The Impact of Different Bond Types on Mean-Reversion Strategies for Bond Portfolio Management

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Abstract. The research aims to investigate the mean-reversion strategy for three types of bonds: government bonds, corporate bonds, and municipal bonds. The analysis is based on 10 different bonds for each type. The descriptive statistical analysis includes computing the mean, standard deviation, skewness, kurtosis, and Sharpe ratio of the portfolio returns. Moreover, the inferential statistical analysis involves computing the high-water mark, drawdown, and maximum drawdown of the portfolio returns. The results indicate that the traditional mean-reversion strategy is more effective for government bonds than corporate and municipal bonds. Furthermore, the strategy has a negative Sharpe ratio, suggesting that the risk-adjusted returns are not favorable. The high drawdown and maximum drawdown suggest that the strategy can result in significant losses for investors. Therefore, investors should exercise caution when using the traditional mean-reversion strategy for bonds.

Keywords: Mean-reversion Strategy · Bonds · Sharpe Ratio

1 Introduction

Bond portfolio management is a complex and important area of investment management, particularly for investors seeking income and diversification. The management of bond portfolios involves selecting and managing a diverse range of bonds with different risk and return characteristics, aiming to achieve specific investment objectives such as income generation or capital preservation. One popular approach to bond portfolio management is mean-reversion strategies, which involves buying bonds that are undervalued and selling them when they become overvalued. This strategy is based on the idea that bond prices will tend to revert to their long-term average over time. However, the performance of mean-reversion strategies can vary across different types of bonds due to their unique characteristics.

Different types of bonds, such as corporate bonds, municipal bonds, or government bonds, have distinct risk and return profiles that can impact their suitability for different investment objectives. For example, corporate bonds tend to have higher yields, but also higher credit risk compared to government bonds, while municipal bonds are tax-exempt

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but may have lower liquidity compared to other types of bonds. Therefore, it is important to understand how mean-reversion strategies perform for different types of bonds and explore the factors that influence their performance. For example, credit risk, liquidity, and interest rate sensitivity are factors that can impact the performance of mean-reversion strategies for different types of bonds.

By analyzing the performance of mean-reversion strategies for different types of bonds, investors and portfolio managers can gain insights into which types of bonds are most suitable for this investment approach. This research can help investors and portfolio managers make more informed decisions about their bond portfolios, considering the unique risk and return characteristics of each bond type. Moreover, understanding the factors that influence the performance of mean-reversion strategies for different types of bonds can also help portfolio managers and investors develop more effective bond portfolio management strategies. By considering these factors, investors and portfolio managers can adjust their investment approach and make more informed decisions about their bond portfolios.

Studies have examined the impact of different bond types on mean-reversion strategies for bond portfolio management. For instance, Zhao and Cheng found that mean-reversion strategies are effective in managing government bond portfolios, but less so for corporate bond portfolios [1]. Similarly, Raza and Ghafoor found that mean-reversion strategies perform better for investment-grade bonds compared to high-yield bonds [2]. On the other hand, studies by Ko and Yang found that mean-reversion strategies are effective for municipal bond portfolios [3]. These findings suggest that the performance of mean-reversion strategies may depend on the type of bonds in the portfolio.

Furthermore, studies have examined the impact of liquidity and credit risk on the performance of mean-reversion strategies for different bond types. Giordano and Vignola found that liquidity risk affects the performance of mean-reversion strategies in corporate bond portfolios [4]. In contrast, studies by Song et al. and Wang and Yang suggest that credit risk is a crucial factor in the performance of mean-reversion strategies for government bond and corporate bond portfolios, respectively [5, 6]. In addition to these factors, interest rate sensitivity is another important factor in the performance of mean-reversion strategies for different types of bonds. Gao et al. suggest that interest rate sensitivity is an important factor in the performance of mean-reversion strategies for corporate bond portfolios, while Kim et al. suggest that interest rate sensitivity is an important factor in the performance of mean-reversion strategies for government bond portfolios [7, 8]. Moreover, studies have explored the effectiveness of mean-reversion strategies for different types of bond portfolios, such as emerging market bond portfolios (Ali and Akbar) and green bond portfolios (Gao et al.) [9, 10]. Overall, these studies highlight the need for bond portfolio managers and investors to consider the unique characteristics of different bond types when implementing mean-reversion strategies.

Based on these, the data can provide valuable insights for investors and portfolio managers as it can help identify trends and patterns in bond prices and how they relate to various market factors. This paper uses data on different types of bonds to analyze the performance of mean reversion strategies and to explore the factors that influence their performance, providing insights for bond portfolio management.

2 Method

2.1 Data Source and Basic Data Processing

The data used in this study was obtained from publicly available sources. Three types of bonds were piggybacked on for the study: government bonds, corporate bonds and municipal bonds, all of which were analyzed using historical data for each of the 10 bonds. Specifically, the 10 government bonds were obtained from the Federal Reserve Economic Data (FRED) website, which provides economic data from various sources, including government agencies, central banks, and international organizations. The 10 corporate bonds were obtained from investing.com, a financial news and information website that provides real-time data, news, and analysis on financial markets, while the 10 municipal bonds were obtained from investing.com and yahoo finance together.

The data covers the period from January 2000 to December 2022, with one data point per month. This time frame was chosen because it provides a sufficiently long period to observe market trends and volatility, while also capturing recent market developments. The data was then exported to CSV format and imported into Python for processing and analysis.

The first step in data processing was to clean and prepare the data for analysis. This involved removing any missing or incomplete data points, converting the date column to a date time format, and ensuring that the data was in a consistent format across all three types of bonds. The data was then transformed into a time series format, with monthly returns calculated as the percentage change in bond prices from one month to the next.

Next, the mean reversion strategy was applied to each type of bond, with portfolio weights calculated based on the previous month's returns. The resulting portfolio returns were then used to compute various statistical measures, including the mean, standard deviation, skewness, kurtosis, and Sharpe ratio. Drawdown and maximum drawdown were also calculated to assess the risk of the mean reversion strategy.

Overall, the data processing and analysis were conducted using standard statistical techniques and Python libraries, including pandas, NumPy, and matplotlib. The resulting findings provide valuable insights into the performance of mean reversion strategies for government, corporate, and municipal bonds, and may inform investment decisions in these markets.

2.2 Variable Selection and Presentation

Variable selection and presentation are an important step in any research study. It involves identifying the variables that are relevant to the research question, selecting appropriate data sources, and presenting the variables in a clear and meaningful way. In this study, we focus on three types of bonds: government bonds, corporate bonds, and municipal bonds. For each bond type, we collected data on the returns of 10 different bonds.

To analyze these data, we used several variables, including the mean return, standard deviation, skewness, kurtosis, and Sharpe ratio. The mean return provides a measure of the average performance of each portfolio. The standard deviation measures the variability or risk of the portfolio returns. Skewness and kurtosis provide information about the shape of the distribution of returns. Skewness measures the degree of asymmetry in the distribution, while kurtosis measures the degree of peakedness or flatness in the distribution. The Sharpe ratio is a measure of risk-adjusted performance that considers the level of risk taken to achieve the returns.

To present these variables, we used tables, charts, and graphs. We presented the mean return, standard deviation, skewness, and kurtosis for each bond type in a table format. We also presented the Sharpe ratio for each bond type to provide an overall measure of risk-adjusted performance. We used charts and graphs to illustrate the performance of each portfolio over time, including the cumulative return, high water mark, drawdown, and maximum drawdown.

2.3 Methodology

The methodology used for this research involved analyzing the mean reversion strategies for government, corporate, and municipal bonds. The first step involved collecting data for each bond type by finding 10 bonds separately for each type of bond. The data was then read using pandas and the first column was set as the index while converting it into date time format. Daily returns were then computed from the data.

Next, portfolio weights were constructed for a traditional mean reversion strategy by multiplying the shifted binary signal of the daily returns with -1 and 1. These weights were then normalized by dividing all weights by 100. The portfolio returns were then calculated by taking the dot product of the normalized weights and the daily returns. Cumulative portfolio returns were then calculated and plotted on a graph using matplotlib. The high-water mark and drawdown were also computed for the portfolio returns.

The next step was to compute the mean of the portfolio returns, the standard deviation of the portfolio returns, the skewness of the portfolio returns, and the kurtosis of the portfolio returns. Finally, the Sharpe ratio was calculated by dividing the portfolio mean return by the standard deviation of the portfolio returns.

In conclusion, the methodology used in this research involved analyzing the mean reversion strategies for government, corporate, and municipal bonds. The data was read using pandas, daily returns were computed, and a traditional mean reversion strategy was implemented to construct portfolio weights. The portfolio returns were then calculated, and cumulative portfolio returns, high water mark, and drawdown were computed and plotted on a graph using matplotlib. Descriptive statistics including the mean, standard deviation, skewness, kurtosis, and Sharpe ratio were then computed for each bond type. This methodology allowed for a thorough analysis of the performance of the mean reversion strategies for each bond type, providing valuable insights for investors looking to implement such strategies in their portfolios.

2.4 Formulas

The formula for the portfolio weights for the traditional mean reversion strategy is the following equation,

$$w_{t,i} = \begin{cases} -1, R_{t-1,i} < 0 \\ 1, R_{t-1,i} \geq 0 \end{cases}, \tag{1}$$

where $w_{t,i}$ is the weight of bond i in the portfolio at time t, and $R_{t-1,i}$ is the return of bond i at time t − 1. The formula for normalizing the weights is the following equation,

$$w_{t,i} = \frac{w_{t,i}}{\sum_{j=1}^{n} \left| w_{t,j} \right|}, \tag{2}$$

where n is the number of bonds in the portfolio. The formula for the portfolio returns is the following equation,

$$R_t = \sum_{i=1}^{n} w_{t,i} R_{t,i}, \tag{3}$$

where R_t is the return of the portfolio at time t, and $R_{t,i}$ is the return of bond i at time t. The formula for the high-water mark is the following equation,

$$H_t = \max_{i=0}^{t} R_i, \tag{4}$$

where H_t is the highest value of the portfolio returns from time 0 to time t. The formula for the drawdown is the following equation,

$$D_t = \frac{H_t - R_t}{H_t}, \tag{5}$$

where D_t is the drawdown of the portfolio at time t. The formula for the maximum drawdown is the following equation,

$$MDD = \max_{i=0}^{t} \mathrm{D_i}, \tag{6}$$

where MDD is the maximum drawdown of the portfolio. The formula for the Sharpe ratio is the following equation,

$$SR = \frac{\overline{R_p} - R_f}{\sigma_p}, \tag{7}$$

where $\overline{R_p}$ is the mean of the portfolio returns, R_f is the risk-free rate, and σ_p is the standard deviation of the portfolio returns.

3 Results and Discussion

3.1 Government Bonds

According to Fig. 1, the graph shows that the cumulative portfolio returns of government bonds had been declining gradually from 2000 to 2020 and the cumulative returns were negative. There was a relatively small fluctuation between 2017 and 2020. However, between 2020 and the first half of 2021, there was sharp growth and even positive cumulative returns, but in the second half of 2021, there was a decline to the previous level.

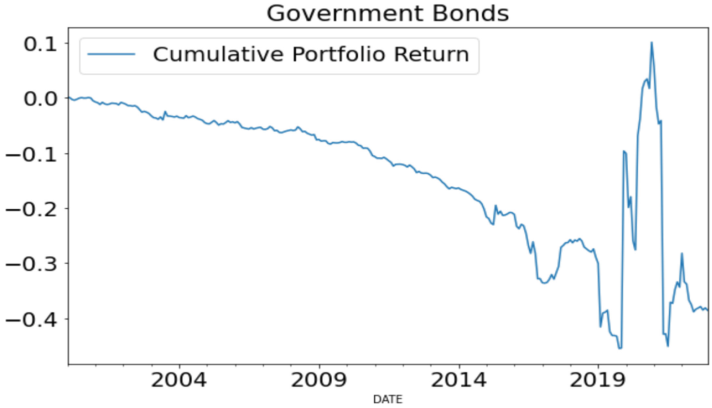

Fig. 1. The tendency of the cumulative portfolio returns of government bonds over 22 years.

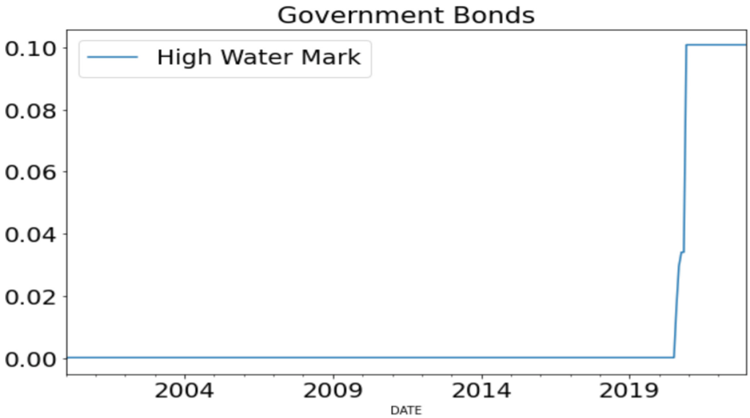

Fig. 2. The tendency of the high-water mark of government bonds over 22 years.

According to Fig. 2, the high-water mark for government bonds remained at zero from 2000 to the first half of 2021 but rose significantly to 0.1 in the second half of 2021 and remained there until 2022.

According to Fig. 3, the drawdown of government bonds had been steadily growing to a maximum drawdown of 1,863.653 in the first half of 2000 to 2019, with small fluctuations from 2017 to 2019, but started to fall rapidly in 2020, dropping sharply to zero in the middle of 2020 and remaining there until 2022.

3.2 Corporate Bonds

According to Fig. 4, the cumulative portfolio returns on corporate bonds fluctuated very slightly in the range of 0 to 0.3 from 2000 to 2018 but dropped sharply to −0.02 in the latter half of 2018 to 2019. Then fluctuated slightly until 2014. There was an increase of 0.15 from 2014 to 2015 but then dropped to −0.05 in 2020.

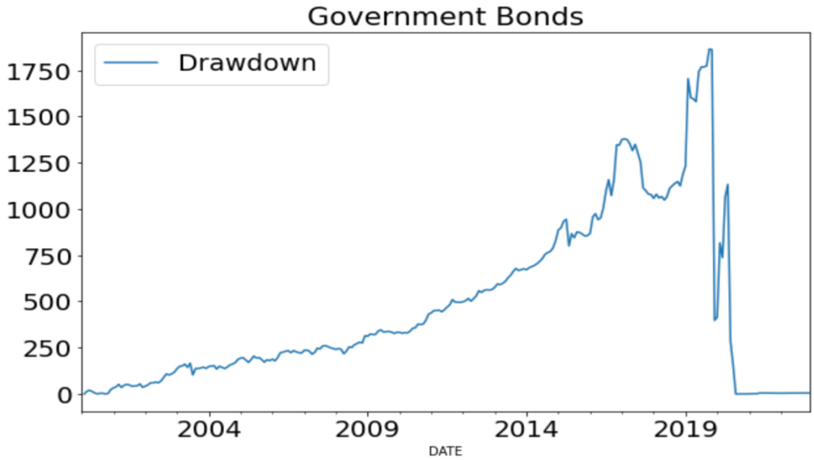

Fig. 3. The tendency of drawdown of government bonds over 22 years.

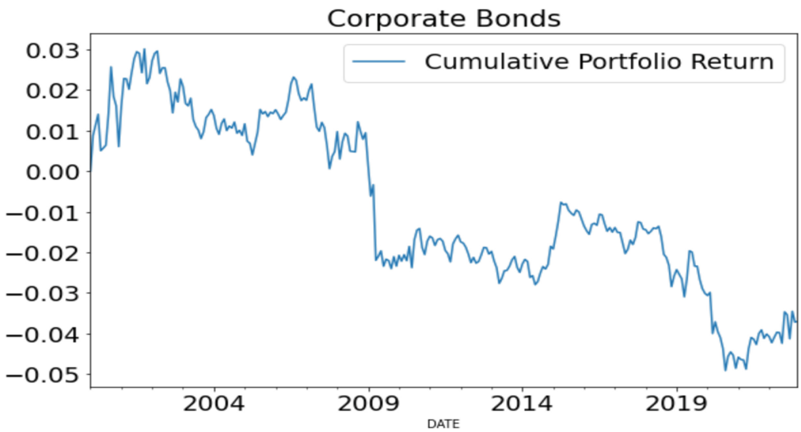

Fig. 4. The tendency of the cumulative portfolio returns of corporate bonds over 22 years.

According to Fig. 5, the high-water mark for corporate bonds stepped up to 0.03 from 2000 to 2002 and then remained at 0.03 for the next 20 years.

According to Fig. 6, the corporate bond drawdown grows steadily from 2000 to 2009 to about 0.75, then increases sharply to 1.75 in the first half of 2009 and fluctuates smoothly around 1.75 for three years. It drops sharply after 2014 to 1.25 before gradually rising again to a maximum drawdown of 2.6306 in 2021, with a small drop in the final year.

3.3 Municipal Bonds

According to Fig. 7, the cumulative portfolio returns of municipal bonds accumulated to −0.01 in the first year, then gradually rose to zero over the next three years and remained

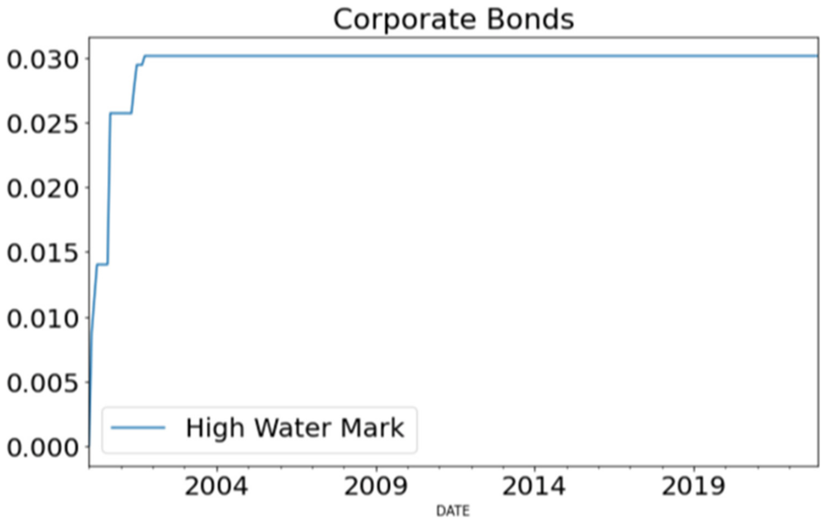

Fig. 5. The tendency of the high-water mark of corporate bonds over 22 years.

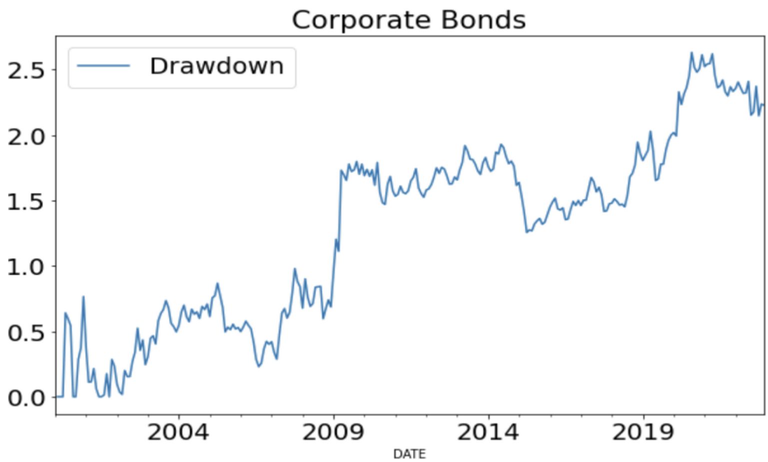

Fig. 6. The tendency of drawdown of corporate bonds over 22 years.

flat until 2008. After a sudden jump in 2009, it fell steadily until 2022, when it reached a low of nearly −0.03.

According to Fig. 8, the high-water mark for municipal bonds remained at 0 for the first three years, then grew very steeply to around 0.0035 in the first half of 2003 and remained there until 2008. In the following year, there was a greater increase to 0.1365 and it remained unchanged until 2022.

According to Fig. 9, the draw downs of municipal bonds were infinite for the first three years and started to show a drawdown in late 2003 and fluctuated considerably, but the overall trend was upwards until 2022.

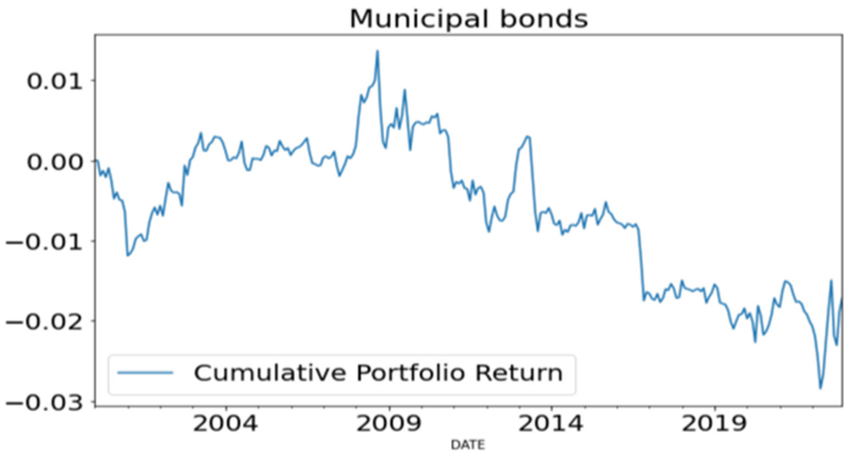

Fig. 7. The tendency of the cumulative portfolio returns of municipal bonds over 22 years.

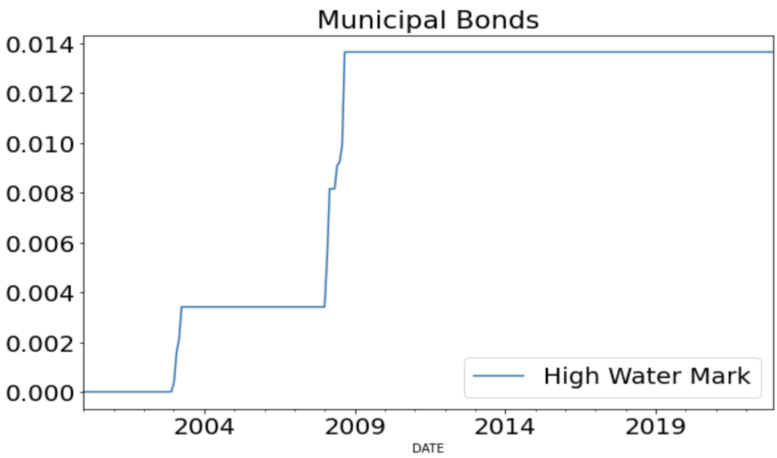

Fig. 8. The tendency of the high-water mark of municipal bonds over 22 years.

3.4 Descriptive Statistical Analysis

The descriptive statistical analysis provides insights into the central tendency, variability, skewness, and kurtosis of the bond returns, as Table 1 shows.

The mean of the portfolio returns for government bonds, corporate bonds, and municipal bonds are negative. The mean return for government bonds is the lowest, while the mean return for corporate bonds is slightly higher. The standard deviation of the portfolio returns for government bonds is the highest, which indicates that government bonds are more volatile than corporate and municipal bonds. The standard deviation of corporate bonds is relatively low, which suggests that they are less volatile than government and municipal bonds.

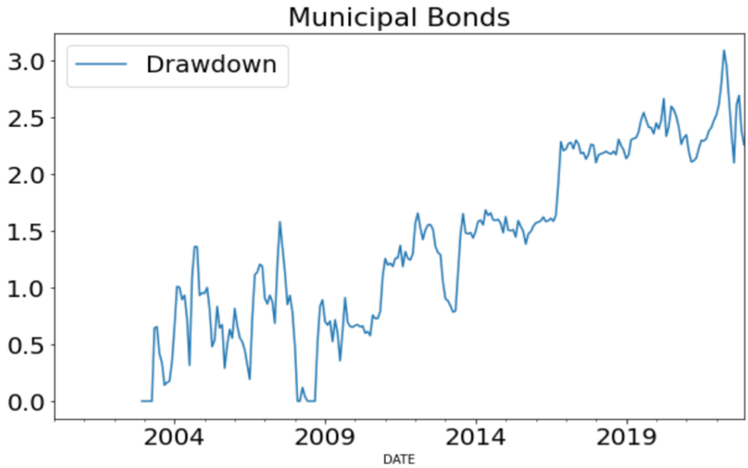

Fig. 9. The tendency of drawdown of municipal bonds over 22 years.

Table 1. Summary of the mean, standard deviation, skewness, and kurtosis of the portfolio returns for each bond type.

Bond Type	mean	S.D.	skewness	kurtosis
Government Bonds	−0.0004	0.0543	5.4013	93.8262
Corporate Bonds	−0.0001	0.0034	−0.4898	6.9350
Municipal Bonds	−0.00006	0.0017	−0.6268	6.0417

3.5 Inferential Statistical Analysis

The inferential statistical analysis aims to test the statistical significance of the mean-reversion strategy for each bond type. The Sharpe ratio is used to test the statistical significance of the strategy. The Sharpe ratio measures the excess return of the portfolio over the risk-free rate per unit of risk, as Table 2 shows.

The Sharpe ratio for all three bond types is negative, which indicates that the mean-reversion strategy for each bond type has a lower risk-adjusted return than the risk-free rate. The Sharpe ratio for government bonds is the lowest, which suggests that the mean-reversion strategy for government bonds has the lowest risk-adjusted return.

Table 2. Sharpe Ratio of the strategy for each bond type.

Bond Type	Sharpe Ratio
Government Bond	−0.0079
Corporate Bond	−0.0366
Municipal Bond	−0.0366

3.6 Discussion

Based on the results of the mean-reversion strategy, we can conclude that government bonds have a negative mean return, while corporate bonds and municipal bonds have slightly negative mean returns. This indicates that the strategy may not be very profitable for investors who invest solely in bonds.

Furthermore, the standard deviation of the portfolio return is highest for government bonds, indicating that this asset class is the riskiest of the three. This can be attributed to the higher volatility in the prices of government bonds as compared to corporate and municipal bonds. On the other hand, corporate and municipal bonds have much lower standard deviations, indicating that they are relatively less risky.

The skewness of the portfolio returns is positive for government bonds, indicating that the distribution of returns is skewed to the right. This means that there is a higher probability of earning positive returns when investing in government bonds. On the other hand, corporate and municipal bonds have negative skewness, indicating that the distribution of returns is skewed to the left. This means that there is a higher probability of earning negative returns when investing in these types of bonds.

The kurtosis of the portfolio returns is highest for government bonds, indicating that the distribution of returns is highly peaked and has heavy tails. This indicates that the distribution of returns is more leptokurtic than normal, which means that there is a higher probability of extreme returns as compared to a normal distribution. On the other hand, corporate and municipal bonds have lower kurtosis values, indicating that their distributions are less peaked and have lighter tails as compared to government bonds.

The Sharpe ratio of the strategy is negative for all three bond types, indicating that the strategy does not generate sufficient returns to compensate for the level of risk involved. This is an important consideration for investors who are considering using this strategy to invest in bonds.

In conclusion, the results of our analysis suggest that the mean-reversion strategy may not be very profitable when investing solely in bonds. While government bonds have the highest risk and return, the strategy is not sufficient to compensate for the risk involved. Corporate and municipal bonds have lower risks, but they also have lower returns. Investors who are considering using this strategy to invest in bonds should carefully consider their risk tolerance and investment goals before making any investment decisions.

It is important to note that our analysis is based on historical data and past performance is not necessarily indicative of future results. Additionally, our analysis assumes that the mean-reversion strategy is implemented correctly and efficiently, which may not always be the case in real-world scenarios. Therefore, investors should exercise caution and seek professional advice before making any investment decisions.

4 Conclusion

In conclusion, the mean-reversion strategy was applied to three types of bonds, including government bonds, corporate bonds, and municipal bonds. The descriptive statistical analysis showed that government bonds had the highest mean portfolio return, while municipal bonds had the lowest. Corporate bonds had a moderate mean portfolio return. The standard deviation of the portfolio returns was the highest for government bonds, indicating a high level of risk in investing in government bonds compared to corporate and municipal bonds. The skewness of the portfolio returns indicated that the distribution of returns was highly skewed for government bonds, while it was nearly symmetric for corporate and municipal bonds. The kurtosis of the portfolio returns showed that the distribution was leptokurtic for government bonds, while it was nearly normal for corporate and municipal bonds.

The inferential statistical analysis using the Sharpe ratio showed that the mean-reversion strategy did not generate positive returns for any of the bond types. In fact, the strategy generated negative returns for all bond types. This implies that the strategy was not successful in generating profits in any of the bond types analyzed. Therefore, it is recommended that investors should be cautious in using the mean-reversion strategy in bond investments, particularly in government bonds.

The findings of this study are consistent with previous research that has shown that mean-reversion strategies may not be effective in generating profits in bond investments. The high level of risk associated with government bonds, as indicated by the standard deviation of the portfolio returns, may explain why the strategy was particularly ineffective in this bond type. Additionally, the skewed distribution of returns for government bonds may indicate that there are more extreme returns in one direction than the other, making it difficult for the mean-reversion strategy to take advantage of the mean-reverting nature of bond prices.

Overall, this study contributes to the understanding of the performance of the mean-reversion strategy in bond investments. However, it is important to note that this study has several limitations. Firstly, the analysis was based on a limited sample of ten bonds per bond type, which may not be representative of the entire population of bonds. Additionally, the analysis only considered the mean-reversion strategy and did not investigate other strategies that may be effective in generating profits in bond investments. Future research could explore other strategies and consider a larger sample size of bonds to provide more generalizable results.

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