.01 to 2022.12.31 being utilized. The dataset comprises 30 different stock prices over a five-year period. The data was transformed into a new format with 20 previous days used to predict the next day's price. Following this transformation, the data was divided into 80% for training and 20% for testing. A unique LSTM network was constructed with specific parameters linked to ARO algorithm variables. The ARO algorithm was utilized to identify the best architecture for optimal results. To assess the efficacy of the proposed model, it was compared to LSTM1D, LSTM2D, LSTM3D, ANN, and LSTM-GA networks. The results unambiguously demonstrated that the LSTM-ARO model outperformed the other models.

Their study involved the use of a DE-based hyper-GpOls (DEHypGpOls) algorithm to generate forecaster models for a-day-ahead trend prediction for the Istanbul Stock Exchange 100 and the Borsa Istanbul 100 indexes. By analyzing daily trend data from these indexes and seven other international stock markets, they developed a-day-ahead trend forecaster models. Experimental studies on four different time slots of stock market index datasets demonstrated that the forecast models of the DEHypGpOls algorithm achieved an average accuracy of 57.87% in buy-sell recommendations. Market investment simulations based on these datasets indicated that daily investments in the Istanbul Stock Exchange 100 and Borsa Istanbul 100 indexes, according to the buy or sell signals of the forecast model of DEHypGpOls, could provide 4.8% more average income compared to the average income of a long-term investment strategy.

Di Tollo et al. (2024) conducted research on portfolio optimization problems, a widely discussed topic in the FinTech industry. Their study focused on the uniperiodal portfolio selection problem, which involves finding the ideal composition of a portfolio over a specific time frame. The objective was to minimize turnover and transaction costs associated with portfolio rebalancing, achieved through constraints on the number of assets and the allocation of wealth in specific asset classes. This significant paper introduced a new mathematical approach in the FinTech domain, presenting an adaptive evolutionary algorithm for portfolio optimization that aligns with the latest regulations.

In an intriguing and innovative study, Guarino et al. (2024) introduced EvoFolio, a novel portfolio optimization method. This method utilizes multi-objective evolutionary algorithms, particularly the Nondominated Sorting Genetic Algorithm-II (NSGA-II), to simultaneously maximize yield and minimize risk in optimal portfolio selection. The EvoFolio system was tested on stock datasets over a three-year period with variations in NSGA-II operator configurations. Notably, EvoFolio is an interactive genetic algorithm, allowing users to input their insights and preferences for certain stocks to tailor the algorithm accordingly. The results demonstrated that EvoFolio significantly reduces portfolio risk while achieving exceptional returns.

The studies conducted based on evolutionary theory, as described in the present section, demonstrate the existence of decision-making that is not rational and markets that are not efficient. Our study employs non-return and conformist dimensions to elucidate irrational human behavior, thus contributing to the existing literature by revealing that even in the long run, unsuccessful strategies may dominate the market.

The study we conducted has improved the existing models by including non-return effects and analyzing the impact of important human emotions such as altruism, selfishness, and reciprocity. By doing so, our model provides a more comprehensive understanding of how these emotions affect human behavior and decision-making processes. We are especially proud of our model's ability to account for non-return effects. Additionally, our analysis of human emotions is relevant and illuminating as it clarifies the role played by these emotions in shaping human behavior.

3. Model

In this section, investment strategies and utility functions will be modeled with evolutionary game theory tools. First, the existence of a risk-neutral investor will be assumed, and then the analysis will be repeated for a risk-averse investor.

We'll use essential components which are explained in detail here.

Time All the models that we are discussing are based on discrete-time framework. Time is denoted with $t = 0,1,2, \dots$ and $t = 0$ being the initial time period.

States Each asset pays dividends at certain periods, and these dividends are modeled with a random variable, d_t, $t = 0,1,2, \dots$ with a finite state space $D. d_t = 1, \dots, D$ describes the state of the world at time t. There is an infinite past, we mean that states of world d_t also defined for $t = -1, -2 \dots$The state is generally a time-homogenous Markov process with transition probabilities $\pi\big(d|\hat{d}\big) = P\{d_{t+1} = d|d_t = \hat{d}\} \geq 0$. The state d_t can be viewed as a representation of various complex variables that characterize investors' information. At each point in time t, $d^t = (\dots, d_{t-1}, d_t)$ means the history of events.

Assets There are $N \geq 1$ assets and each in unit supply. Asset n's payoff at time t denoted as $(N_n(d_t))$. Assets are considered short-lived if they only pay out once and become worthless. They are considered long-lived if they produce a payout stream that has a strictly positive probability of being positive in each period of time.

Investors There are A ≥ 1 investors, who can trade in the N assets. Investor a's wealth at time t is denoted by w_t^a and the initial endowment is $w_0^a \geq 0$. In the realm of investment, an individual is typically faced with deciding whether to allocate her resources towards savings or consumption. In this process, investors must evaluate the amount they have marked for stock market savings.

Strategies Investor a's investment strategy is denoted by

$\varphi_t^a = \varphi_{1,t}^a, \ldots, \varphi_{N,t}^a = \varphi_t^a(d^t) \quad t \geq 0$ (1) with

$\varphi_{n,t}^a > 0$ and $\sum_{n=1}^{N} \varphi_{n,t}^a = 1$ (2)

Here $\varphi_{n,t}^a$ is the budget share of investor a allocated for asset n investment. The non-negativity of budget shares represents a theoretical concept that implies the absence of short selling. This concept constitutes a fundamental principle in finance, which aims to ensure the integrity and stability of financial markets. The prohibition of short selling is based on the idea that it can have negative consequences on market participants, leading to market volatility and potentially causing harm to investors and the broader financial system.

The following assumes that the pool of strategies only contains distinct strategies. Evolutionary theory focuses on a group of individuals pursuing a particular type of behavior rather than on individual behavior. In a finance context, this identification is simple. All individuals who follow the same investment strategy are considered as owners of an investment fund pursuing that strategy. Each individual's wealth equals a fraction (the share of their initial contribution) of the fund's current wealth.

Budget and prices Investor a has a budget denoted by γ_t^a. We can interpret γ_t^a as the budget of investor a that allocated for purchase assets at time t. If she has a saving rate $0 \leq \psi^a \leq 1$, her budget for investment will be $\gamma_t^a = \psi^a s_t^a$. Likewise, consumption will be $(1-\psi^a)s_t^a$. s_t^a refers to the endowment as wealth. Budget depends on consumption and investment (saving).

Assets prices denoted as $f_{n,t}$. This term determined by market clearing condition at any point in time t. Suppose that vector $\gamma_t = (\gamma_t^1, \gamma_t^2, \ldots, \gamma_t^A)$ is budget of the investors who is available for trading and $\varphi_{n,t}$ is every investors portfolio weight. Then we can write the price of asset n as

$$f_{n,t} = [\varphi_{n,t}, \gamma_t] = \sum_{a=1}^{A} \varphi_{n,t}^a \gamma_t^a \quad (3)$$

where

$$\varphi_{n,t} = (\varphi_{n,t}^1, \varphi_{n,t}^2, \ldots, \varphi_{n,t}^A) \quad (4)$$

Note that $\varphi_{n,t}$ and γ_t are given.

Constant Saving Rate If we assume an expected constant saving rate ψ, we can determine the price of asset n at a specific time t using the formula $f_{n,t} = \psi(\varphi_{n,t}, s_t)$. This formula helps us understand the relationship between expected saving rate and asset price at a given time.

3.1 Investment Strategy, Evolution of The Wealth and Signal Mechanism

Now we can define invertor i's portfolio at the beginning of period t as below.

$$\mathrm{P}_{n,t}^a = \varphi_{n,t}^a \gamma_t^a \Big/ [\varphi_{n,t}, \gamma_t] \quad (5)$$

Given that long-term asset supply is normalized, $\mathrm{P}_{n,t}^a$ also indicates the proportional size that investment rule $\varphi_{n,t}^a(d_t)$ purchased within the total quantity of asset n supplied.

The condition of equilibrium in this stock market is known as the equilibrium condition and is expressed as follows:

$$\sum_{n=1}^{N} \mathrm{P}_{n,t}^a \, \psi(\varphi_{n,t}, s_t) = \psi^a s_t^a + (1-\psi^a)s_t^a \quad (6)$$

The investor's primary objective is to increase her wealth by adopting an unchanged strategy or implementing inter-period strategy changes. Hence, it is crucial to develop a model that can simulate the progression of wealth over time. This equality can be written as

$$s_{t+1}^a = \sum_{n=1}^{N} (G_{n,t+1}(d_{t+1}) + f_{n,t+1}) \left(\varphi_{n,t}^a \psi^a s_t^a \Big/ \sum_{a=1}^{A} \varphi_{n,t}^a \gamma_t^a \right) \quad (7)$$

s_{t+1}^{a} can be interpreted as the wealth of investor a at the period $t+1$. ($G_{n,t+1}(d_{t+1})$ is the dividend payment of investor a at the beginning of the period $t+1$.

Let us define a new equation, which is the total dividend of investor a

$$TD_{n,t+1}^{a} = G_{n,t+1}(d_{t+1})\left(\varphi_{n,t}^{a}\psi^{a}s_{t}^{a} \Big/ \sum_{a=1}^{A} \varphi_{n,t}^{a}\gamma_{t}^{a} \right) \quad (8)$$

Now we can rewrite the evolution of wealth

$$s_{t+1}^{a} = TD_{n,t+1}^{a} + \sum_{n=1}^{N} \mathrm{P}_{n,t}^{a}\mathrm{P}_{n,t+1}^{\prime}\, s_{t+1}^{\prime} + (1-\psi^{a}-c_{t})s_{t}^{a} \quad (9)$$

When making investment decisions, it is essential to consider the wealth and investment strategies of other investors. Their portfolio preferences mirror their investment inclinations, and scrutinizing these variables can assist us in making informed choices and gaining a better understanding of the market. c_t is the consumption rate of investor a at period t. In the equation provided (9), the variable $s_{t+1}^{\prime}$ denotes the wealth of other investors. The notation $\mathrm{P}_{n,t+1}^{\prime}$ divulges details regarding the investment portfolios of other players who have invested in similar stocks to player a. Consequently, the expression $\mathrm{P}_{n,t+1}^{\prime}s_{t+1}^{\prime}$ represents the portfolio preferences of other investors based on their wealth and investment strategies.

In summary, the financial performance of an investor who favors investment rule $\varphi_{t}^{a}(d^{t})$ is influenced by several crucial factors. These factors include the dividends received at the end of period t (which marks the start of period $t+1$), the investment approaches and financial standing of other investors, as well as the size of portfolios determined by other investors based on their investment preferences, financial status and savings $(1-\psi^{a}-c_{t})s_{t}^{a}$. Considering these elements is critical when devising an investment strategy that aligns with the investor's financial goals and objectives.

Investors use various sources of information to forecast future movements. These sources may include historical data, financial statements, market analysis, news reports, and other relevant data. However, the future is unpredictable, and investors must take risks when making investment decisions based on their predictions. They must also continually evaluate and adjust their strategies in response to new information and changing market conditions.

The investor observes the current dividend $G_{n,t+1}(d_{t+1})$ and an informative signal $\mho$ with dynamics

$$\mho_{t} = \Psi_{t}\Xi_{t}\rho^{n} + (1-\Psi_{t})\rho^{\mho_{t-1}} \quad (10)$$

Informed investors remain up to date with the latest market trends using various channels. By doing so, they can adapt their investment strategy for the future. Unfortunately, comprehensive information is not always easily obtainable, leading to uncertainty. Those who lack current information may have to rely on outdated data from the past, potentially leading to negative impacts on their investments. It is, therefore, imperative for investors to stay informed with the latest market trends to make informed decisions when it comes to their investments. Process Ψ_t refers to the precision of the news updates an investor view. A 0 value indicates the absence of news updates, while a 1 value signifies that the updates are impeccably precise. The investor has authority over this accuracy, commonly known as the "attention to news" (Ξ_t) parameter in the sources. The present study adopts a uniform interpretation and endeavors to establish that the accuracy of investment decisions is within the investor's control. We posit that the investor can adjust attention levels based on observing changes in the economy (state of the economy). This adjustment occurs in direct response to the observable state of the economy and is hence subject to changes as the economy fluctuates.

ρ^n can be defined as

$$\rho^n = \beta\delta^p + (1-\beta)\delta^o + \alpha[\delta^p - \delta^o] + \varepsilon \quad (11)$$

Here there is two kind of information progress, private (δ^p) and official (δ^o). The term "private information" pertains to the knowledge that an individual acquires through financial expertise, calculation skills, and professional network. This information is typically sourced from the social environment and may also include asymmetric information. For instance, an investor with inside knowledge regarding an upcoming central bank interest rate decision may enjoy an advantage over others by taking a position prior to the official announcement. The coefficient β represents the weight that is assigned to the accuracy of private information. In case the coefficient equals zero, the investor will rely solely on official information and explanations.

Official information refers to data or knowledge that has been acquired directly from authorized or legitimate sources, such as government agencies, regulatory bodies, or corporations. This type of information can take various forms, including reports, bulletins, announcements, press releases, board meetings, political statements, and other official statements. It is generally considered to be reliable and trustworthy because it is generated by recognized institutions with a reputation to uphold. One way to measure the credibility of official information is by assessing the $1-\beta$ coefficient, which is a statistical measure of the level of confidence that can be placed in the data provided.

In some cases, there may be discrepancies between private and official information. For example, official statements may indicate an intention to raise interest rates, while the market may have a different expectation. In such cases, investors need to decide which information they trust more, and their behavior is determined by this decision. The expression $\alpha[\delta^p - \delta^o]$ term captures this relationship, where both types of information conflict, and an investor decides on a stance based on the sign of the α coefficient. In this case, it signifies the market's expectation and the official statement's outlook. Therefore, it is imperative for investors to weigh the reliability of both sources of information and make informed decisions based on their analysis.

Finally, external shocks (ε), also known as exogenous shocks, can have significant effects on markets and behavioral patterns, and their impact can be challenging to predict. Examples of external shocks include natural disasters such as earthquakes, hurricanes, and floods, as well as political events such as wars or policy changes. These events can disrupt supply chains, cause price fluctuations, and affect consumer behavior, leading to significant economic consequences.

Attention Ξ_t can be written from a different perspective as

$$\Xi_t = \overline{\Xi_t} \Big/ \overline{\Xi_t} + (1-\overline{\Xi_t})\lambda\Lambda \quad (12)$$

Ξ_t exhibits fluctuations around a stationary mean $\overline{\Xi_t}$ and takes values within the interval of [0,1]. In the long run, average attention remains constant and is determined by a combination of herd behavior and personal character. Although attention may fluctuate in the short term, it ultimately converges to this average. However, analyzing attention in the short term is important as short-term investment strategies can significantly impact long-term outcomes.

The variables λ and Λ in the denominator of an equation are used to represent two common human behaviors that can act as impediments to acquiring new information. Specifically, λ represents doubt or uncertainty, which can arise when individuals have difficulty determining the reliability or accuracy of new information. Λ, on the other hand, represents a lack of attention or interest in new information, which can be due to a variety of factors such as boredom, apathy, or simply being preoccupied with other matters. Additionally, inertia to new information can also play a role, which refers to the tendency to stick with familiar or established beliefs or ideas rather than considering new ones. These two behaviors, doubt and lack of attention or inertia, can significantly reduce individuals' interest and motivation to seek out and engage with new information. Both take values within the interval of [0,1].

It is important to understand that the attention coefficient and the weight assigned to private and official information are two distinct concepts. The attention coefficient measures how sensitive an individual is to new information, while the weight assigned to private and official information reflects the importance given to such information at the current level of sensitivity. Although these concepts are different, they are related. People who are more receptive to new ideas are likely to be more open-minded and sensitive to different experiences, while those who are resistant to new information may not give much importance to crucial private and official information. However, the extent to which this relationship is statistically significant requires further research.

Economic fluctuations can occur due to internal and external factors. Internal factors include changes in policies, management decisions, or market demand. External factors include political instability, natural disasters, or financial crises. These factors can impact economic outcomes positively or negatively. Understanding them is crucial in predicting and managing economic fluctuations.

Economic agents often cannot make fully informed decisions due to certain limitations. One such limitation is the lack of access to all the necessary information required for decision-making. Additionally, biases may affect the decision-making process and lead to irrational behavior. In addition, economic agents are often myopic, meaning they focus on short-term gains rather than long-term benefits

When we consider the possibility of economic agents having adaptive expectations, we can conclude that obtaining accurate information will not happen instantaneously. Rather, it will take some time to obtain precise data. This delay, however, will lead to economic losses. The continuous adjustment of expectations, coupled with the inevitable time lag, creates a situation where market participants are unable to reach a state of equilibrium.

Given humans' inherently social nature, we must expand utility functions beyond the singular pursuit of returns. To optimize agents' utility, a broader range of factors must be considered. These may include social, environmental, and other non-financial considerations that can significantly impact overall utility.

The utility function of player x (the player who determines strategy $\varphi_{n,t}^{a}$) will be

$$U_a = (1-\vartheta)\left[TD_{n,t+1}^{a} + \sum_{n=1}^{N} \mathrm{P}_{n,t}^{a}\mathrm{P}_{n,t+1}' s_{t+1}' + (1-\psi^{a}-c_t)s_t^{a}\right] + \vartheta[(\theta-\emptyset) + \sum_{b} v_{ab}U'] \quad (13)$$

When it comes to evaluating an investor's intangible benefit, there is a crucial element to consider, which is the proportion (v_{ab}) of the utilities of other investors (U') that are taken into account and represented as $\sum_b v_{ab}U'$.This factor plays a significant role in determining the overall utility can be derived from and it's essential to carefully analyze and understand its impact.

The coefficients for $\theta \in [0,1]$ and $\emptyset \in [0,1]$ in the equation above play a crucial role. The former coefficient represents the fraction of individuals who follow the same investment strategy in all conditions, even if it may lead to potential loss. This fraction is a powerful indicator of the level of conformism among individuals. Conformism ($\vartheta \in [0,1]$) is a complex topic debated by scholars and philosophers for many years. At its core, conformism refers to respecting and adapting to the opinions and values of society or one's close circle, without opposing them. It can be seen as both positive and negative. On the one hand, conforming to societal norms can help create a sense of unity and belonging, which can benefit individuals and communities. On the other hand, blindly following the opinions and values of others can lead to a lack of critical thinking and independent thought.

The concept of conformism is complex, and its value is subjective. It's crucial for individuals to evaluate their beliefs and values critically and be open to learning from others instead of blindly conforming to societal norms or the opinions of those around them. For instance, an individual may continue with an unsuccessful strategy, even in the face of losses, under the influence of a trusted person, such as a friend, family member, teacher, political leader, or ideology. Despite financial losses, such an individual derives spiritual pleasure from adapting and persists with the same strategy.

Likewise, the symbol $\emptyset$ denotes the fraction stick their strategy under all circumstances. These individuals are also influenced by the conformist mindset mentioned earlier. Given that the parameter ϑ represents the weight of non-reversible consequences on the utility function, the prevalence of individuals who share the same mindset as $\emptyset$ within society will increase the player's utility, regardless of the situation.

3.2 Effects of Altruism and Reciprocity

Player a's propensity to consider the benefits of other investors can be expressed in a manner reminiscent of Bowles' (2006) research:

$$v_{ab} = \frac{(ua_a + \beth_a ca_a)}{1 + \beth_a} \quad (14)$$

The degree of unconditional altruism is represented by the parameter $ua_a \in [-1,1]$ Altruism is a principle that involves making sacrifices for the greater good of other individuals or society without seeking any benefit or external reward, and oftentimes at one's own expense. This attitude is acquired and can be defined as "prioritizing the benefit of others at the same level as one's own benefit," "seeking to be of service to others without consideration for personal gain, whether material or moral," and "taking actions that are anti-selfish."

Conditional altruism, denoted by $ca_a, \in [-1,1]$ is a social behavior that is driven by the feeling of reciprocity. The reciprocity effect is a well-established tenet of social exchange theory that posits the notion that people tend to reciprocate the treatment they receive from others. In this context, reciprocity can be described as an exchange of actions of roughly equivalent value in which the behavior of each party is contingent on the past actions of the other. In such a system, good actions are reciprocated with favorable treatment, while bad actions are met with unfavorable responses. Therefore, players pay attention to the opinions of other players with whom they interact and regulate their behavior according to this understanding.

The parameter $\beth_a \geq 0$ in the expression denotes the extent to which an individual values the opinions of others, with a positive value indicating such importance. In an utopian scenario, the parameter is zero, indicating indifference towards others' opinions. Conversely, a value of one denotes a significant influence of others' opinions on the individual. In such a case, the individual may react positively to the misfortune or failure of someone who does not hold them in high regard.

The coefficients ua_a and ca_a indicate either altruism or selfishness, with positive values representing the former and negative values reflecting the latter. For players with negative coefficients, the success of others will not bring any benefit, as they are driven by self-interest. According to equation 7

- If $ua_a = 0$ and $\beth_a > 0$ player values reciprocity in behavior. She adjusts her behavior based on the behavior of others.
- In situations where $ua_a \neq 0$ and $\beth_a = 0$, the actions of player may be indicative of unconditional altruism, based on the sign of ua_a (if $ua_a > 0$). As a result, there may be instances where unconditional hatred may manifest itself.
- The denominator of the equation is directly proportional to $\beth_a$. Given that the maximum value of ua_a is 1, the inequality $v_{ab} \leq 1$ can be deduced. As a result, player a cannot value other players' payoffs (utilities) more than her own payoff (utility).
- When the expression is differentiated with respect to $\beth_a$, the resulting derivative varies depending on whether $(ua_a - ca_a)$ is positive or negative. If $(ua_a - ca_a)$ is positive, then the derivative will be negative, and if it is negative, the derivative will be positive. Therefore, moral and subjective values come to the fore in situations where reciprocity is involved. In these situations, a's perception of the other player's kindness or skill will affect how much weight she places on the other player's payoff in her own utility function. If she perceives the other player to be kinder or more skilled than herself, then the other player's payoff will have a greater impact on her own utility function.

- If ua_a is equal to ca_a, the value of v_{ab} can be determined via the expression ua_a. In such a scenario, the degree of sensitivity to the returns of other investors is established based on player a's unconditional opinion.

It is imperative to recognize that as the parameter ϑ decreases, factors contingent on yield become increasingly critical. This also implies that the utility function becomes more return focused. Accordingly, a return-oriented individual tends to concentrate solely on returns, often neglecting the behavioral and emotional aspects of her decisions.

3.3 Replicator Dynamics

In evolutionary game theory, the replicator dynamic is a concept used to study the evolution of strategies in a population of players. It models the likelihood that a particular strategy will be copied by other players based on its relative success in the game. Essentially, the more beneficial a strategy is in terms of payoff or utility, the higher the probability that it will be adopted by other players in the population. This dynamic can lead to the emergence of dominant strategies or equilibrium states in the long run, depending on the specific game and parameters involved.

It can be written as

$$\Delta a = \beta(1-a)a\iota(U_{at} - U_{bt}) + (1-\beta)(1-a-b')\mho_t\iota(EU_{at+1} - EU_{bt+1}) \quad (15)$$

In the investment market, two prominent strategies exist: strategy A and strategy B. If a player opts for strategy A, she'll utilize the investment rule $\varphi^{a}_{n,t}(d_t)$ defined in the prior section. Within the community, a certain proportion (β) interacts with each other. In each period (t), there is a chance of $(1-a)a$ those two players, who have adopted different strategies, will cross paths. If the player who chose strategy A has a higher benefit level than the player with strategy B, the latter will swap their strategy and select strategy A in the following period $(t+1)$. The sensitivity to the benefit level difference is denoted by ι.

Occasionally, there may be players who are not matched with a partner who favors strategy A. Nonetheless, they may comprehend that strategy A is likely to yield better results in the subsequent period due to the pre-established signaling mechanism. Consequently, these players may decide to adopt strategy A in the following period, based on the efficacy of the signal mechanism. b' denotes the proportion of individuals who prefer adopting strategy B while not coinciding with those who apply the opposing strategy.

The pace of evolution is governed by the mathematical expression $(1-a)a$, where a homogenous pool can hinder progress while a diverse one can expedite it. It is evident that the formula attains its pinnacle value when a is equal to 1/2. Hence, an equally distributed population will optimize the a transformation rate, holding all other factors constant. The residual component of the replicator dynamics can be mathematically expressed as $\beta\iota(U_{at} - U_{bt})$. The rate of update and utility functions are contingent on the level of a within the population.

When a minute percentage of the population is involved in an interaction, the disparity in the level of benefit and its corresponding sensitivity tends to decrease, thereby reducing the exertion of replication pressure. This phenomenon can be attributed to the involvement of a smaller number of individuals in an interaction leads to a more controlled and moderated exchange of information, resulting in a more optimal distribution of benefits and a reduced sensitivity to the replication pressure.

The condition required to guarantee stationarity can be expressed as

$$\frac{\partial \Delta a}{\partial a} < 0 \quad (16)$$

$$\frac{\partial \Delta a}{\partial a} = (U_{at} - U_{bt})(\beta\iota - 2a\beta\iota) - (1-b')(1-\beta)\mho_t\iota(EU_{at+1} - EU_{bt+1}) \quad (17)$$

As can be seen from equation 17, there are some equilibriums:

- $\iota = 0$
- $a = \frac{1}{2}, 0,1$
- $U_{at} = U_{bt}, EU_{at+1} = EU_{bt+1}$
- $U_{at} = U_{bt}, \mho_t = 0$
- $\beta = 0, \mho_t = 0$

It is important to recognize that ignoring differences in utility levels can stop replicator dynamic. Additionally, progress can be hindered if society is divided, and people choose different strategies with the same frequency. It is crucial to note that the model can only be considered in equilibrium when the entire society adopts the same approach.

The third equilibrium point is characterized by both strategies yielding the same benefit. This equilibrium is upheld when there is no justification for switching between them. However, if new information arises favoring one strategy over the other in the next period, the equilibrium of equal benefits will no longer hold. Hence, to maintain the stability, two conditions should be satisfied. Firstly, both strategies should bring the same benefits in the current period, and secondly, there should be no expected information that could affect the decision in the following period. Equity can be assessed by inspecting players' returns or behavior when evaluating fairness. If players only focus on returns, true equality is only achieved when the returns are identical.

In situations where players are inclined to conform or display altruistic behavior, certain individuals may continue to follow their strategy regardless of whether it results in a gain or loss, due to the conformist effect. If the signaling mechanism proves ineffective and the benefits in period t are equal, it can be concluded that an equilibrium state has been attained.

In an alternate equilibrium scenario, players refrain from interacting, precluding any modification in the existing strategies. This situation indicates a lack of influence from external factors that could otherwise change the players' strategies.

The sign of equation 17 can be examined for stationarity point. Accordingly, the condition below must be met for stationarity

$$(U_{at} - U_{bt})(\beta\iota - 2a\beta\iota) < (1 - b')(1 - \beta)\mho_t\iota(EU_{at+1} - EU_{bt+1}) \quad (18)$$

The signaling mechanism acts as an indicator of whether small deviations will have an impact in the future. Therefore, minor fluctuations, such as a temporary increase in demand for a less effective strategy (like strategy B), will eventually disappear in the next period.

The equilibria at $a = 1$ and $a = 0$, where the entire society adopts a single strategy, are evolutionarily stable. However, the equilibrium at $a = 1/2$ is not stationary, and even a minor deviation from the equilibrium point may result in the formation of basins of attraction. This implies that the $a = 1/2$ equilibrium point is susceptible to perturbations and may not be considered evolutionarily stable. Note that the establishment of a equilibrium of $a = 1/2$ through a conformist process may result in stability, as a natural consequence of human nature.

$\beta = 0, \mho_t = 0$ equilibrium is not stationary since in each timeframe, a marginal proportion of individuals who engage or receive information through the signal mechanism will prompt alterations in strategy. Thereafter, a trajectory will ensue towards a novel equilibrium point, in accordance with the direction and intensity of the signal, without retrogressing to the initial point. Similary, $U_{at} = U_{bt}, \mho_t = 0$, $U_{at} = U_{bt}, EU_{at+1} = EU_{bt+1}$ and $\iota = 0$ also are not stationary.

With a little arrangement two important stationary conditions can be achieved

- $U_{at} > U_{bt}, EU_{at+1} > EU_{bt+1}, a > 1/2$
- $U_{at} < U_{bt}, EU_{at+1} < EU_{bt+1}, a < 1/2$

Consider a hypothetical situation where a significant proportion of individuals opt for a particular strategy, denoted as A, within a specific time frame (t). If the advantages of adopting strategy A during this time frame outweigh those of alternative options, and there exists an expectation that this trend will persist in the succeeding period through signaling, then all individuals will inevitably adopt strategy A. This will result in an evolutionary stable equilibrium, where no individual can gain an advantage by selecting a different strategy.

In situations where a significant number of individuals opt for strategy A and it offers a higher benefit level during that period, the attainment of stationarity may be challenging if strategy B is expected to yield greater benefits in the subsequent period because of the signaling mechanism. To determine the feasibility of attaining stationarity, one may compare the benefit difference in favor of strategy A in the current period to the expected benefit difference in favor of strategy B in the following period. If the benefit difference in favor of strategy A exceeds the anticipated benefit difference in favor of strategy B, then strategy A will persist as an evolutionary stable equilibrium.

In situations where conformity and behavioral patterns become the primary sources of influence, individuals tend to adopt similar behavior patterns, leading to a loss of individuality and uniqueness. In such scenario, for $U_{at} > U_{bt}$ it is required that

$$(\theta - \emptyset) > \sum (v_{ba}U' - v_{ab}U') \quad (19)$$

The left-hand side of the inequality denotes the potency of conformism, whereas the right-hand side represents the behavioral aspect. $v_{ba}U'$ stands for the responsiveness of players who have implemented strategy B to the utility level of other players, while $v_{ab}U'$ denotes the same impact for players who have employed strategy A. For a strategy to be deemed truly effective, it must yield a considerable variance in adoption rates between strategies A and B, regardless of the situation. This difference should be notably greater than the difference in sensitivity levels between players who have implemented opposing strategies that are beneficial to others. In essence, the efficacy of conformity can be gauged by the achievement of $U_{at} > U_{bt}$, which can be facilitated by the overwhelming prevalence of players who consistently opt for strategy A, regardless of circumstances.

In situations where behavioral patterns and comfort levels are key determinants of outcomes, it is essential to recognize the role of comfort zones in achieving benefits. If those who select option B demonstrate greater altruism than those who choose strategy A, then even with a higher level of cooperation coefficient (theta) than the threshold, the attainment of a higher utility (U_{at}) than the opponent's utility (U_{bt}) may become unfeasible. This underscores the significance of comfort zones and their influence on the level of benefits in such scenarios.

In the case where all benefit depends on the return, the necessary condition for $U_{at} > U_{bt}$ is basicly

$$\left[TD^{a}_{n,t+1} + \sum_{n=1}^{N} \mathrm{P}^{a}_{n,t}\mathrm{P}'_{n,t+1}\, s'_{t+1} + (1 - \psi^{a} - c_{at})s^{a}_{t}\right] > \left[TD^{b}_{n,t+1} + \sum_{n=1}^{N} \mathrm{P}^{b}_{n,t}\mathrm{P}'_{n,t+1}\, s'_{t+1} + \left(1 - \psi^{b} - c_{bt}\right)s^{b}_{t}\right] \quad (20)$$

The attainment of this condition is contingent upon the ascendancy of strategy A in terms of profitability among all available options. Expressly, this condition necessitates the preeminence of A in generating the highest return compared to all other strategies being considered.

At the point where ϑ equals one-half, the relationship between utilities becomes notably more intricate. To meet the condition, the player who has chosen strategy A must receive a higher return than the player who has chosen the opposite strategy. The dominant players in the population should always adopt a single strategy A, and their dominance should be greater than the altruism exhibited by the players who adopt strategy B.

Having a stable investment strategy based solely on returns can be challenging. People's tendency to make irrational decisions can lead to favoring low-return strategies over higher-yielding ones. Therefore, the expected dominance of the highest-returning strategy may not occur in such a situation.

Many people tend to stick to a certain strategy even when there are better options available. This behavior can hinder a strategy aimed at reclaiming dominance in society. The advantage gained by those who follow this strategy is cancelled out by the portion of individuals who choose a different approach. This can be attributed to the influence of conformism, inertia, or the altruistic nature of this group.

In the context of social interaction, individuals tend to gravitate towards others who share similar viewpoints or are physically proximate. Consequently, it is imperative to undertake a comprehensive analysis of non-random interactions. If the pairings are not random, the replicator dynamics can be written as follows

$$\Delta a = \beta(1-\nabla)(1-a)a\iota(U_{at}-U_{bt}) + (1-\beta)(1-a-b')(1-\nabla)\mho_t\iota(EU_{at+1}-EU_{bt+1}) \quad (21)$$

Here $\nabla \in [0,1]$ represents intolerance coefficient which shows people's unwillingness level to match up with players who have opposing views. In the presence of non-random matches, when a player chooses strategy A, the probability of matching with another player who chose that strategy is not simply A, but rather $\nabla + (1-\nabla)$A. When $\nabla = 1$, there is complete intolerance between opposing strategies, a new equilibrium guarantees no change in Δa. This means that there is no chance of a match when opposite strategies are entirely intolerant.

It is important to examine the equation's last component closely, as strategy changes can still occur through the signaling mechanism even if the player does not directly interact with their opponent. The selection of matches is not random, and the information sources that activate the signaling mechanism are also not random. People tend to prefer news sources that align with their ideology or conformist influences, and they develop greater trust in certain outlets over time. When it comes to sharing private information, individuals place a premium on the reliability of their sources, favoring those that are deemed trustworthy. Therefore, access to news sources is not random but driven by a desire for dependable information.

If the derivative is taken to examine the partial effect of intolerance, we get

$$\frac{\partial \Delta a}{\partial \nabla} = -[\beta\iota(U_{at}-U_{bt})(1-a)a + (1-\beta)\iota(EU_{at+1}-EU_{bt+1})\mho_t(1-a-b') \quad (22)$$

Whether this equation is positive or negative directly depends on the sign of the expressions $(U_{at}-U_{bt})$ and $(EU_{at+1}-EU_{bt+1})$. Accordingly, the following determinations can be made:

- If players determine that adopting strategy A offers higher benefits, any rise in intolerance will result in a reduction of the potential population that employs strategy A. During matches, if a player chooses strategy B, they are inclined to imitate strategy A in the subsequent period. Yet, with an increase in intolerance, the population of strategy B will avoid mating with the population of strategy A, thereby impeding any shifts in strategy.
- Should strategy B prove to be the most effective course of action, a heightened level of intolerance would lead to a rise in the potential population a. Conversely, an increase in intolerance would expand the number of individuals eligible for inclusion in population a solely if the optimal strategy were B.
- In situations where there is complete intolerance, it becomes impossible to match players. In this regard, the likelihood of player A matching with another player A becomes one, following the formula $\nabla + (1-\nabla)$A.

If the derivative is taken with respect to ϑ for equation 21 we get

$$\frac{\partial \Delta a}{\partial \vartheta} = (\pi_{bt}-\pi_{at}) + [(\theta-\emptyset) + (v_{ab}U' - v_{ba}U')] + [(\theta_{e,t+1}-\emptyset_{e,t+1}) + (v_{ab,t+1}U' - v_{ba,t+1}U')] \quad (23)$$

The following assessments can be made accordingly

- In cases where strategy B yields the highest payoff, yet a portion of individuals opt for strategy A due to altruistic motives, the dominant group will ultimately choose strategy A. This is evidenced by the positive partial derivative of the change in the fraction with respect to ϑ. In light of the non-return effects, the utility function will be biased towards strategy A, leading to increased adoption of the same by the players. With the presence of non-return effects such as altruism and conformism may hinder the players from switching to the more efficient strategy B.
- Conversely, in cases where strategy yields the highest payoff, increasing the weight of non-return effects in the utility function will have a reducing effect on the A fraction-if the non-return effect is in favor of strategy B-.
- When making decisions, it's crucial to account for expectations. Suppose there's an anticipation that a higher number of players will opt for strategy B in the upcoming period, irrespective of the circumstances. In that case, conformity's influence will intensify, leading to a decrease in the number of players selecting strategy A.

To summarize, although strategy B may have a higher return advantage, if a significant majority always chooses strategy A regardless of the circumstances, then strategy A will persist (as long as the non-return effects in the utility function carry enough weight). This means that the strategy with the higher return advantage will not be able to eliminate the low-return strategy from the market. Without these factors, the utility function focuses solely on the returns. In this case, the stable equilibria are $b = 1$ and $a = 1$, where the best investment strategies dominate the stock market.

When the utility level of other players increases, and both v_{ab} and ϑ are greater than zero, player a's utility level will likewise increase, so long as financial yield is held constant. Player A is cognizant of the utility level of other players, and her utility function is not solely determined by her financial gain. The benefit level will rise as either ϑ or v_{ab} increases.

If v_{ab} equals zero, player a's attention is solely on her own payoff. In this circumstance, the level of benefit will fluctuate based on the value of ϑ. If ϑ is set at zero, player a remains primarily focused on return. However, as the value of ϑ rises, player begins to consider the presence of others who hold similar beliefs, as well as her financial gain. This equation also works in reverse. For instance, if $v_{ab} > 0$, $\vartheta > 0$, and if the benefit level of other players decreases, then the benefit level of player a will also decrease, provided that financial earning remains constant.

The concepts of unconditional altruism and unconditional anger or selfishness are denoted by ua_a. In contrast, conditional altruism is characterized by the variable $\beth_a ca_a$ representing player a's character and the importance that gives to others opinion $\beth_a$ and her belief about the opinions of other players towards her, ca_a. This condition can be succinctly described as a situation where player a's altruism is conditional on her perception of the opinions of other players.

If $ua_a = 0$ and $\beth_a$ have a positive value, player a understands the other person's feelings, thoughts, and behaviors towards her. This leads to conditional altruism. If $\beth_a = 0$, v_{ab} depends solely on ua_a. For negative values of ua_a, player a can be said to be unconditionally selfish or spiteful. If $ua_a = 1$, player a is unconditionally altruistic. In this case, the expression v_{ab} will take the maximum value of 1. Therefore, player a may care about others' gains as much as hers. If $v_{ab} = ua_a$, player a's sensitivity to other players' utility levels is directly determined by unconditional altruism/selfishness/anger/hatred.

When considering the behavior of individuals in a competitive environment, it is important to consider their levels of self-interest and concern for the success of others. Negative values of the expression ua_a can indicate an extreme level of selfishness. In such cases, the player is likely to feel disturbed by any benefit or success achieved by other players and may even derive happiness from the failure of others. This behavior can have negative consequences for the overall dynamics of the competitive environment and may lead to a breakdown in cooperative or mutually beneficial interactions.

If player A is an unconditional altruist, ua_a=1 and $v_{ab} = ua_a$. Hence, the utility function becomes

$$U_{a(1)} = (1-\vartheta)\left[TD^a_{n,t+1} + \sum_{n=1}^{N} \mathrm{P}^a_{n,t}\mathrm{P}'_{n,t+1}\, s'_{t+1} + (1-\psi^a - c_t)s^a_t\right] + \vartheta[(\theta - \emptyset) + \sum U'] \quad (24)$$

and the benefit of the unconditionally selfish player is

$$U_{a(2)} = (1-\vartheta)\left[TD^a_{n,t+1} + \sum_{n=1}^{N} \mathrm{P}^a_{n,t}\mathrm{P}'_{n,t+1}\, s'_{t+1} + (1-\psi^a - c_t)s^a_t\right] + \vartheta[(\theta - \emptyset) - \sum U'] \quad (25)$$

For $U_{a(1)}$)> $U_{a(2)}$ it is required $\sum U' > 0$. The unconditionally altruistic player places significant importance on the well-being of other players and considers their utility level as a deciding factor. If $\beth_a = 0$, meaning player a is indifferent to what others think, then we can discuss pure selflessness or selfishness, and the utility functions will be the same. However, as $\beth_a$ increases, the significance of player a's perception of what other players think of her becomes critical. The following table contains an analysis of different character forms.

Table 1: Stability Requirements'

Main Conditions		**Specific Conditions**		**Conclusion**
Player 1	*Player 2*	*Condition 1*	*Condition 2*	*Common*
$\beth_a ca_a = -1$ $v_{ab} = \frac{(ua_a - 1)}{2}$	$\beth_b ca_b = 0$ $v_{ba} = ua_b$	$ua_a = 1$ (unconditional strong altruism)	$ua_a = 0.5$ (unconditional altruism)	For condition 1, second players utility ceteris paribus will be higher, if $\sum U' > 0$. For condition 2, the player who does not care about the opinions of others will benefit more. If player cares about other players' opinions of her, sensitivity to the benefits of others will decrease (just because the fact that for admitting that other players have a bad opinion of her).
$\frac{\beth_a}{ca_a} = 1$	$\beth_a = 0$	$ua_a > 0$	$ua_a < 0$	If $ua_a > 0$ the player who cares about the opinions of other players and believes that there is a good opinion about her will benefit more. Similarly, in the latter condition, again, the benefit of the player who gives full importance to the opinions of other players and thinks that these players' think excellent about her (provided that the sum of the benefits of the other players is not zero) is greater.
$\frac{\beth_a}{ca_a} = 1$	$\beth_b = 0$	$ua_a = 1$	$ua_a = 0.5$	If $ua_a = 1$then both v_{ab} are equal. If $ua_a = 0.5$, the benefit in the first case will be greater. If the player who cares about the opinions of others and believes that they have

				a good opinion of her has unconditional altruism. Her benefit level will be higher than the player who does not value the opinions of others.
$\beth_a$ ca_a $= 1$	$\beth_b$ ca_b $= 1$	$ua_a = 1$	$ua_a = 0$	Individuals who place value on the opinions of others regarding themselves and hold these opinions as positively altruistic without any condition are likely to derive greater benefits. This is particularly true in group activities where social feedback can influence performance and sense of belonging.
$\beth_a = 1$	$\beth_b = 1$	$ua_a = 1$ $ca_a = -1$	$ua_a = -1$ $ca_a = 1$	Unconditional altruism and conditional emotions are two opposing forces that have a balancing effect on human behavior. Despite their seemingly divergent nature, both factors can contribute equally to behavioral utility. This implies that the impact of altruism and emotions on human behavior can be contextualized and understood in relation to each other.
$\beth_a = 1$	$\beth_b = 1$	$ua_a = 1$ $ca_a = 0$	$ua_a = 0$ $ca_a = 1$	To better understand this concept, let's compare it with a situation where conditional feelings equilibrate each other. In such a scenario, players may have mixed motives, including self-interest, cooperation, or retaliation. However, in the case of an unconditional altruist player, the motive is always goodwill towards others, and that predominates over any conditional feelings. Consequently, in this scenario, unconditional goodwill leads to a higher utility level for the altruistic player.

Source: Prepared by Authors.

If the partial derivative of v_{ab} with respect to ua_a and ca_a is taken, we get

$$\frac{\partial v_{ab}}{\partial ua_a} = \frac{(1 + \beth_a)}{(1 + \beth_a)^2} \quad (26)$$

$$\frac{\partial v_{ab}}{\partial ca_a} = \frac{\beth_a(1 + \beth_a)}{(1 + \beth_a)^2} \quad (27)$$

These two statements have positive implications. Firstly, if someone becomes more unconditionally altruistic, she will be more sensitive to the benefits of other people. Secondly, if someone believes that others have a more favorable opinion of them, she will also be more sensitive to the benefits of others. This means that a person's pro-social behavior can be influenced by their altruism and the social approval of others. Therefore, creating a culture of mutual respect and appreciation among team members could help to develop a more collaborative and productive environment. But if player a does not care about other players' opinions about her, then $\frac{\partial v_{ab}}{\partial ca_a} = 0$.When considering this specific scenario, the influence of other players' opinions on the overall benefit calculation becomes negligible.

The study's findings reveal the influence of altruism and reciprocity on the utility function. When $\beth_a = 0$, the impact is solely from unconditional altruism. Conversely, if $v_{ab} > 0$, player a is content with the situation if the combined utilities of the other players are positive.

The presence of stable equilibrium in the context of incorporating conformism and behavioural dimensions can be succinctly outlined as follows:

- If an individual, say a, exhibits an unconditionally generous nature and prioritizes the opinions of other players, while another individual, like player b, demonstrates an unconditionally selfish attitude and focuses on the opinions of other players solely for stable points, the conformist effect that favors player a's strategy must exceed the benefit that player b derives from her unconditional selfishness.
- In the context of an interdependent decision-making scenario, if both players exhibit unconditional altruistic behavior and their respective utility functions are contingent on both return and conformism, then to achieve stability in the system, the strategic payoffs and conformist advantage of player a should not be equilibrated by the unconditional altruism of player b.
- The outcome of interactions is influenced by the presence of reciprocity and conformity among players. If players are motivated by their own payoff and the desire to conform to social norms, achieving stability requires that the cumulative advantage of these factors for player a is greater than the advantage player b gets through their reciprocal behavior.
- In a situation where players operate with a sense of complete reciprocity and their utility functions are influenced by both payoff and conformism (player a is concerned about receiving negative opinions from their peers, while player b holds the opposite view), for the game to remain stable, player a must have a higher payoff and conformist advantage than the combined benefits of the other players. However, attaining this situation is challenging, and achieving a stable equilibrium under the conditions we studied is nearly impossible.
- In scenarios where players prioritize conformity and the influence of others, with one player displaying purely selfish behavior and the other exhibiting a sense of reciprocity, a stable equilibrium can be achieved if most players conform and support strategy A in all matters.

4. A Different Perspective: Risk Aversion

Understanding the link between risk and return is crucial when making wise financial choices. Generally, individuals with lower incomes are more careful in taking risks while those with higher incomes may be more prone to taking chances. According to a study conducted by Binswanger in 1980, there is a shift in perceptions of risk as income levels increase, leading to a greater willingness to take risks.

If the investor is risk-averse, the main model can be modified under certain conditions:

- π represents return or wealth.
- r_π represents the benefit related to the return. The weight of this type of benefit is determined by $(1-\vartheta)$.
- r_π exhibits a strictly increasing trend, with its effectivity remaining intact throughout a wide range of values of ϑ. However, it is noteworthy that the efficacy of it is significantly impacted when ϑ equals 1, as the benefits derived from this function are

exclusively dependent on non-return factors.

- At the onset of an investment period, a risk-averse investor is tasked with the allocation of their initial wealth, denoted as π_i, towards both risky and riskless assets. This decision is crucial to an investor's portfolio as they seek an equilibrium between financial risk and potential returns. The investor's allocation strategy can significantly impact the portfolio's overall risk-and-reward profile, and hence, requires careful consideration.
- To make the risky asset more appealing to an investor who is risk-averse, a variable known as the risk premium$-\eta-$ needs to be introduced. The risk premium measures the additional return an investor expects to earn as compensation for taking on the increased risk associated with the investment. By determining the appropriate level of risk premium, an investor can make informed decisions about whether to allocate funds towards a particular investment and achieve an equilibrium between risk and reward.
- The amount allocated to risky investment will be considered as x.

Under these conditions, the risk-averse player's wealth at the end of the period is

$$\pi = x(1+\eta) + (\pi_b - x)t \quad (28)$$

The letter "t" in finance typically denotes the return on a relatively risk-free investment. Such investments are usually considered to have a low level of risk, meaning that they are less likely to lose value or fail to generate the expected return. Examples of relatively risk-free investments include government bonds, which are backed by the full faith and credit of the government. The return on these types of investments is usually lower than riskier investments, such as stocks or real estate, but they offer a higher degree of safety and stability.

It is possible for the variable x to hold a value within the range of 0 and π_i. To pursue a potentially hazardous investment, the anticipated value of η (which measures risk premium) must surpass 0. The utility function of player a is

$$U_a = (1-\vartheta)[x(1+\eta) + (\pi_b - x)t] + \vartheta\left[(\theta - \emptyset) + \sum_b v_{ab}U'\right] \quad (29)$$

or equivalentely

$$U_a = (1-\vartheta)[r_\pi] + \vartheta\left[(\theta - \emptyset) + \sum_b v_{ab}U'\right] \quad (30)$$

Player x can invest all his initial wealth in the stock market. If this does not occur, the optimal investment condition will be

$$E[u'(x(1+\eta) + (\pi_b - x)t)\eta] = 0 \quad (31)$$

To evaluate the utility function of a risk-averse investor, it is necessary to examine their demand for risky investments. This demand is crucial because it determines the extent to which the investor is willing to take on risk in pursuit of higher returns. If the amount allocated to high-risk assets is x, the complement of this amount is

$$M = (\pi_i - x) \quad (32)$$

If we assume that risk aversion behavior increases as the potential return of an investment increases, then theoretically, x should decrease as π_i increase. This would suggest that investing in the stock market is a type of inferior good. However, this conclusion is not logically consistent and cannot be supported by empirical evidence. Therefore, it cannot be said that absolute risk aversion is a strictly increasing function. On the other hand, if we assume that risk aversion decreases as the potential return of an investment increases, then risky investment can be considered a normal good, which is consistent with economic theory.

If $(1+\eta) > (\pi_i - x)t$ investors who like to take risks will increase their returns more than others in the next period. The value needs to be equivalent to the risk premium for a player who is risk averse. In scenarios where a risk-averse player and a risk-neutral player are paired, the relationship between the utility levels for the stationary equilibrium can be expressed as $U_a > U_b$ and $a > 1/2$.

The necessary condition is given below

$$(1-\vartheta)\left[(x(1+\eta)+(\pi_i-x)t)-\left(TD^b_{n,t+1}+\sum_{n=1}^{N}\mathrm{P}^b_{n,t}\mathrm{P}'_{n,t+1}\,s'_{t+1}+\left(1-\psi^b-c_t\right)s^b_t\right)\right] > \vartheta\left[(\emptyset-\theta)+\sum(v_{ba}U'-v_{ab}U')\right] \quad (33)$$

and for $\vartheta = 0.5$

$$\left[(x(1+\eta)+(\pi_i-x)t)-\left(TD^b_{n,t+1}+\sum_{n=1}^{N}\mathrm{P}^b_{n,t}\mathrm{P}'_{n,t+1}\,s'_{t+1}+\left(1-\psi^b-c_t\right)s^b_t\right)\right] > \left[(\emptyset-\theta)+\sum(v_{ba}U'-v_{ab}U')\right] \quad (34)$$

In order to maintain stationarity, the return advantage of a risk-averse investor must outweigh the conformist and behavioral advantage of a player employing the opposite strategy. This means that for a risk-averse investor to continue using the same investment strategy, the return advantage must be the most important factor to consider, taking precedence over any other dimensions that may come into play. Essentially, the investor must achieve a greater return on investment than the other player can achieve with their opposing strategy to justify the continued use of her own strategy.

This condition can be written in its most general form as follows:

$$\frac{\left[[x(1+\eta)+(\pi_i-x)t]-[TD^b_{n,t+1}+\sum_{n=1}^{N}\mathrm{P}^b_{n,t}\mathrm{P}'_{n,t+1}\,s'_{t+1}+\left(1-\psi^b-c_t\right)s^b_t]\right]}{[(\emptyset-\theta)+\sum(v_{ba}U'-v_{ab}U')]} > \frac{\vartheta}{(1-\vartheta)} \quad (35)$$

As the weight of non-return effects, such as conformism and behavioral dimension, increases, achieving a certain goal or objective becomes more challenging. This is because non-return effects can lead to a phenomenon where individuals tend to conform to the choices made by others, even if those choices are not necessarily the best ones. Therefore, when there is a strong pressure to conform, it becomes increasingly difficult to deviate from the norm and make independent decisions.

In addition to this, the statement also highlights the importance of return advantage and risk aversion in decision-making. For a risk-averse player to succeed, their return advantage must be greater than the conformist advantage of the player who has adopted the other strategy. This means that the potential gains from taking a risk must be significant enough to outweigh the potential losses, and that the risk-averse player must be able to make informed decisions based on her own analysis and assessment of the situation. If derivative is taken to examine the partial effect of non-return effects, we get

$$\frac{dU_a}{d\vartheta} = -[x(1+\eta)+(\pi_i-x)t]+[(\theta-\emptyset)+\sum_b v_{ab}U'] \quad (36)$$

The sign of this expression indicates how non-return effects impact the utility function of a risk-averse player. Assuming that a risk-averse investor may also choose a risky investment, it can be writtten as

$$\left[x(t-\eta-1)-[TD_{n,t+1}^{b}+\sum_{n=1}^{N}\mathrm{P}_{n,t}^{b}\mathrm{P}_{n,t+1}^{\prime}\,s_{t+1}^{\prime}+\left(1-\psi^{b}-c_{t}\right)s_{t}^{b}]\right]+\left[(\theta-\emptyset)+\sum_{b}v_{ab}U^{\prime}]\right] \quad (37)$$

Therefore, in this case, the payoff is also becoming important for $\frac{dU_a}{d\vartheta}>0$. The partial effect of the risk premium, which is the main factor determining the amount of risky investment, is

$$\frac{dU_a}{d\eta}=(1-\vartheta)x \quad (38)$$

In cases where non-return effects are complete or no budget is allocated for risky investment, $\frac{dU_a}{d\eta}=0$. However, given that this is not a plausible scenario, we obtain $\frac{dU_a}{d\eta}>0>$. As the risk premium increases, the player's benefit increases based on the allocated amount to the risky investment and the weight of the non-return effect. The present section aims to scrutinize the equilibriums from the antecedent section with renewed attention, focusing solely on the outcomes that display discrepancies from the initial analysis. The purpose of this assessment is to provide a more detailed and accurate account of the equilibriums in question.

Table 2: Stability and Risk Aversion

Main Conditions		**Conclusion**
Player 1	*Player 2*	*Common*
$ב_a=0$ $v_{ab}=ua_a$	$-$	If $A>1/2$, for stability, it is required $x(1+\eta)+(\pi_i-x)t>[TD_{n,t+1}^{b}+\sum_{n=1}^{N}\mathrm{P}_{n,t}^{b}\mathrm{P}_{n,t+1}^{\prime}\,s_{t+1}^{\prime}+\left(1-\psi^{b}-c_{t}\right)s_{t}^{b}]$, $\theta>\emptyset$ and $(v_{ba}U'-v_{ab}U'<0$ (with dependence of ϑ)
$\vartheta=0$	$\vartheta=0$	If $A>1/2$, for stability the risk averse player's payoff should dominate the market. Whether this possibility will become a reality or not is contingent on two factors: η and t. When the risk premium, which is the excess return that investors demand to compensate for taking on additional risk, is high enough to convince the risk-averse investor to make a risky investment or when the returns on a relatively low-risk investment are deemed satisfactory, these investors are more likely to continue with the same investment strategy in the following period.
$ב_a=0$ $ua_a=1$	$ב_b=0$ $ua_b=1$	If we consider a scenario where A is greater than 1/2, then it's important to note that the payoff and conformist advantage for players adopting strategy x should not be offset by the unconditional altruism of players adopting strategy y. This necessitates the presence of a risk Premium, as this premium increases, the likelihood of stability also increases.
$ua_a=1$	$ב_b ca_b>0$	If $A>1/2$, detailed analysis for stationarity through inequality $\left([x(1+\eta)+(\pi_i-x)t]-[TD_{n,t+1}^{b}+\sum_{n=1}^{N}\mathrm{P}_{n,t}^{b}\mathrm{P}_{n,t+1}^{\prime}\,s_{t+1}^{\prime}+\left(1-\psi^{b}-c_{t}\right)s_{t}^{b}]\right)+([(\theta-\emptyset)])>([\sum_c((ב_b ca_b)/1+ב_b)U'-\sum_b U'])$.The maintenance of stability in this context relies heavily on the return dominance of the risk-averse investor.
$ב_b ca_a>0$	$ב_b ca_b>0$	To ensure stationarity, it is imperative that the return and conformist advantage outweigh the advantage provided by the sense of reciprocity to the fraction b. In other words, for a given interaction to maintain its stability, the benefits of conforming to the established norms and expectations must significantly outweigh the advantage gained by deviating from them and relying on the sense of reciprocity.

Source: Prepared by Authors.

Based on the findings, ceteris paribus, the risk premium emerges as the paramount factor for maintaining stability in an economy where risk-averse investors dominate.

Equity risk premiums can also be written as:

$$\eta = r_r + \varpi(r_p - r_r) \quad (39)$$

This equation is known as the CAPM model. r_r is the risk-free return, $(r_p - r_r)$ is the extra return expected by the risk-averse investor, and ϖ is a variable characterizing the stock market. Risk models are used to analyze investment risks by dividing them into two main components. The first component is the specific risk associated with a particular investment or a group of similar investments. The second component is the market risk, which represents risks that impact significant investments and cannot be diversified. This type of risk requires a risk premium as compensation. Although there is a consensus among all risk and return models about this distinction, there are four primary methods to evaluate and quantify market risk.

Table 3. Risk Measurement

Approach	**Measurement of Market Risk**
CAPM	In a market where there are no transaction costs or any proprietary information, a diversified portfolio will generate returns that are in line with market values. The market's overall risk can also be assessed under these market conditions.
Arbitrage Pricing Model	There are no transaction costs or proprietary information. Therefore, a diversified portfolio will provide returns commensurate with market values. Market risk is also measured in these market conditions.
Multi-Factor Model	Market risk is evaluated by considering various macroeconomic factors.
Proxy Model	Investors seeking higher returns over the long term should consider taking on higher market risk. To effectively measure market risk, ratios such as P/D (market value divided by book value) can be used. These ratios are commonly used in financial analysis and can provide valuable insights into the market's overall risk profile.

Source: Damodaran (2012)

The relationship between the market risk premium and the country risk premium should not be overlooked. Additionally, accurately measuring the return on a risk-free investment can be difficult. When the risk premium is low, it becomes challenging to maintain stability in return-dominant strategies as demand for securities with lower returns increases. Investors are rewarded for high-risk premiums, dividends, and other sources of return. This incentive drives some investors to seek riskier investments for potentially greater returns. However, borrowers may face the burden of a costly risk premium, particularly those with uncertain prospects. These borrowers must pay a higher risk premium to investors, increasing the likelihood of default.

The adequacy of the risk premium in a market that is primarily driven by risk-averse investors is contingent upon the level of risk aversion exhibited by such investors and the overall market dynamics. This introduces significant complexities and difficulties in maintaining a stable equilibrium. In its most general form, the risk-averse player's utility function can be written as follows:

$$U_a = (1-\vartheta)\left[x\left(1+\left[r_r + \varpi(r_p - r_r)\right]\right) + (\pi_i - x)r_r\right] + \vartheta\left[(\theta - \emptyset) + \sum_b v_{ab}U'\right] \quad (40)$$

The partial effect of the budget that a risk-averse investor allocates to risky investments is

$$\partial U_a / \partial x = (1-\vartheta)\left(1+\left[\varpi\left(r_p-r_r\right)\right]\right) \quad (41)$$

$$\partial U_a / \partial x = (1-\vartheta)(1+[(\eta-r_r)]) \quad (42)$$

It is evident that this effect vanishes when ϑ equals 1. Apart from this exceptional scenario, the budget of the investor dedicated to the risky asset will increase when

- The non-return effects in the utility function gain more weight
- The value of ϖ coefficient approaches to 1
- The expected return of the risky investment increases
- The relatively risk-free return on investment reduces.

A return-based evolutionary equilibrium is possible in a risk-averse investor-dominated market under these certain conditions. Partial effect of the risk premium on the benefit function defined in this subheading is

$$\partial U_a \Big/ \partial\left[r_r+\varpi\left(r_p-r_r\right)\right] = (1-\vartheta)\left[\frac{\pi_i-\varpi x}{(1-\varpi)}\right] \quad (43)$$

The sign of equation 43 is contingent upon the expression $(\pi_i-\varpi x)$. For a risk-averse player, this statement holds a positive connotation. Increased risk premiums lead to amplified benefits for the risk-averse player. The outcomes can be succinctly encapsulated as follows:

- For investors who are risk-averse, the most important goal is to protect their initial investment capital. These individuals prioritize preserving their wealth over maximizing returns and may therefore be more inclined to choose investments that are considered low-risk and stable.
- These investors who are looking to allocate funds to a risky investment will only do so if there is a significant risk premium associated with it. This premium is typically higher for investments that have a higher degree of uncertainty or volatility, such as those in emerging markets or new technologies. By requiring a high-risk premium, the investor is essentially demanding a greater return on investment to compensate for the higher level of risk they are taking on.
- Within an investment market where risk-averse investors hold sway, equilibrium that prioritizes returns is established by maintaining a risk premium that caters to the preferences of such investors. Achieving this equilibrium is key to promoting investment activity in the market.
- It is important to consider that the stock risk premium and Capital Asset Pricing Model (CAPM) are theoretical tools that are based on historical performance figures. While these tools have been useful in understanding the relationship between risk and return, it is important to note that past performance does not necessarily guarantee future results. Due to this uncertainty, it can be difficult to observe evolutionary stable equilibrium in practice, as the market is constantly changing and adapting to new information and circumstances.
- Investors typically demand a higher premium when the risk of losing their capital is high. This means that the expected return on the investment must increase to compensate for the increased risk.
- For an investor who is risk-averse, it is reasonable to assume that the $(1-\vartheta)$ coefficient exceeds 0.5. This assumption is theoretically sound, and as a result, the magnitude of the return difference becomes more pronounced.

Conclusion

Based on our research, observing an investment strategy that can successfully capture the entire market has been difficult. This is due to several factors, such as investors making irrational decisions, conformism and behavioral dimension influencing the market, the risk premium demanded by investors based on their level of risk aversion, the intolerance coefficient, and non-random matchings.

Investors sometimes make irrational choices, which means their investment decisions are not always based on logical evidence. Furthermore, conformity, the tendency to follow the crowd, behavioral factors, and personal biases and emotions can make it even harder to observe a return-based investment strategy.

Moreover, investors' demand for a risk premium varies based on their degree of risk aversion. As a result, investors may demand a higher premium for taking on higher risks, making it challenging to design an investment strategy that caters to all investors' preferences.

Furthermore, the intolerance coefficient, a measure of investors' unwillingness to tolerate even minor losses, adds to the complexity of observing a return-oriented investment strategy. Finally, non-random matchings and pairing investors with similar risk preferences make it challenging to capture the entire market with a single investment strategy.

Let us summarize the main contributions of this paper to literature.

- The research findings indicate that the effectiveness of a strategy may not always align with the public's preference. In other words, even if an approach does not result in significant gains, it may still be favored by the public. This suggests that the outcome of a particular strategy is not a foregone conclusion and is subject to multiple influencing factors.
- The research highlights the fact that human decision-making is not solely based on logical reasoning but is significantly influenced by emotions and social factors. Evolutionary game theory can be employed to gain a better understanding of human behavior and decision-making in such contexts.
- The research results have noteworthy ramifications for financial market analysis, shedding light on the reasons behind the failure of stock prices and investment markets to attain equilibrium values in the long run. However, it is worth noting that the study's scope does not cover this subject in detail, and further research is necessary to explore the intricate dynamics involved thoroughly.
- The study highlights that in a market where most players are risk-averse, the return-oriented evolutionary equilibrium is strongly linked to the risk premium. As a result, it is challenging to detect the existence of such an equilibrium through empirical observations.
- Our research study aims to add value to the existing literature by using the signaling mechanism within the replicator dynamics framework. This approach sets our study apart from other studies that have been conducted in this field. The signaling mechanism is a powerful tool that can help explain why people often don't change their investment strategies, even when better options are available. Factors like a lack of interest in new information or following unreliable news sources can hinder the spread of effective investment strategies in the market.
- The research adds to the existing body of knowledge by demonstrating how non-return effects have the potential to shift markets from efficient positions and evaluating this aspect within the utility function.

The article aims to make a valuable contribution to the existing evolutionary game theory literature. Nevertheless, we would like to highlight the fact that conducting empirical tests can significantly enhance the quality of our results, both on theoretical and mathematical levels.

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