

Analysis of Betting Strategies in the NFL Playoffs Through Bayesian Hierarchical Simulation

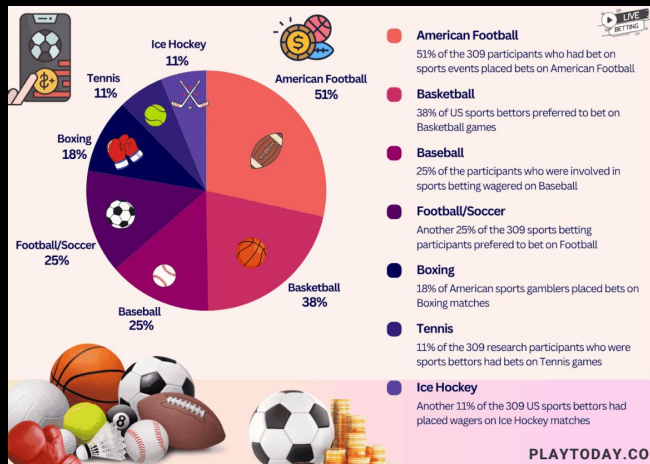
BRANDON OWENS

INTRODUCTION



- Professional and Amateur Sports Protection Act (PASPA)
 - Legalization of online sports betting in 2018
- Journal of Quantitative Analysis in Sports (ASA)
- Team-side explosion in Statistics + Analytics

INTRODUCTION



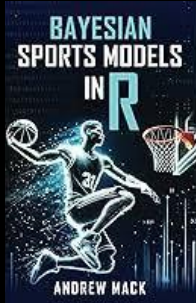
● \$70 billion market size in 2024

- NFL 17.5 million viewers/ game
- \$1.39 Billion wagered on Super Bowl LIX
- 127.7 million viewers in the super bowl
- 51% of all sports wagers on the NFL

● 2024-2025 NFL Season

2024 NFL Regular Season Schedule																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	2023
1	DAL @Cin	NO @Bal	@NYG @Pit	Det @W	@SF	@Ad	Phi Hou	@Waa NYG	Cin	@Car TB	@Phi Was	DAL	12.5 WC						
2	PHI GB	Atl @NO	@TB	Det @Cin	@NYG @Cin	Jac	@Dal Was	@LAR @Bal	Car	Pit @Waa	Dal NYG	PHI	11.4 WC						
3	NYG Min	@Waa	@Cle Dal	@Sea	Cin	Phi	@Phi Was	@TB	@Bal	NO	Atl NYG	WAS	4-11						
4	WAS @TB	NYG @Cin	@Atl	Chi @Bal	Car	Chi	@NYG Pit	@Phi Dal	Ten	@NO	Phi Ad	WAS	4-11						
5	DET LAR	TB @Atl	Sea @Pit	@Min Ten	@GB	@Hou Jac	@Ind Chi	GB	Buf @Chi	@SF Min	DET	12.5 CG							
6	GB @Phi	Ind @Ten	Min @LAR	Ari	Hou @Jac	Det	@Chi SF	Mia	@Det	@Sea NO	@Min Chi	GB	9.8 DP						
7	MIN @NYG	SF Hou	@GB NYJ	@Pit	Det	@LAR Ind	@Jac	@Ten	@Chi Ari	Atl @Sea	GB @Det	MIN	7.40						
8	CHI Ten	@Hou @Ind	LAR Car	Jac	Det	NE GB	Min @Det	@SF	@Mia Det	Sea	@TB	CHI	7.40						
9	NO Was	@Det Den	Phi @Atl	@NO Bal	Atl	@KC SF	Ind @NYG	@Car LV	@LAC	@Dal Car	NO	CHI	9.8 DP						
10	CAR @NO	LAC @LV	Cin @Phi	NO TB	Car	Sea	@TB Dal	@NO	@Det	LAC	@Min @LV	NYG	7.40						
11	ATL Pit	@Phi KC	NO TB	Car	Sea	@TB Dal	@NO	@Det	LAC	@Min @LV	NYG	@Car	ATL	7.40					
12	CAR @NO	LAC @LV	Cin @Phi	NO TB	Car	Sea	@TB Dal	@NO	@Det	LAC	@Min @LV	NYG	@Car	ATL	7.40				
13	NYJ @LAR	NE @Atl	@Sea KC	Dal	Ind	Sea	@GB	@Buf Chi	LAR	@Mia Det	@Atl SF	SEA	12.5 SB						
14	LAR @Det	@Atl SF	@Chi GB	Ind	LV	Min @Sea	Mia @NE	Phi @NO	Buf @SF	@NYJ Atl	Sea	LAR	10.7 WC						
15	SEA Den	@NE Mia	@Det NYG	SF @Atl	Buf LAR	Ind	@SF Ari	@NYJ GB	Min @Chi	@LAR SF	ARI	SEA	9.8						
16	ARI @Buf	LAR Det	Was @SF	@GB LAC	Mia Chi	NYJ	@Sea	@Min Sea	Sea	@Car	@LAR SF	ARI	4-13						
17	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	2023
18	ARI	Atl @Mia	Jac @Bal	@Hou @NYJ	Ten @Sea	Mia @NE	Phi @NO	Buf @SF	@NYJ Atl	Sea	LAR	SEA	11.4 DP						
19	NE	Jac	Buf	@Sea Ten	@NE	Ind	Ind	@Buf LAR	LV	NE	@GB NYJ	@Hou SF	@Cle	Buf	NE	11.4 WC			
20	NYJ	@SF	@Ten NE	Det @Phi	NE	Hou	Ind	Ind	Ind	Sea	@Mia @Jac	LAR	@Buf	Mia	NYJ	7.40			
21	NE	Cin	Sea	@NYJ @SF	Mia Hou	@Jac NYJ	@Ten	@Chi LAR	@Mia Ind	@Atl	@Buf LAC	Buf	NE	NE	NE	4-13			
22	BAL	KC	LV	@Dal Buf	@Cin Was	@TB @Cle	Den Cin	@Pit @LAC	Phi	@NYG Pit	@Hou Cle	BAL	13.4 CG						
23	CLE	Dal	@Jac NYG	@LV	@Waa @Phi	Cin Bal	LAC	@Pit	@NO	Pit @Det	@Pit KC	Cin	Mia	@Bal	CLE	11.4 WC			
24	PIT	@Ind	LAC @Ind	Dal @LV	NYJ NYG	Ind	@Waa Bal	@Cle	@Cin Cle	@Phi @Bal	KC Cin	Cin	PIT	10.7 WC					
25	CIN	NE	@KC Was	@Car Bal	@NYG @Chi	Phi LV	@Bal	@LAC	Ten	Pit @Dal	@Ten Cle	Det	@Pit	CIN	9.8				
26	IND	@Ind	Cin @Min	Jac @Buf	@NE @GB	Ind @NYJ	Det @Dal	Ten @Jac	Mia	@KC Bal	@Ten	IND	10.7 DP						
27	JAC	@Mia	Cle @Buf	@Hou Ind	NE	GB	@Phi Min	@Det	Det	Hou	@Ten NYJ	@LV Ten	@Ind	JAC	9.8				
28	IND	Hou	@Chi Phi	@Jac	@Ten	NE	@Hou	Buf @NYJ	Det	@NE	Ind	@Ten	@NYG	Jac	IND	9.8			
29	TEN	@Chi NYJ	GB @Mia	Ind	Ind	NE	@Waa	Jac	Cin	@Ind	@Jac	Hou	TEN	TEN	6-11				
30	KC	Bal	Cin	@Atl @LAC	NO	@SF	@LV TB	Det	@Buf	@Car LV	LAC	@Cle	Hou	@Pit	Det	KC	11.4 CG		
31	LV	@LAC	@Bal Car	Cle @Det	Pit @LAR	KC	@Cin	@TB Ad	Jac	@NO	LAC	LV	LV	LV	8.9				
32	DEN	@Sea	Pit @TB	@NYJ LV	LAC	@NO Car	@Bal	@KC	Atl @LV	Cle	Ind	@LAC	@Cin KC	DEN	8.9				
33	LAC	LV	@Car	@Pit KC	NO	@Det	@Atl NO	@Bal	@KC TB	B	Det	@NE	@Mia	LAC	9-12				
34	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	2023

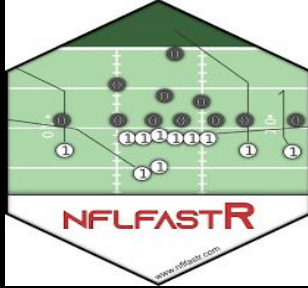
LITERATURE REVIEW



- BAIO & BLANGIARDO (2010)
- ATTARD ET AL. (2023)
- MACK (2024)
- KELLY (1956)



METHODOLOGY – TOOLS

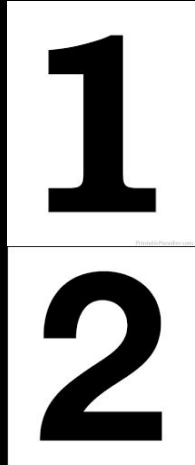


- sportsoddshistory.com
 - BetMGM via Kansas Crossing Casino and Hotel
- R
 - RStan
 - Hamiltonian Monte Carlo (NUTS)
 - [nflReadR](#)
 - 2024-2025 Play-by-Play NFL Data
 - – Week 18
 - Data Cleaned and Processed

METHODOLOGY – SCORING



**TOUCHDOWNS
(6)**



**POST-
TOUCHDOWN
(1 OR 2)**



FIELD GOAL (3)



SAFETY (2)

METHODOLOGY – MODELING

- $\text{PassingTouchdowns}_{gj} \mid \theta_{gj\text{PassTD}} \sim \text{Poisson}(\theta_{gj\text{PassTD}})$ (1A)
- $\text{RushingTouchdowns}_{gj} \mid \theta_{gj\text{RushTD}} \sim \text{Poisson}(\theta_{gj\text{RushTD}})$ (1B)
- $\text{ReturnTouchdowns}_{gj} \mid \theta_{gj\text{RetTD}} \sim \text{Poisson}(\theta_{gj\text{RetTD}})$ (1C)
- $\text{DefensiveTouchdowns}_{gj} \mid \theta_{gj\text{DefTD}} \sim \text{Poisson}(\theta_{gj\text{DefTD}})$ (1D)
- $\text{FieldGoals}_{gj} \mid \theta_{gj\text{FG}} \sim \text{Poisson}(\theta_{gj\text{FG}})$ (1E)
- $\text{Safeties}_{gj} \mid \theta_{gj\text{Safety}} \sim \text{Poisson}(\theta_{gj\text{Safety}})$ (1F)
- $P(M=m) = (e^{-\theta_{gjM}} \theta_{gjM}^m) / (m!)$ (2)

g denotes game #

j denotes home(1) or away(0)

m represents observation of count

METHODOLOGY – MODELING

- θ_{gjM} represent rate of scoring intensity for M scoring type for team j in game g.

- $\log(\theta_{g1M}) = \alpha_{g1,M} + \beta_{g0,M} + \text{int}_M + \text{home}_M \quad (3)$

- $\log(\theta_{g0M}) = \alpha_{g0,M} + \beta_{g1,M} + \text{int}_M \quad (4)$

Thus, $\alpha_{g1,M}$ represents the home team's attacking ability, $\beta_{g0,M}$ represents the away team's defensive strength, int_M represents the intercept, and home_M is a home adjustment in the gth game for scoring type M.

METHODOLOGY – MODELING

- Need to account for scoring coming from a strong team attack vs. a weak team defense.
 - $\sum \alpha_{T,M} = 0$
 - $\sum \beta_{T,M} = 0$
 - For team T and scoring type M.
- $N_{gjM} \sim \text{Binomial}(\text{TotalTouchdowns}_{gj'}, \delta_{jM})$ (5)
- $x_{gjM} \sim \text{Binomial}(N_{gjM}, \psi_{jM})$ (6)

METHODOLOGY – MODELING

- Hyper Priors

- $\mu_{\alpha M}, \mu_{\beta M} \sim \text{Normal}(0, 0.05)$ (11)

- $\sigma_{\alpha M}, \sigma_{\beta M} \sim \text{Gamma}(0.1, 0.1)$ (12)

- $\delta_{j\text{EXP}}, \delta_{j2P} \sim \text{Dirichlet}(9,1)$ (13)

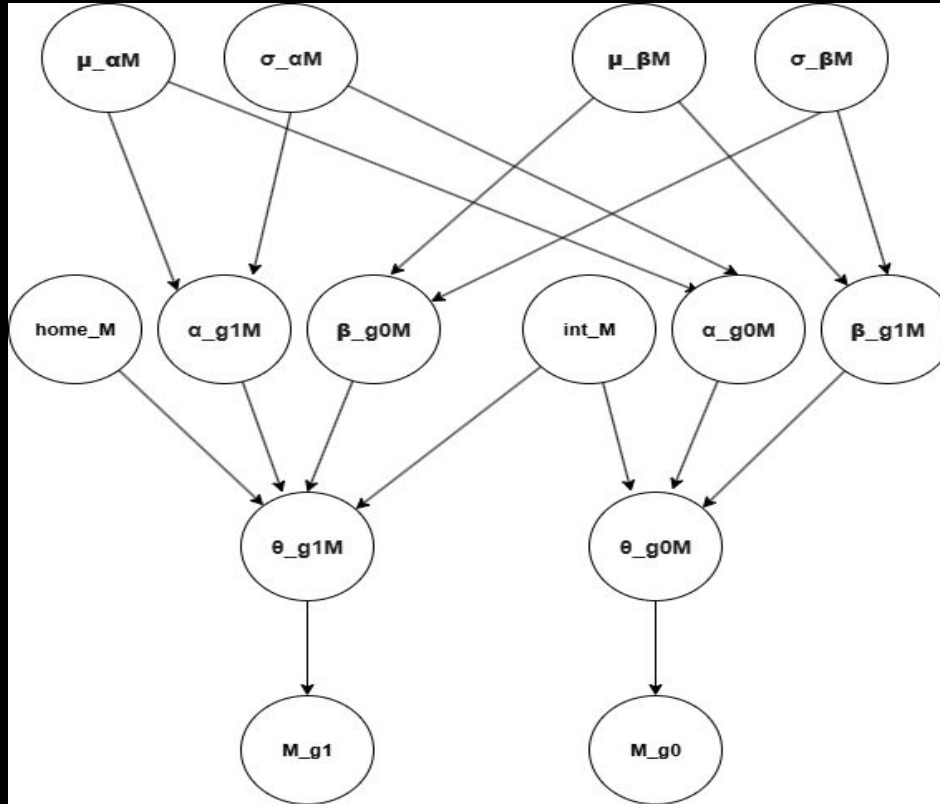
- Priors

- $\alpha_{TM} \sim \text{Normal}(\mu_{\alpha M}, \sigma_{\alpha M}), \beta_{TM} \sim \text{Normal}(\mu_{\beta M}, \sigma_{\beta M})$ (9-10)

- $\text{home}_M \sim \text{Normal}(0, 0.05), \text{int}_M \sim \text{Normal}(0, 0.05)$ (7-8)

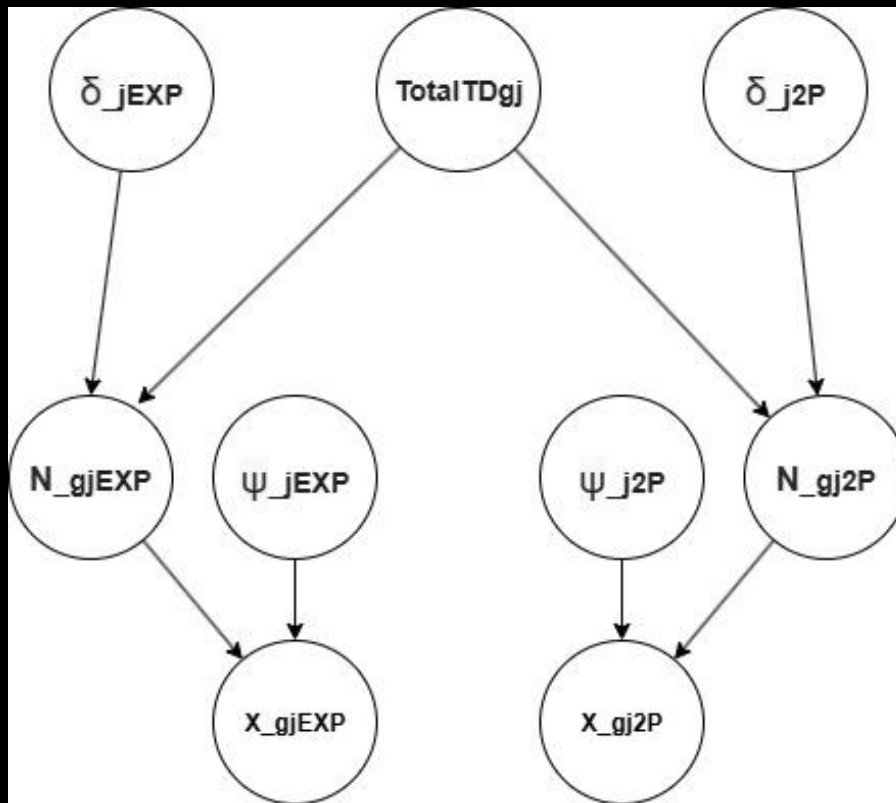
- $\psi_{j\text{EXP}} \sim \text{Beta}(9,1), \psi_{j2P} \sim \text{Beta}(1,1)$ (14-15)

METHODOLOGY – DAGs

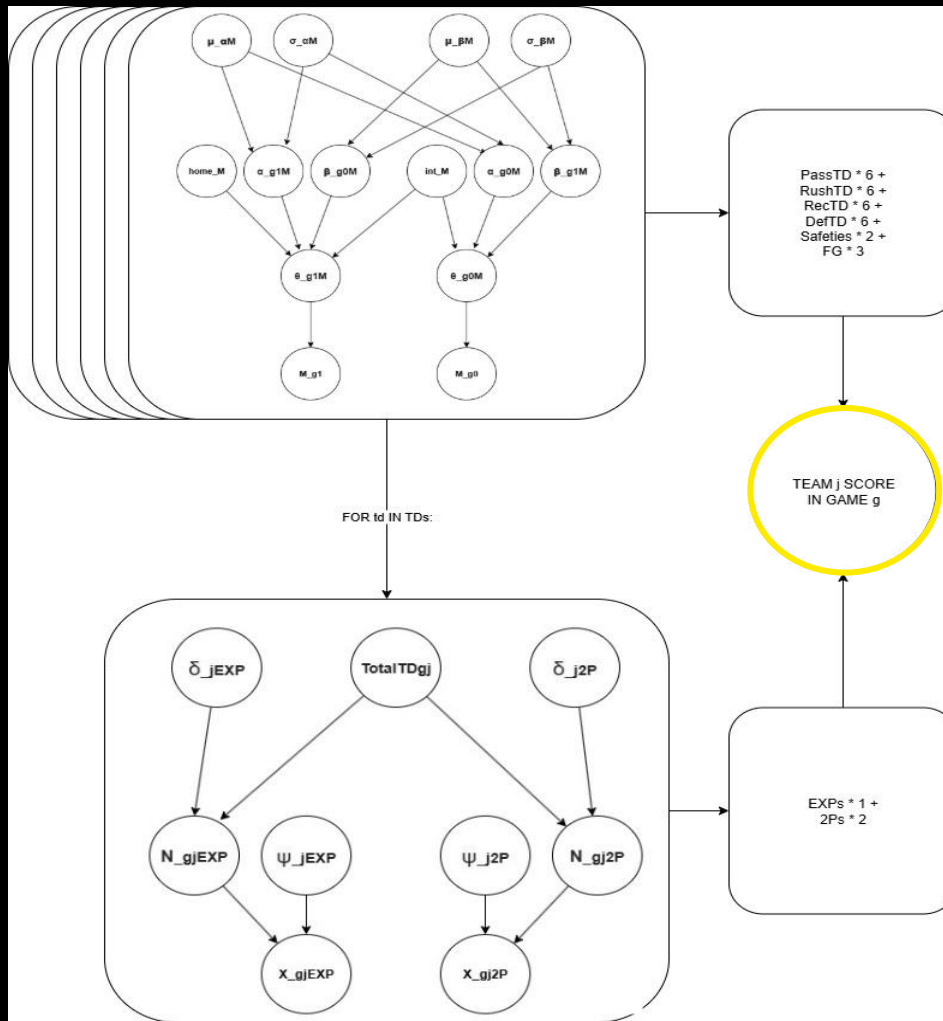


Touchdowns, field goals, and safeties

METHODOLOGY – DAGs

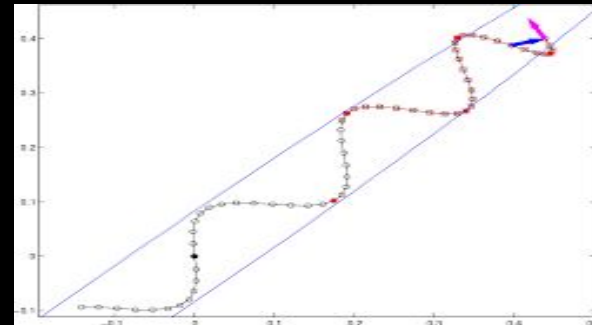
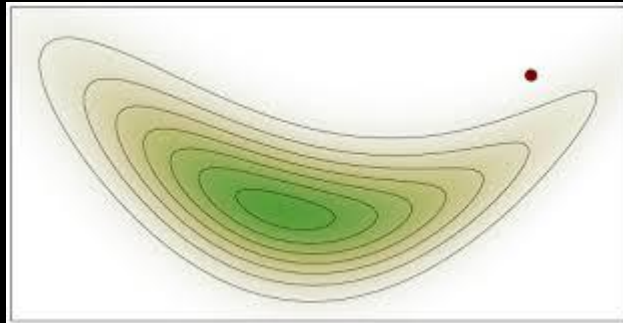


Extra Points and two-point conversions



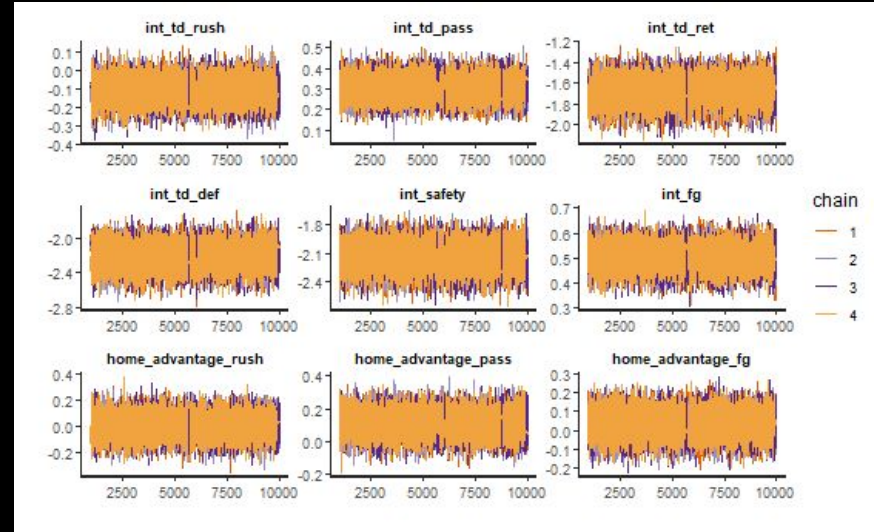
METHODOLOGY – Monte Carlo Simulation

- Hamiltonian Monte Carlo (HMC)
 - Potential Energy landscape defined by negative log-posterior
 - Particle trajectory simulated for acceptance.
- No-U-Turn-Sampler (NUTS)
 - Avoids trajectories that turn back on themselves.
 - Highly efficient.



METHODOLOGY – Monte Carlo Simulation

- Sampling:
 - 10,000 iterations / chain
 - 1,000 burn-in
 - 4 parallel chains
 - Thinned
- Gelman–Rubin Statistic
 - $(R_hat) \sim \sqrt{1 + m/ESS}$
- Posterior Predictive Updating for every playoff round
 - $f(\tilde{Y}|Y, \theta) = f(\tilde{Y}|\theta) f(\theta|Y, \text{prior}) d\theta$



(16)

METHODOLOGY – EVALUATION

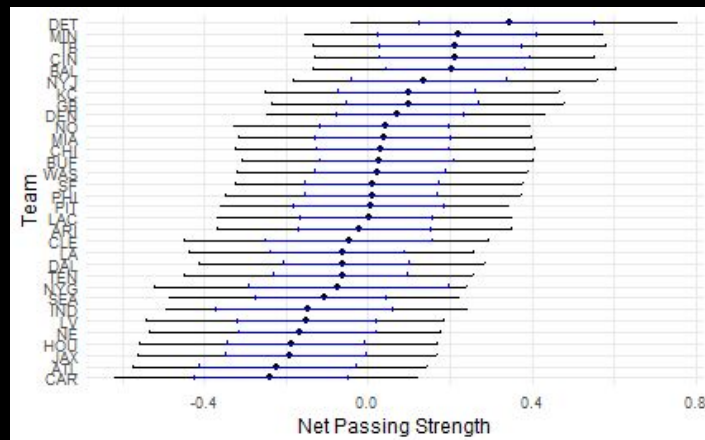
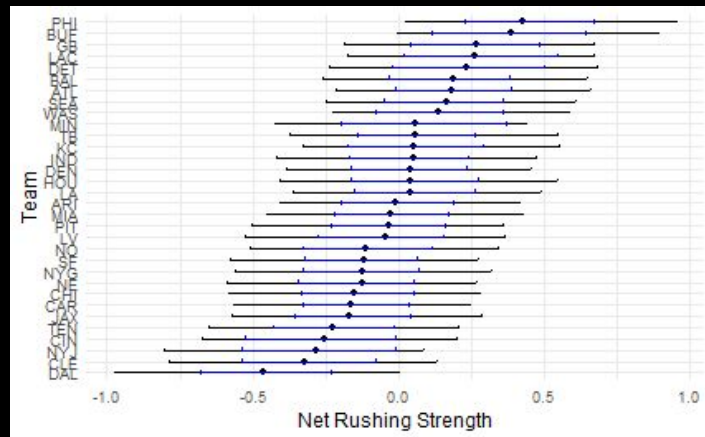
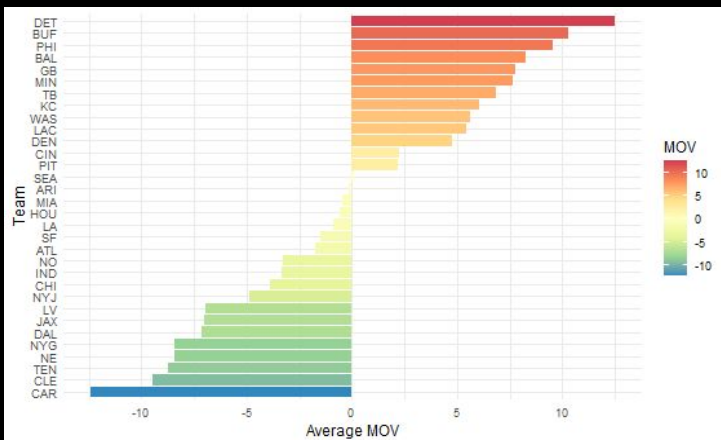
- Simulate each playoff game 10,000 times.
- Evaluate Spread (+/-)
- Make Decisions (\$100 bankroll)

Decision	Strategy
Straight	Kelly Criterion
Straight	Flat Unit
Value	Kelly Criterion
Value	Flat Unit

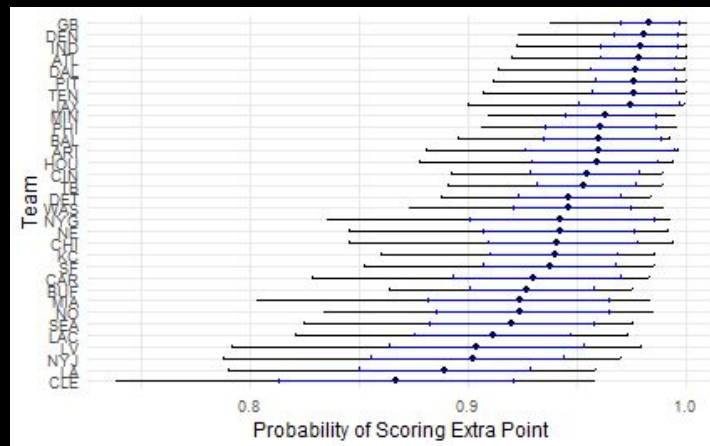
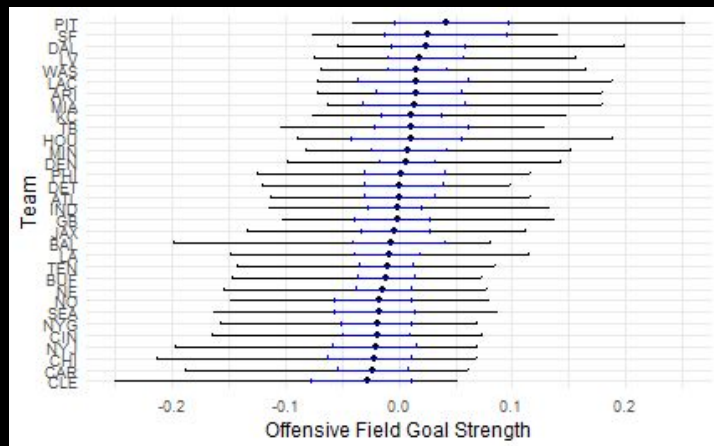
- Straight Decision
 - Comparing median simulated outcomes to lines.
- Value Decision
 - $P_- = O / (O + 100) * 100$ (18)
 - $P_+ = 100 / (O + 100) * 100$ (19)
 - $\text{Hold \%} = [1 - (P_{\text{favorite}} + P_{\text{underdog}})] / 2$ (20)
- Kelly Criterion
 - $f = (bp - q) / b$ (17)
- Flat Unit Strategy
 - Fixed wager (\$100 / # of games).

RESULTS & ANALYSIS

- 95% credible intervals of team Net Strengths
 - Passing
 - Rushing
- Team MOV
 - "Margin of Victory"



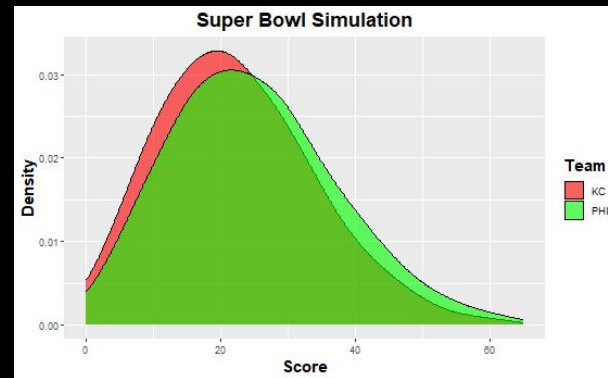
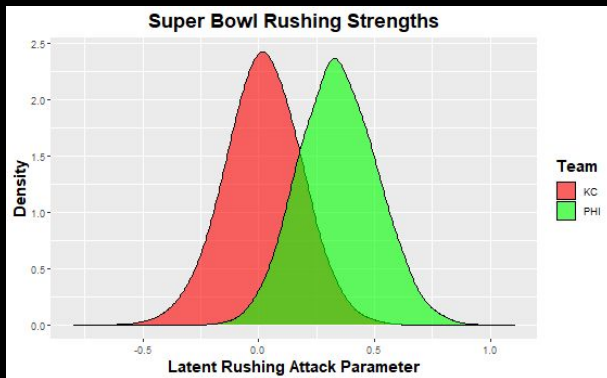
RESULTS & ANALYSIS



- 95% credible intervals of $\alpha_{T,FG}$ and $\psi_{T,EXP}$
 - Key Point:
 - CLE
 - 66.7% of FG (worst)
 - 27 total FG makes (worst)
 - 85.7% of EXP (worst)

RESULTS & ANALYSIS – PLAYOFFS

- 13 Playoff Games (each simulation 10,000x)
 - (6 Wild Card, 4 Divisional, 2 Conference Championships, Super Bowl)
- Super Bowl example: Kansas City Chiefs vs. Philadelphia Eagles



RESULTS & ANALYSIS – PLAYOFFS

- Spread Betting

Strategy	Median P/L	95% Prediction Interval P/L	Summarized Singular Choice
Kelly Criterion - Value	0.50%	(-15.45, 12.87)	-2.88%
Kelly Criterion - Straight	11.50%	(3.84, 12.87)	7.68%
Flat Unit - Value	2.80%	(-56.00, 47.93)	-10.87%
Flat Unit - Straight	41.70%	(14.70, 63.40)	28.70%

CONCLUSION

- Across All Simulations
 - Variable profitability
 - Kelly Criterion → Mitigated Risk
 - Flat bets → Nominal Gains
 - Value based → Underperformed
- Single-Decision
 - Small sample size, hard to make consistent profitability.
- More value in less liquid markets
 - Player Props
 - Smaller market sports
- THIS IS NOT BETTING ADVICE



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<https://playtoday.co/blog/stats/how-much-money-do-americans-bet-on-sports/>

APPENDIX

CODE: <https://github.com/brandonowens24/NFL-Count-Modelling>

The screenshot shows the GitHub interface for the repository 'NFL-Count-Modelling'. The repository is public and has 1 branch, 0 tags, 0 forks, and 0 stars. The file list on the left includes:

File	Description	Time
.gitignore	Update .gitignore	2 weeks ago
Analysis.Rmd	Prod Analysis	2 weeks ago
Bayesian-Win-Totals.Rproj	init commit	6 months ago
Data_Gathering.Rmd	Prod Data_Gathering	2 weeks ago
Data_Modeling.Rmd	Prod Data Modeling	2 weeks ago
Data_PreProcessing.Rmd	Prod Data PreProcessing	2 weeks ago
README.md	Update and rename README.Rmd to RE...	2 weeks ago
Simulation.Rmd	Prod Simulations	2 weeks ago
scoring.stan	Prod Stan Model	2 weeks ago

The right sidebar shows the 'About' section with no description, website, or topics provided. Below this are sections for 'Releases' (no releases published) and 'Packages' (no packages published).