

# Personal Wealth, Risk Tolerance, and Stock Allocation: A Markov Chain Approach

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**Abstract.** As a matter of fact, personal wealth management remains a hot topic in order to gain extra return from financial market. With this in mind, the paper seeks to decipher the impact of an individual's wealth and risk tolerance on their propensity to invest in stocks in three different market sectors and risk allocations. On this basis, primarily using the Markov chain approach, the most appropriate investment allocations can be derived for different wealth and risk profiles. By exploring these transitions, the goal is to identify the optimal allocation of equity funds for individuals at different levels of wealth and risk tolerance. According to the analysis, this study provides insights into investment strategies for wealth dependence and risk tolerance, as well as hopes that a relatively reasonable allocation of financial resources for different income and courage groups can be studied at the same time. Overall, these results shed light on guiding further exploration of stock allocation.

**Keywords:** Markov chain; wealth and risk tolerance; stock allocation.

## 1. Introduction

In complex financial markets, when discussing individual investment strategies, two factors often dominate the discussion: the individual's level of wealth and risk tolerance. The former provides a quantitative measure of financial potential, while the latter is a complex mix of psychology, financial goals, and past experience. These two factors play an important role in investment allocation decisions, especially when investors are faced with multiple investment options. Generally speaking, when individuals or the whole have more funds available, they may be more inclined to invest, and wealth accumulation will affect the improvement of individual or overall risk tolerance [1]. However, the choice of stocks or bank deposits varies according to subjective personality traits [2]. Overall, as the global investment landscape is constantly changing and evolving, it is crucial for individuals or investors to have a deep understanding of how these factors affect their portfolio choices. It is very important for companies to find a relatively suitable investment method.

An individual's level of wealth is objective and affects their investment choices [1, 3]. Historically, wealthier individuals or groups have tended to diversify their portfolios by investing in a combination of risky and safe assets [4]. For example, Huawei not only sells mobile phones, but also sells cars. Conversely, those with limited means may adopt a conservative approach out of fear of losing their limited capital, or take disproportionate risks in order to reap good returns [5].

Unlike an individual's level of wealth, risk tolerance is inherently subjective. Even if there is not much difference in the level of personal wealth among investors, the risk tolerance varies greatly. Traditional schools of thought classify investors as risk-averse, risk-neutral, or risk-seeking [6]. Risk-averse individuals tend to shy away from volatile assets and seek out stocks with stable investment returns. Risk seekers, on the other hand, are often attracted by the potential for higher returns and seek high-risk high-reward stocks. This combination of risk psychology and actual financial ability affects the decision-making of investors.

By taking a closer look at these different stock types, one seeks to understand how different investors allocate capital between these options based on their wealth and risk appetite. To illuminate this complex relationship, this study examines three stocks, each representing a different industry and risk profile:

Tech giant Apple (AAPL). According to Apple's annual and quarterly reports released every year, overall, it appears to have continued to grow and be relatively stable.

Pharmaceutical giant Pfizer (PFE). The healthcare industry is risky and risky, but potentially very profitable [7].

NextEra Energy (NEE). A leading clean energy company. The green energy field is high risk and high reward.

Each stock has a unique investment narrative driven by industry trends, market sentiment and, most importantly, its inherent volatility. For example, while a technology stock like AAPL may attract investors more interested in or knowledgeable about the technology industry, the same individuals may be wary of the unpredictable waves of the pharmaceutical industry or the nascent unpredictability of the renewable energy industry. Because people tend to believe things they know better [8].

Beyond pure industry differences, these stocks carry varying degrees of risk and potential reward. While the impact of wealth and risk tolerance on investment behavior is well established [9], predicting how these factors will affect investment allocations to specific stocks remains a challenge. For this challenge, one used a Markov chain approach to map out the paths each stock might take under different market conditions. By considering stock price evolution as a stochastic process, where the probability of future prices depends only on the current price and not on the previous price sequence. The mapped pathways can provide the analytical basis for the wider investigation. Past literature has emphasized the role of personal attributes in investment decisions, while other literature has discussed in detail the impact of stock type on investor behavior. However, there is still a gap in incorporating these aspects into the predictive framework of Markov chains. This article aims to bridge this gap, providing actionable insights for individual investors and the wider financial community.

## 2. Data and Method

In order to conduct stock analysis from September 30, 2021 to September 30, 2022, the stock data of 3 companies with different risks and different types were obtained from Yahoo Finance. Apple Inc. (AAPL) is an American multinational technology company specializing in the design, development and sales of consumer electronics, computer software and online services. Since the early 2000s, especially after the iPhone was released in 2007, Apple's market value and influence have grown significantly, making it one of the most valuable companies in the world. In 2022, its total revenue was approximately US\$394.3 billion, the basic average number of shares was approximately 16.2 billion, and the basic earnings per share was US\$6150. Pharmaceutical giant Pfizer (PFE) is a leading global pharmaceutical company located in New York City, USA, and has long been the market leader in many prescription drugs. It initially started with the production of chemical products and later shifted to pharmaceuticals. Pharmaceutical giant Pfizer (PFE) has developed a wide range of medicines across a variety of diseases and conditions, including cardiovascular, neurological, oncology, immune system and infectious diseases. In 2022, its total revenue will be approximately US\$100.3 billion, its basic average number of shares will be approximately 5.6 billion shares, and its basic earnings per share will be US\$5590. NextEra Energy (NEE) is one of the largest electric power companies in North America and an industry leader in renewable energy. NEE has significant investments in wind, solar and nuclear energy, and it plays a central role in driving America's clean energy transition. In 2022, its total revenue will be approximately US\$20.95 billion, its basic average share count will be approximately 1.97 billion shares, and its basic earnings per share will be US\$2,100. As households become wealthier, they tend to invest in more stocks, and households are more likely to sell all of their direct holdings if those stocks perform well, and are more likely to exit direct holdings if the stock portfolio performs well [1]. Furthermore, the degree of risk aversion has an inverse relationship with the level of wealth [6]. When a person is approximately risk averse, the person's wealth level may be lower. With two factors at play, it becomes very difficult to select the most suitable stocks to invest in for a person or company.

For this challenge, one uses a Markov chain approach to map the possible future paths that each stock could take under different market conditions. Think of stock price evolution as a stochastic

process where the probability of future prices depends only on the current price and not on the previous price sequence. The two big factors that influence people's choices will be separated into multiple small factors to look at.

Wealth levels are affected by annual income and wealth accumulation [10]. Therefore, the big factor of wealth level will be divided into small annual income but large wealth accumulation, large annual income but small wealth accumulation, low annual income and small wealth accumulation, and annual income. Four situations include large income and large wealth accumulation. Once the annual income of an individual or company is higher than the average income of the region, the annual income is considered to be more, and vice versa. The same goes for wealth accumulation. Stock investment risk tolerance will be affected by factors such as gender, age, height and parental background [11]. In addition, there are many various factors that directly or indirectly affect the risk tolerance of stock investment. Therefore, the major factor of stock investment risk tolerance will be divided into three levels, high, medium and low risk. One assumes that the probability that each state (high, medium, and low risk) will move to a specific state (high, medium, and low risk) in the next time period is the same, and the probability that an investor is at high risk in this period is  $p_1$ , medium risk is  $p_2$ , low risk is  $p_3$ , and no matter which state the previous stage was in, the probability of selecting high-risk stocks in a time period is  $p_4$ , the probability of selecting medium-risk stocks is  $p_5$ , and the probability of selecting low-risk stocks is  $p_6$ . Then, the transition probability matrix  $P$  is:

$$P = \begin{bmatrix} p_4 & p_5 & p_6 \\ p_4 & p_5 & p_6 \\ p_4 & p_5 & p_6 \end{bmatrix} \quad (1)$$

The first row represents the transition probabilities from the high-risk state to each of the other states. The second row represents the transition probabilities from the medium risk state to each other state. The third row represents the transition probabilities from the low-risk state to each other state. Then, the investor's current status is:

$$S = \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix} \quad (2)$$

To calculate the state probability for the next time period, one performs matrix multiplication:

$$S' = S^T \times P \quad (3)$$

Since  $p_1+p_2+p_3 = 1$ , the result can be further simplified to:

$$S' = \begin{bmatrix} p_4 \\ p_5 \\ p_6 \end{bmatrix} \quad (4)$$

To investigate further, assume that each state (high, medium, low risk) has a different probability of moving to a specific state (high, medium, low risk) in the next time period. The probability that investors are at this stage is high risk  $p_1$ , medium risk  $p_2$ , and low risk  $p_3$ . When the risk was low in the previous stage, the probability of selecting high-risk stocks was  $p_4$ , the probability of selecting medium-risk stocks was  $p_5$ , and the probability of selecting low-risk stocks was  $p_6$ . When the risk was medium in the previous stage, the probability of selecting high-risk stocks was  $p_7$ , the probability of selecting medium-risk stocks was  $p_8$ , and the probability of selecting low-risk stocks was  $p_9$ . When the risk was high in the previous stage, the probability of selecting high-risk stocks was  $p_{10}$ , the probability of selecting medium-risk stocks was  $p_{11}$ , and the probability of selecting low-risk stocks was  $p_{12}$ . Constructing the transition probability matrix  $P$  according to the given information:

$$P = \begin{bmatrix} p_{10} & p_{11} & p_{12} \\ p_7 & p_8 & p_9 \\ p_4 & p_5 & p_6 \end{bmatrix} \quad (5)$$

To calculate the state probability for the next time period, one performs matrix multiplication:

$$S' = \begin{bmatrix} p_1p_{10} + p_2p_7 + p_3p_4 \\ p_1p_{11} + p_2p_8 + p_3p_5 \\ p_1p_{12} + p_2p_9 + p_3p_6 \end{bmatrix} \quad (6)$$

Therefore, the probabilities of the investor choosing high-risk, medium-risk, and low-risk stocks in the next time period are respectively.

### 3. Results and Discussion

The study's primary goal is to determine how an individual's wealth level and risk tolerance affects their investment preferences, such as Apple (AAPL), Pfizer (PFE), and NextEra Energy (NEE). The Markov Chain approach allows us to predict potential investment decisions based on various market conditions. An interesting aspect is the breakdown of wealth levels based on annual income and wealth accumulation. This disagreement highlights the complexities inherent in defining wealth. As proposed, individuals with high annual income but low wealth accumulation may have different investment preferences than individuals with high wealth accumulation but low annual income. This distinction further amplifies the complexity of investor behavior, making any one-size-fits-all strategy ineffective. The study breaks down risk tolerance into aspects such as gender, age, height and parental background, which is another key point. These breakdowns provide a more nuanced understanding of what risk tolerance is. It's clear that a range of personal, social and psychological factors influence an individual's investment decisions. For low-risk investors, p4, p5, and p6 can help us understand the future investment tendencies of such investors, part of the current market status and investors' demand for returns.

If the value of p4 is relatively high, it may mean that investors are more inclined to increase their investment risk in the next period. This may be due to their optimism about market prospects or their pursuit of high returns. There is the possibility that there may be some positive signals in the current market that cause low-risk investors to start considering higher-risk investments. For example, a major policy change, the emergence of new technology, or positive financial reporting from an important company may spur such a shift. There is also the possibility that as the economy grows, investors may seek higher returns. If the value of p5 is relatively high, this may mean that these investors may tend to look for moderate returns while still finding a balance between being conservative and taking risks. If the value of p6 is relatively high, it may mean that in a relatively stable economic environment, low-risk investors may believe that their current strategy is good enough and are more inclined to maintain their conservative investment strategy.

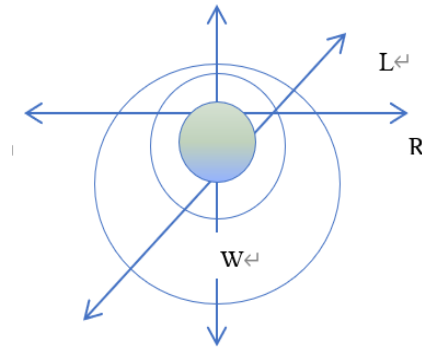
For medium-risk investors, p7, p8, and p9 can help us understand the future investment tendencies of such investors, part of the current market status and investors' demand for returns. If the value of p7 is relatively high, this may mean that this type of investor is attracted by the potential high return opportunities in the market. For example, one may see rapid growth in a certain industry or field, the creation of new companies, or the emergence of new technologies. thereby increasing their risk tolerance. Additionally, there is the possibility that as the economy grows, investors may seek higher returns. If the value of p8 is relatively high, it may mean that these investors still want to maintain a medium-risk investment strategy in the future. If the value of p9 is relatively high, this may mean that investors will switch to a more conservative strategy. There may be market uncertainty. For example, encountering external shocks or signs of a global economic slowdown. For high-risk investors, p10, p11, and p12 can help us understand the future investment tendencies of such investors, part of the current market status and investors' demand for returns. If the value of p10 is relatively high, it may mean that investors have seen more opportunities in the market or have experienced high returns from high-risk investments and intend to continue their high-risk strategies. If the value of p11 is relatively high, it may mean that investors are considering reducing some risk and switching to a medium-risk strategy. If the value of p12 is relatively high, it may mean that investors, having already made certain profits, plan to reduce risks and choose to lock in part or all of the profits, or they may no longer be so optimistic about the market outlook.

Considering that the annual returns of the stocks selected at the beginning are also different, the annual income, wealth accumulation and courage of different users after a period of time may change and be different from the current stage. For the investor's profile, consider three dimensions: risk tolerance (R), annual income (I), and wealth accumulation (W) seen from Fig. 1):

Risk Tolerance: R1 (Low), R2 (Medium), R3 (High)

Annual Income: I1 (Low), I2 (Medium), I3 (High)

Wealth Accumulation: W1 (Low), W2 (Medium), W3 (High)



**Fig. 1** A sketch of 3 dimensions.

There are a total of 27 possible combined states, for example, I1W1R1, I1W1R2, I3W3R3. First, calculate the annual growth rates of the three stocks:

Growth RateAAPL=0.0847

Growth RateNEE=0.1538

Growth RatePFE=0.4260

Based on the stocks selected in the previous period and its growth rate, the updated annual income and wealth accumulation status is:

$\Delta R = \text{Growth Rate chosen stock} \times R$

$\Delta W = \text{Growth Rate chosen stock} \times W$

$\Delta I = \text{Growth Rate chosen stock} \times I$

Then, after a time period,

Yearly Income:  $I_x + \Delta I$

Wealth Accumulation:  $W_x + \Delta W$

Risk Tolerance:  $R_x + \Delta R$

For AAPL investors: Year Income will become 1.0847R, Wealth Accumulation will become 1.1538W and the risk tolerance will become 1.426I. When the original grades W, I and R are not the highest grade, if 1.0847R, 1.1538W, 1.426I is greater than the W, I and R that are one grade higher than the original grade, then the original circle will protrude from that axis and There is the potential to bring about new types of equity investments. Anticipating these possible transitions in advance may help people make the transition in advance after weighing the pros and cons,

#### 4. Limitations

This study uses a Markov chain model to provide a novel perspective on the dynamics of investment decisions based on wealth levels and risk tolerance. However, some limitations of this study must be acknowledged. While the stock selection represents three different industries (technology, energy, and healthcare) with different risk profiles, it is still a limited representation of the financial market as a whole. These three stocks (i.e., AAPL, NEE, and PFE) while different, do not encompass all types of investment opportunities available. In addition, the risk level of stocks is artificially set, and there are many stocks between the two risks. These stocks may fall right in between the two risks, or they may lean more toward one risk. The study only considered a fixed time frame (from 2021 to 2022) to analyze stock price movements. However, markets are affected by a variety of economic, political and global events, and the time frame chosen for this study may not be

representative of long-term trends or explain major future events. The world is changing every moment, and it is possible that the economy that one thought was relatively stable during this period will be very different from this period in the coming period. Furthermore, while the Markov chain is a robust model, it is based on the assumption that the future state depends only on the current state, without taking into account external factors or historical context. For stocks, this simplification can be a limitation because there are many external factors that affect stock prices.

## 5. Conclusion

In summary, while this study reveals a complex relationship between wealth, risk tolerance, and stock selection, there is significant potential for future research. Addressing limitations and broadening research horizons can lead to more refined strategies for individual investors, ultimately contributing to a broader understanding of financial markets. This study only looks at personal wealth and risk tolerance as determinants of investment decisions. Other factors such as financial literacy, market knowledge, past experience and even emotions also play a crucial role in investment decisions. In real life, these factors should also be considered as influencing factors in the model. Addressing these limitations could provide a promising avenue for future research. Future research could consider a wider selection of stocks from more industries. Combining small-cap, micro-cap and international stocks provides a more comprehensive analysis. Moreover, to capture more variability and potential black swan events, longer studies may be beneficial. This will also allow for consideration of cyclical trends in the market. Additionally, using advanced psychometric tools or artificial intelligence to assess risk tolerance can provide a more accurate representation of an individual's risk profile. Multi-factor models that consider other personal factors such as age, financial goals, investment horizon and past investment experience can provide a more comprehensive understanding of investment decisions.

## References

- [1] Fang M, Li H, Wang Q. Risk tolerance and household wealth--Evidence from Chinese households. *Economic modelling*, 2021, 94: 885-895.
- [2] Aren S, Hamamci H N. Relationship between risk aversion, risky investment intention, investment choices: Impact of personality traits and emotion. *Kybernetes*, 2020, 49(11): 2651-2682.
- [3] Arora J, Chakraborty M. Role of financial literacy in investment choices of financial consumers: an insight from India. *International Journal of Social Economics*, 2023, 50(3): 377-397.
- [4] Barasinska N, Schäfer D, Stephan A. Individual risk attitudes and the composition of financial portfolios: Evidence from German household portfolios. *The Quarterly Review of Economics and Finance*, 2012, 52(1): 1-14.
- [5] Chhabra A B. Beyond Markowitz: a comprehensive wealth allocation framework for individual investors. *The Journal of Wealth Management*, 2005, 7(4): 8-34.
- [6] Arrow K J. *Aspects of the theory of risk-bearing*. Springer, 1965.
- [7] Skinner J S, Staiger D O, Fisher E S. Is Technological Change in Medicine Always Worth It? The Case of Acute Myocardial Infarction: Waste and inefficiency are not inevitable by-products of technological growth. *Health affairs*, 2006, 25(Suppl1): W34-W47.
- [8] Alba J W, Hutchinson J W. Dimensions of consumer expertise. *Journal of Consumer Research*, 1987, 13(4): 411-454.
- [9] Guiso L, Paiella M. Risk aversion, wealth, and background risk. *Journal of the European Economic association*, 2008, 6(6): 1109-1150.
- [10] Carroll C D. Buffer-stock saving and the life cycle/permanent income hypothesis. *The Quarterly journal of economics*, 1997, 112(1): 1-55.
- [11] Dohmen T, Falk A, Huffman D, et al. Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic association*, 2011, 9(3): 522-550.