# Risk and Reward of Various Gambling Methods

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# 1 Abstract

In this paper, we compare different methods of gambling money, mainly focusing on NFL betting. From data collected from The Odds API, we tested the accuracy of bookmaker predictions, the impact of timing on the accuracy of odds, and the overall effectiveness of various betting strategies.

We began by analyzing historical odds data for the NFL (2020–2023 seasons) to calculate probabilities and assess prediction accuracy. Using paired t-tests, we determined significant variations in accuracy among bookmakers, with some outperforming up to 22 other bookmakers. Additionally, paired difference tests revealed that odds accuracy improved by an average of less than 2% closer to game time, highlighting the influence of updated information. Comparative analyses show that betting on unfavored teams offers the highest return with the lowest variance among sports betting strategies.

From there, we went on to compare the rate of return of NFL betting to roulette and mega millions. Finally, we found the level of risk aversion required to favor gambling over investing in the S&P 500, providing insights into decision-making under uncertainty.

# Contents

## 2 Introduction

As sports betting has become legalized and more popular in the US, concerns have grown about the level of risk incurred by participants. However, this has sparked an interesting debate about the risk in other legalized forms of gambling such as casinos and lotteries, the latter of which is typically sanctioned by the state. It also raises questions about speculative markets.

The primary objective of this report is to compare both the returns and risks of these different methods. Additionally, we plan to analyze different strategies that could be used in sports betting to see how they affect the return and risk and then use that to see what level of risk aversion someone would need to choose sports betting over the other options. Finally, we want to analyze the accuracy of sports bet makers, to see how well their analysts have historically determined odds. To summarize, the key questions addressed through various tests and statistical analyses in this report include:

1. What strategies can maximize returns and minimize risk for winnings from sports betting?
2. How accurately do bookmakers predict outcomes?
3. How does the amount of time until the game affect the accuracy of the prediction?
4. How does the expectation and variance of sports betting compare to typical gambling methods?
5. What level of risk-aversion would someone need to choose one of these strategies over investing in the S&P 500?

## 3 Data Collection

To answer these questions, we started by looking for relevant datasets to analyze. For the S&P 500, we obtained historical performance data from the Wall Street Journal that contained daily open and close prices since September 2020. For sports betting, we utilized The Odds API, which provided historical odds and outcomes for the 2020-2023 NFL seasons, allowing us to calculate implied probabilities and assess their accuracy. For casino games, we referenced probabilities and payout structures documented on Wikipedia to model potential outcomes. Finally, for lotteries, we used official resources such as Lottery USA and the Mega Millions website to extract prize structures and associated probabilities for Powerball and Mega Millions. These datasets will serve as the foundation for our comparative analysis of returns, risks, and strategies across different forms of gambling and speculative markets.

# 4 Analysis of Sports Betting

Before comparing the statistics between sports betting with other activities, this section outlines key statistics in sports betting, including expectation and variances, which serve as a foundation for understanding the differences in the risk-reward relationship across sports betting, casinos, lotteries, and the S&P 500.

**Question 1: What strategies can maximize returns and minimize risk for winnings from sports betting?**

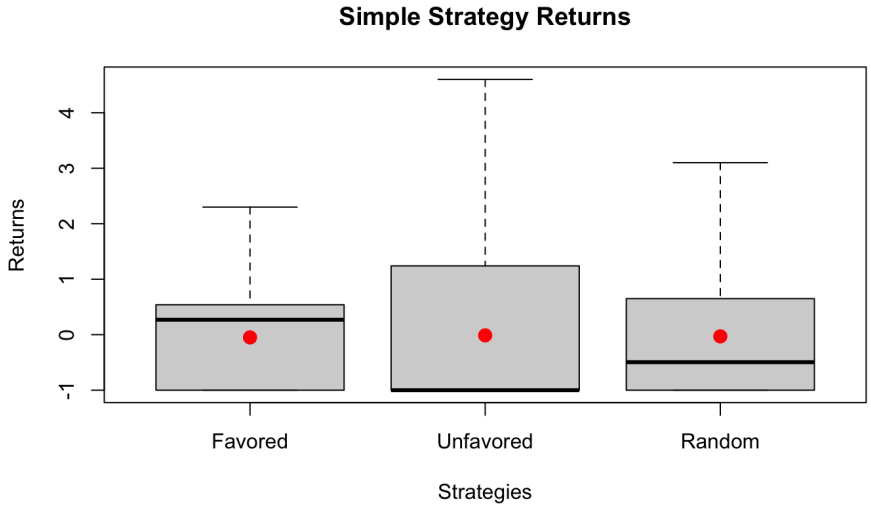


Figure 1: Boxplot with Means for Simple Strategy Returns
(Outliers excluded due to size)

Figure 1 presents a comparison of three distinct betting strategies: wagering exclusively on the favored team, betting on only the underdog, and randomly selecting a team. In this case, the favored strategy has expectation of -0.049 and variance of 0.514. For the unfavored strategy the expectation is -0.012 and the variance is 16.418. Finally for a random strategy the expectation is -0.030 and the variance is 8.467. We found using a 1 sided t-test, the unfavored strategy has greater returns than the favored strategy within a 95% CI of $(0.0186, \infty$ and the unfavored team has a variance $(31.63302, \infty)$ times higher than the favored strategy according to a 95% CI. This is a crucial find as it shows there is a risk premium for betting using the unfavored strategy, where standard concepts of Utility hold, a greater risk requires a greater expected return. It is important to note that if a strategy were to yield a high expectation along with a

high variance, a strategy with a lower expectation but lower variance may still be more compelling in terms of profit, due to its more favorable risk-return rate.

**Question 2: How accurately do bookmakers predict outcomes?**

To evaluate the reliability and overall appeal of sports betting, we assess the variations in accuracies across different bookmakers and the overall effectiveness under different conditions, such as time until the event.

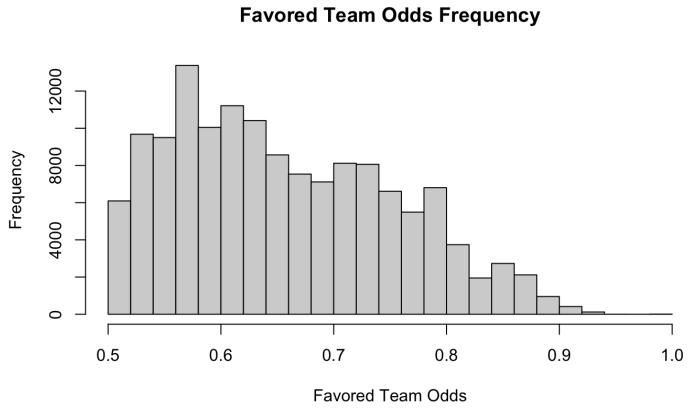


Figure 2: Histogram of Maximum Odds Between Home and Away Teams

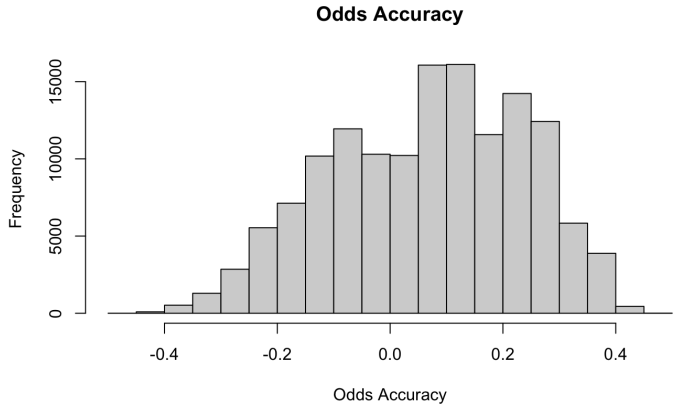


Figure 3: Histogram of Odds Accuracy

Figure 2 illustrates the distribution of maximum odds between home and

away games to be right-skewed, ranging from 0.5 to 0.95. A large concentration of odds are observed in the 0.5 to 0.65 range indicating competitiveness with no team heavily favored. The rarity of odds set at rates greater than 0.8 indicates bookmakers' tendencies of avoiding extreme disparities and promoting more balanced match-ups. The histogram of odds accuracy displayed in Figure 3 is shown to have a slight left skew with values from -0.45 to 0.45. The left skew suggests a tendency of bookmakers to underestimate outcomes through undervaluing underdogs or overvaluing favorites. While a majority of the values are seen in the 0.5 to 0.1 range, indicating reasonably accurate predictions, the presence of outliers reflects unexpected results and opportunities for bettors to capitalize on.

Building on insights gathered from the distribution of odds and accuracies, we now investigate variations in accuracy across different bookmakers and the impact it has on betting outcomes. Identifying bookmakers with higher predictive accuracy reduces risk for bettors thereby inherently increasing long-term profitability.

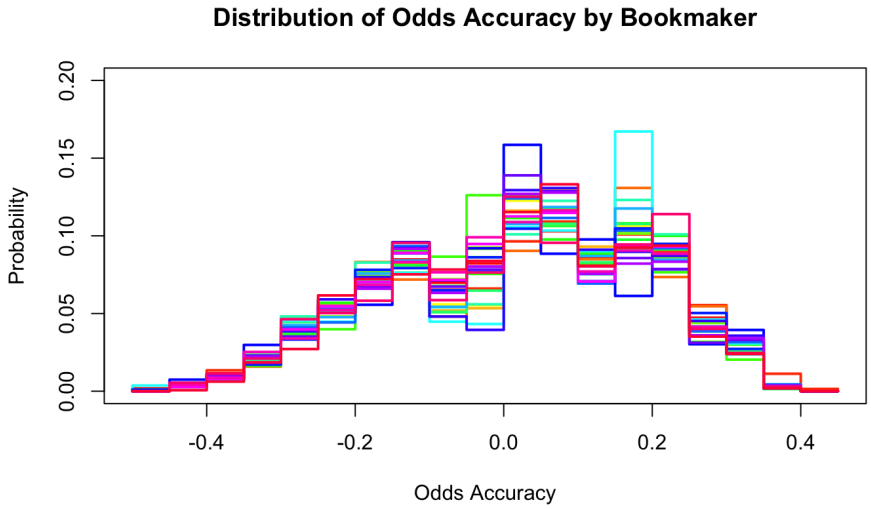


Figure 4: Bookmakers' Odds Accuracy PMFs

Figure 4 shows the probability mass functions of each bookmaker's odds accuracy. The PMFs resemble a bell curve which supports the assumption of normality in the distribution of bookmakers' odds accuracy. Because of the varying probabilities across bookmakers and normality, we can identify those with lower risk based on their accuracies.

Using paired t-tests we were able to find more information on the relative

accuracies of the bookmakers. Given below are five bookmakers—GTbets, BetOnline.ag, William Hill (US), LowVig.ag, Betfair—that demonstrate relatively higher accuracy compared to others, and five bookmakers—DraftKings, Unibet, PointsBet, TwinSpires, FOX Bet—that show lower accuracy. However, the paired t-tests conducted do not provide sufficient evidence to establish a ranking or definitive comparison across bookmakers.

- GTbets is more accurate than 22 other bookmakers.
- BetOnline.ag is more accurate than 18 other bookmakers.
- William Hill (US) is more accurate than 18 other bookmakers.
- LowVig.ag is more accurate than 16 other bookmakers.
- Betfair is more accurate than 16 other bookmakers.
- DraftKings is less accurate than 16 other bookmakers.
- Unibet is less accurate than 16 other bookmakers.
- PointsBet (US) is less accurate than 17 other bookmakers.
- TwinSpires is less accurate than 20 other bookmakers.
- FOX Bet is less accurate than 21 other bookmakers.

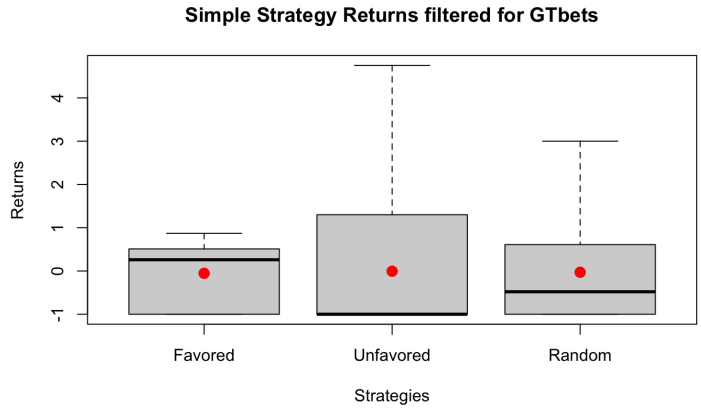


Figure 5: Boxplot with Means for Simple Strategy Returns Filtered for GTbets (Outliers excluded due to size)

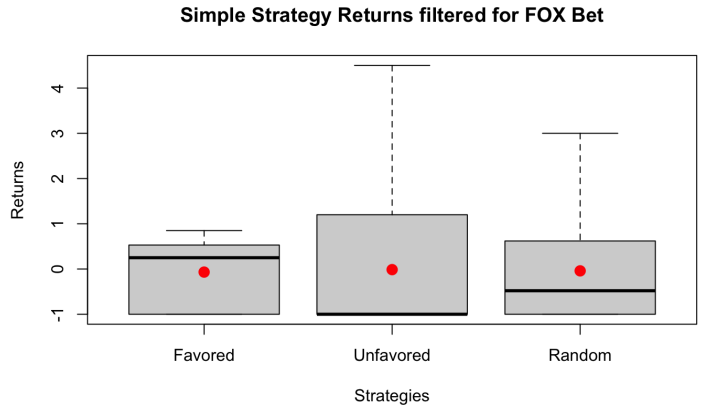


Figure 6: Boxplot with Means for Simple Strategy Returns filter for FOX Bet (Outliers excluded due to size)

To assess how choosing a bookmaker affects a bettor's expected profits, we compare the expectation and variance of the highest and lowest relative performing bookmaker found through the paired t-tests above. The results of our calculation are shown below:

| **GTbets** | **Expectation** | **Variance** |
|---|---|---|
| Favored Teams (Odds $>$ 0.5) | -0.05304007 | 0.4977311 |
| Unfavored Teams (Odds $<$ 0.5) | -0.00570674 | 2.288268 |
| Random Betting | -0.02937341 | 1.393433 |

Table 1: Simple Strategy Returns filtered for GTbets

| **FOX Bet** | **Expectation** | **Variance** |
|---|---|---|
| Favored Teams (Odds $>$ 0.5) | -0.06785427 | 0.4982867 |
| Unfavored Teams (Odds $<$ 0.5) | -0.01332479 | 2.134587 |
| Random Betting | -0.04058953 | 1.316939 |

Table 2: Simple Strategy Returns filtered for FOX Bet

The highest expected profit is observed when betting on unfavored teams through GTbets which aligns with our previous insight that taking higher levels of risk, indicated by larger variance, results in larger profits or expectations. Using a two-sided t-test comparing GTbets, a bookmaker with relative high accuracy, against general betting using all bookmakers, we determined there is not sufficient evidence to conclude that higher accuracy bookmakers result in greater profits for bettors.

Now will we look at the error in the calculated percentages at different levels of favor.

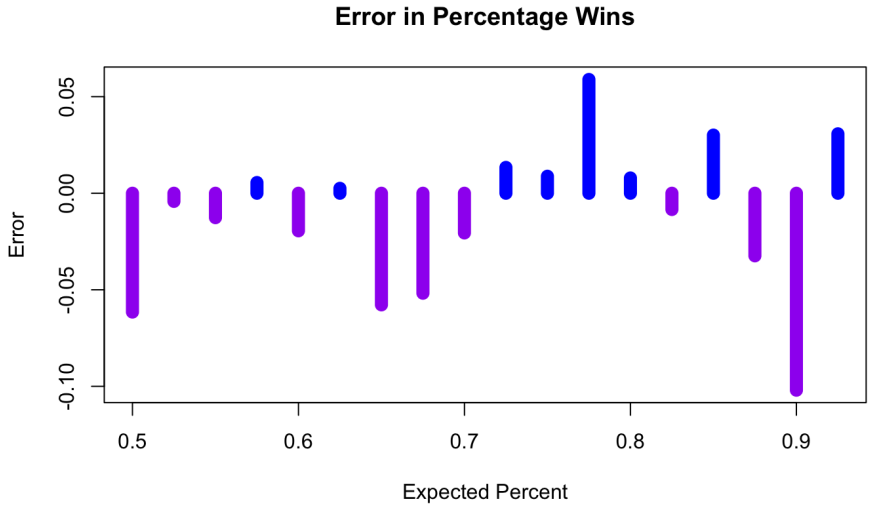


Figure 7: Error at different levels of favor

Figure 7 showed that while there are errors, there is no linearity, so a linear regression model would not be accurate. Instead a test on the inference on population proportions would be a better fit.

| range | expected % | actual % | error | n | $Z_0$ | test $\neq$ | test $>$ | test $<$ |
|---|---|---|---|---|---|---|---|---|
| 0.5, 0.525 | 0.514 | 0.452 | -0.062 | 8851 | -11.582 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.525, 0.55 | 0.537 | 0.533 | -0.004 | 11669 | -0.913 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.55, 0.575 | 0.563 | 0.550 | -0.013 | 14328 | -3.052 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.575, 0.6 | 0.587 | 0.593 | 0.006 | 13518 | 1.311 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.6, 0.625 | 0.612 | 0.592 | -0.019 | 13489 | -4.638 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.625, 0.65 | 0.636 | 0.639 | 0.003 | 12969 | 0.602 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.65, 0.675 | 0.662 | 0.604 | -0.058 | 9613 | -11.979 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.675, 0.7 | 0.686 | 0.635 | -0.052 | 9100 | -10.646 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.7, 0.725 | 0.713 | 0.692 | -0.021 | 10505 | -4.658 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.725, 0.75 | 0.738 | 0.751 | 0.013 | 9266 | 2.927 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.75, 0.775 | 0.762 | 0.771 | 0.009 | 7146 | 1.748 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.775, 0.8 | 0.787 | 0.846 | 0.059 | 8174 | 13.021 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.8, 0.825 | 0.811 | 0.819 | 0.008 | 4323 | 1.330 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.825, 0.85 | 0.838 | 0.829 | -0.008 | 2767 | -1.201 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.85, 0.875 | 0.862 | 0.892 | 0.030 | 3198 | 4.942 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.875, 0.9 | 0.885 | 0.853 | -0.032 | 1216 | -3.546 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.9, 0.925 | 0.910 | 0.808 | -0.102 | 463 | -7.660 | $> 1.96$ | $> 1.645$ | $< -1.645$ |
| 0.925, 0.95 | 0.929 | 0.960 | 0.031 | 75 | 1.039 | $> 1.96$ | $> 1.645$ | $< -1.645$ |

Table 3: Inference on Population Proportions

Table 1 shows the results from the tests on the inference on the population proportions. It shows that at certain ranges the bookmakers do have higher accuracies, and there is something of a pattern as to when they are more or less accurate, but further non-linear analysis or other factors would be necessary to understand.

**Question 3: How does the amount of time until the game affect the accuracy of the prediction?**

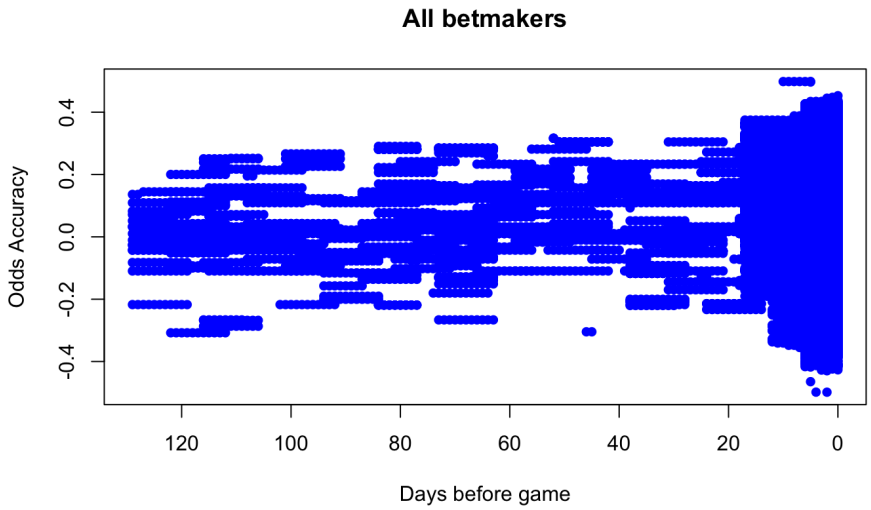


Figure 8: Accuracy of Odds Over Time

The variations observed in odds accuracy from 20 days before the game through to 0 days, supports the impact of time on odd accuracy. This is largely due to more information such as injuries and weather conditions that bookmakers adjust odds to incorporate. The changing variance indicates that a linear regression model would not be a good fit for this. Instead, a difference in 2 paired populations may provide a more accurate analysis.

Table 2 below shows the results from a paired difference test, with red-highlighted values indicating the failure to reject the null hypothesis. While the average improvement is small, at less than 2% across the board, the results from the one-sided hypothesis test and p-value test with significance level of $\alpha = 0.05$, provide sufficient evidence to show that majority of bookmakers' odds become more accurate as time progresses.

| bookmaker | $\overline{d}$ | n | $t_0$ | test $\neq$ | test $\uparrow$ | test $\downarrow$ | p-value |
|---|---|---|---|---|---|---|---|
| FanDuel | 0.009 | 1093 | 4.965 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| Betfair | 0.014 | 805 | 4.191 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.000 |
| GTbets | 0.008 | 796 | 4.411 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.000 |
| BetOnline.ag | 0.003 | 1093 | 2.922 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.002 |
| LowVig.ag | 0.003 | 1047 | 2.568 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.005 |
| Unibet | 0.009 | 1097 | 5.193 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| BetRivers | 0.009 | 1097 | 5.305 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| DraftKings | 0.014 | 1097 | 6.046 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| William Hill (US) | 0.007 | 890 | 4.373 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.000 |
| MyBookie.ag | 0.007 | 1092 | 4.149 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| Bovada | 0.008 | 1092 | 4.925 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| Intertops | 0.003 | 733 | 2.138 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.016 |
| Bookmaker | 0.002 | 254 | 1.132 | $> 1.969$ | $> 1.651$ | $< -1.651$ | 0.259 |
| PointsBet (US) | 0.007 | 1096 | 4.886 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| BetMGM | 0.005 | 1048 | 4.191 | $> 1.962$ | $> 1.646$ | $< -1.646$ | 0.000 |
| SugarHouse | 0.011 | 651 | 4.513 | $> 1.964$ | $> 1.647$ | $< -1.647$ | 0.000 |
| Caesars | 0.014 | 259 | 4.431 | $> 1.969$ | $> 1.651$ | $< -1.651$ | 0.000 |
| BetUS | 0.003 | 827 | 2.490 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.006 |
| SuperBook | 0.003 | 569 | 2.144 | $> 1.964$ | $> 1.648$ | $< -1.648$ | 0.016 |
| WynnBET | 0.002 | 744 | 1.527 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.127 |
| Barstool Sportsbook | 0.008 | 720 | 3.992 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.000 |
| TwinSpires | 0.010 | 715 | 4.784 | $> 1.963$ | $> 1.647$ | $< -1.647$ | 0.000 |
| FOX Bet | 0.005 | 446 | 2.559 | $> 1.965$ | $> 1.648$ | $< -1.648$ | 0.005 |
| Circa Sports | 0.008 | 252 | 3.336 | $> 1.969$ | $> 1.651$ | $< -1.651$ | 0.000 |

Table 4: Paired difference test on bookmaker accuracy over time

**Additional Insight: Has the margin of sports betting changed?**

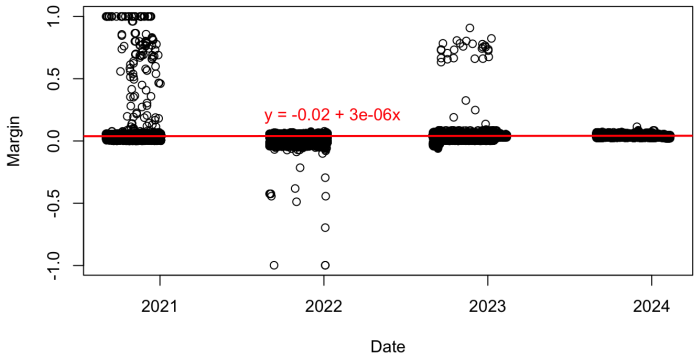


Figure 9: Margin linear regression

Figure 7 shows a linear regression of the margin. However, due to changes in variance and a low $R^2$ value of 0.0021, this model is not a good fit, so we decided to rather use a test on the means of 2 populations to see if there is a difference from year to year.

| **Test** | $F_0$ | $n_{\text{year1}}$ | $n_{\text{year2}}$ | $F_{\alpha/2}$ | $F_{1-\alpha/2}$ | Result |
|---|---|---|---|---|---|---|
| 2020 vs 2021 | 7.886107 | 23553 | 33651 | 1.023803 | 0.9767019 | Not Equal |
| 2021 vs 2022 | 1.020836 | 33651 | 45811 | 1.020085 | 0.9802808 | Not Equal |
| 2022 vs 2023 | 11.24681 | 45811 | 37655 | 1.019478 | 0.9809126 | Not Equal |

Table 5: F-test Results for Equal Variance

Table 3 shows the result of the difference in variances for 2 populations tests. We found the variances for every set of consecutive years are not equal with significance level 0.05.

| **Data Pair** | **Mean (year 1)** | **Mean (year 2)** | **95% CI ($\neq$)** | **95% CI ($\uparrow$)** | **95% CI ($\downarrow$)** |
|---|---|---|---|---|---|
| 2020 Season vs. 2021 Season | 0.0401 | 0.0372 | (0.0030, 0.0045) | $(-\infty, 0.0044)$ | $(0.0031, \infty)$ |
| 2021 Season vs. 2022 Season | 0.0372 | 0.0416 | (-0.0046, -0.0041) | $(-\infty, -0.0041)$ | $(-0.0046, \infty)$ |
| 2022 Season vs. 2023 Season | 0.0416 | 0.0428 | (-0.0015, -0.0011) | $(-\infty, -0.0011)$ | $(-0.0014, \infty)$ |

Table 6: Summary of Welch Two Sample t-tests with Confidence Intervals

Table 4 shows the result of the tests for difference in means for 2 populations. This showed us that the 2020 season had higher average margins than the 2021 season, but since then the margin has decreased every year with significance $\alpha = 0.05$.

# 5 Other Games

**Question 4: How does the expectation and variance of sports betting compare to typical gambling methods?**
In the section, we will explore the return rate of some casino games and the lottery.

1. Roulette
   The expected return of a 1$ bet on a roulette wheel is given by:

$$\frac{36}{n} - 1$$

   where $n$ is the number of pockets in the wheel. Since American Roulette typically has 38 pockets, the expected value is:

$$\frac{36}{38} - 1 \approx -0.052$$

   Or, if somebody bets 1$ over and over again, they are expected to lose 0.052 cents per bet in the long run no matter the bet they make. We can also calculate the variance, although it depends on the type of bet made:

$$\sigma^2 = E[(X - \mu)^2] = p(R_{win} - E[x])^2 + (1 - p)(-1 - E[x])^2$$

   Where $p$ is the probability of winning the bet, and $R$ is the reward from winning the bet. Losing the bet loses the dollar wagered, so the reward for losing is $-1$ For bets on 0 or 00 (single number bets), the reward is 35 for every dollar with a 1 in 38 chance of winning, so we have:

$$\sigma^2 = \frac{1}{38}(35 - (-0.0526))^2 + \frac{37}{38}(-1 - (-0.0526))^2 \approx 33.2078$$

   For Red/Black or Odd/Even bets (Even-Money Bets), the reward is 1 dollar for every dollar wagered with an 18 in 38 chance of winning. So:

$$\sigma^2 = \frac{18}{38}(1 - (-0.0526))^2 + \frac{20}{38}(-1 - (-0.0526))^2 \approx 0.9972$$

   From here, we can compare to the sports data:

| **Type** | **Less** | **Not Equal** | **Greater** |
|---|---|---|---|
| Favored | 0.957 | 0.087 | 0.043 |
| Unfavored | $\approx 1$ | $\approx 0$ | $\approx 0$ |

Table 7: P-Values comparing Sports Betting and Return from Roulette

   From this table, with 95% confidence, that we have sufficient evidence to say that both the favored and unfavored teams have higher returns on average than roulette.

2. Mega Millions
   The odds of each prize is given on the official website. However, the jackpot is different for each time it runs. So, we can calculate the expected value based on the information from the website:

$$\sum_{i \neq jackpot} R_i P_i \approx 0.2466$$

   Where R is the prize and P is the probability of getting that prize for each prize $i$ not including the jackpot. From the list of all the previous jackpots, we can find the expected value of each ticket each time somebody won the jackpot:

$$\frac{R_{jackpot}}{302575350} + 0.2466$$

   Since the price of a ticket is 2 dollars, we can find the expected return of 1 dollar:

$$(\frac{E[R]}{2}) - 1$$

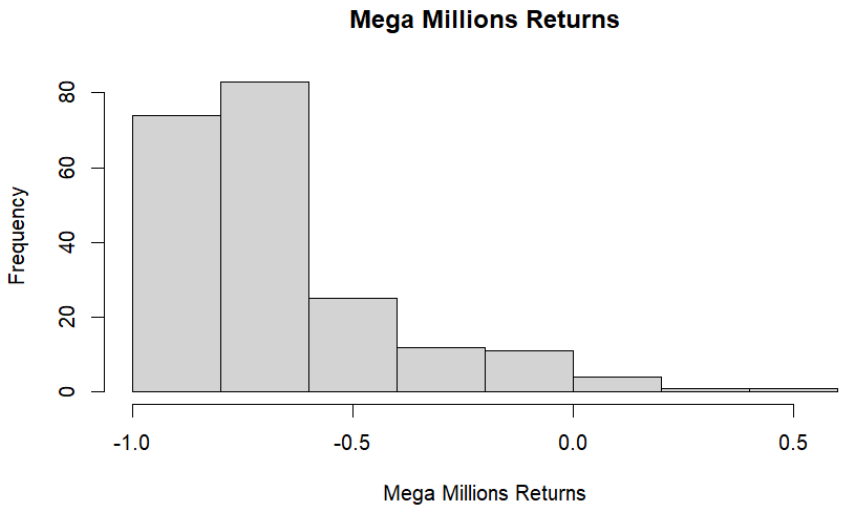


Figure 10: Returns for Mega Millions

Comparing this to the returns on sports betting, we get:

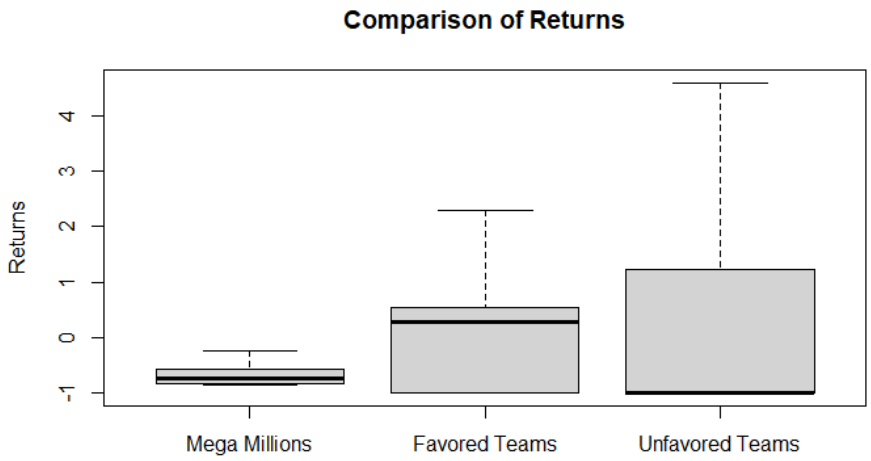


Figure 11: Mega Millions vs Sports Betting

| Type | Less | Not Equal | Greater |
|---|---|---|---|
| Favored | $4.5 \times 10^{-92}$ | $9.0 \times 10^{-92}$ | $\approx 1$ |
| Unfavored | $2.9 \times 10^{-114}$ | $5.8 \times 10^{-114}$ | $\approx 1$ |

Table 8: P-Values for Mega Millions vs Favored and Unfavored Returns

From the table, with 95% confidence, we have sufficient evidence that mega millions has lower returns on average compared to sports betting on both the favored and unfavored teams.

# 6 S&P 500 Comparison

**Question 5: What level of risk-aversion would someone need to choose one of these strategies over investing in the S&P 500?**

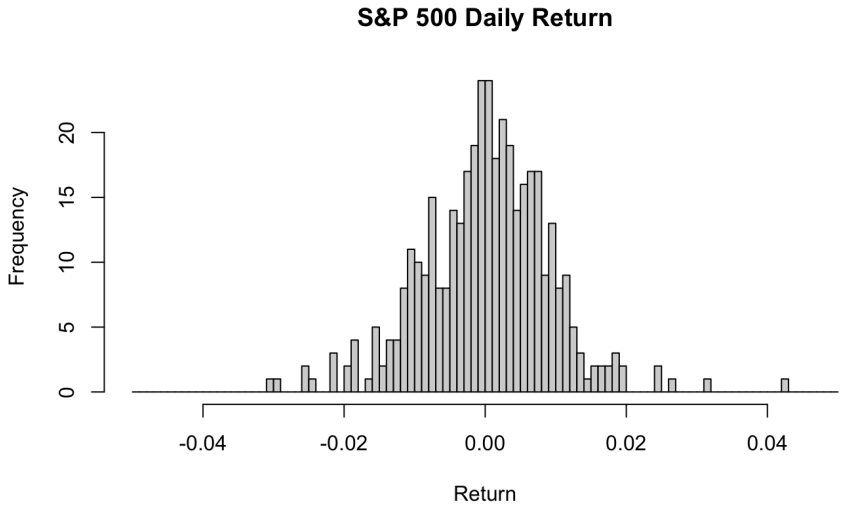


Figure 12: Returns for S&P 500 Over the 2020-2023 NFL Seasons

Expectation: 0.0002 Variance: 0.00008

Using a two-sided 95% CI we found the difference in means for the S&P 500 and the unfavored strategy was (-0.033445269 0.009126891). As this includes 0, we fail to reject that the difference in means is not 0. Using a 95% CI on the ratio of variances, we found that the ratio of S&P 500 to unfavored strategy variances is between $(177724.6, \infty)$. On the other hand, comparing with the favored strategy, we found the difference in means for the S&P 500 using a one-sided 95% CI to be $(-\infty, -0.04566303)$ which shows strong evidence that the mean of the favored strategy is less than the mean of S&P 500. Using a 95% CI on the ratio of variances, we found the ratio of S&P 500 to favored strategy to be between $(5569.046, \infty)$.

Given these findings, the S&P 500 is seen to be the most optimal option of the gambling methods because it has greater than or equal expected return and lower variance. There is no level of positive risk aversion that would make any other method preferable to the S&P.

# 7 Conclusions

Through this study, we analyzed the varying risk-reward dynamics of sports betting. We found that much of sports betting cannot be linearly modeled, but there are some useful insights. A significant conclusion was the risk-premium for betting on the unfavored team. This makes sense in the context of risk-aversion, as higher risk should demand a higher average return.

We also found that there are differences between bookmakers that could lead

to opportunity, but in study did not show any significant results. There was also differences in the accuracy at different levels of favor, but that would require a nonlinear model which was outside of the scope of this study.

Another insight was that bookmakers did get more accurate as they got closer to the date of the game, but the variance changed over time, making it unfit for linear analysis.

We also found the margin of sports betting has changed over the last 4 seasons, and we expect to see further growth in the margin as it becomes more popular.

Finally, we compared sports betting to roulette and the Mega Millions and had evidence to suggest sports betting had the highest returns on average.

Overall, through this report, we are able to see the importance of risk tolerance when it comes the realm of speculation. Future studies could elaborate on this research by expanding the study using broader datasets, alternative analysis methods, and potentially real-time market conditions to further develop the understanding of risk versus reward.

# 8 Future Work

In the future, we would like to see if there are more factors besides the risk premium of unfavored-favored. This would be a factor model, that albeit would be a simple model, but could help inform a more complex algorithm. We were inspired to pursue these ideas initially by the work of Fama-French in finance, and hope to see if similar multi-linear regressions can be done in sports-betting.