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Thesis First Draft

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Examining Asset Pricing Behavior through the lens of Sports Betting Markets

Introduction:

Asset pricing theory, which studies the fundamental drivers of prices across various asset classes, is a major source of study for economists looking to rationalize market behavior. This paper intends to build upon a small subset of the current literature by implementing the use of sports betting markets to test for behavioral tendencies which result in asset pricing anomalies. Yale professor Tobias Moskowitz's prior study on this topic provides the motivation for my own work. In which, he tested momentum, value, and size trading strategies, eventually concluding evidence of overreaction that led to contract mispricing. Hence, the first section of this paper intends to follow a similar procedure to Moskowitz, albeit with modern data that will encompass the increased wagering volumes from the legalization of sports betting markets across 36 states. In the following section, the paper intends to gather data on contract pricing prior to and following major news events in sports betting markets. Evidence of behavioral anomalies in this sports betting study can provide a unique lens onto similar asset pricing anomalies in financial markets.

A central idea within asset pricing theory, that is critical for understanding this paper's motivation for testing pricing anomalies within sports betting markets is Eugene Fama's Efficient Market Hypothesis. The theory argues that the price of any asset is efficient, or at fair market value, because all market participants have access to all relevant information regarding prices. Accordingly, if the asset price were always at the fair market value it's impossible to beat the market and the return of an asset should be proportional to its risk. In practice, however, this theory often fails to hold up to its strict definition. As a result, economists have devoted vast amounts of work to analyze and explain financial returns in relation to market efficiency. However, this literature on market efficiency must also deal with Fama's Joint Hypothesis

Problem, which claims that testing for market efficiency is extremely difficult, if not impossible because any test must use some form of an asset pricing model to predict returns. Thus, it is impossible to say whether the perceived deviation from the predicted returns is because of market inefficiency or rather because of an error in the asset pricing model that predicted the returns. Hence, this issue of needing to simultaneously prove the inefficiency of the market and the accuracy of the asset pricing model has conflicted with academia.

Thus, when constructing a test on asset pricing theory it's critical to limit extra variables and market noise. Asset pricing research using financial markets is then difficult because it must factor in the overall risk premium, as well as rational and behavioral effects of the general market and individuals. For this reason, Moskowitz motivates the use of sports betting markets as a laboratory for empirical research based on two key reasons, which enable his tests to bypass rational asset pricing framework. First, there is no correlation between sports betting and the standard risk of the traditional financial market and the overall economy. While certain individuals betting amounts may decline during a recession, a change in the overall money supply, jobs report, or other economic related news has no impact on the skill or performance of the two teams competing. For this reason, betting lines are completely idiosyncratic from the baseline risk premia in the economy.

Additionally, sport betting contracts follow a simple structure that defines a known termination day, i.e., the day of the game, on which the contract is fully resolved. Furthermore, these contests are played out independently of investor preferences or behavior thus limiting potential noise when examining the pricing of contracts. While some may argue that there have been examples of fixed sports game or point shaving, these are extremely rare examples. Unlike in financial markets where investor preferences and behavior can result in market hysteria, panic,

euphoria or other reactions that will certainly drive price movements, sports betting markets can reasonably assume independence between betting activity and the contest's result. This then alleviates the need to define an asset pricing model for sports betting markets, as we can simply look at the payoffs and compare that to the initial pricing to test for any potential mispricing. For these reasons, we can leverage sports betting markets to test for examples of behavior asset pricing theories more accurately than similar tests which are limited by the joint-hypothesis debate in financial markets.

Importantly, while sports betting markets have these characteristics that enable more favorable conditions for analysis, they are largely subject to the same behavioral patterns that are seen in traditional finance. For instance, we know that market participants are strictly better off when their bet wins, regardless of whether they are primarily betting for the entertainment factor. Additionally, some studies have found presence of an entertainment motive in the stock market as well (Dorn and Sengmueller, 2009) suggesting that the gaming theme of sports betting does not cause a major variation in investor preferences. Most importantly is that much of the behavioral economic literature used to develop models for asset pricing is based on individual psychology regarding generic risky decisions, (Barberis, 2018). Thus, behavioral models used to derive financial asset prices ought to apply for sports betting contracts as well. Since the behavioral conditions then are the same, we can conclude that a sports bet is simply another form of a risky decision that subjects the player to the same behavioral principles and models used to examine participants in capital markets. Ultimately, this enables the paper to test behavioral models while eliminating the presence of risk-based theories.

The paper will begin with an update to the behavioral models chosen by Moskowitz, momentum, value, and size. These behavioral asset pricing theories are often used as predictors

for financial markets but can also be constructed in a suitable manner for testing in a sports betting setting. My methodology in setting up this experiment will follow Moskowitz's basic procedure. Sports betting specific conditions such as the favorite-longshot bias will be ignored in order to focus on analyzing the behavior models. Momentum will be derived from a team's past performance across various time periods. Value can be defined according to the sports market's perception of a team's cheapness relative to others. Finally, size will encompass a team's overall market value. I then follow Moskowitz testing guidelines by first examining if there is any movement in a betting contract's pricing from the opening of the market to the close of the market contract which could be related to these three behavioral models. If any movement is determined to be related to these characteristics, I then will evaluate whether there is any subsequent effect on the contract's return from the end of betting, i.e. the close line, to the game's outcome. Thus, the first section of the paper intends to intend to isolate the three behavior pricing models by implementing updated data to see whether there are meaningful changes to Moskowitz prior findings. Of which Moskowitz's original experiment concluded significant evidence of momentum effects on the pricing movement of sports betting contracts. Additionally, these movements typically were reversed by the outcome of the contest, suggesting a model of overreaction at play. Furthermore, value exhibited a weak presence on the pricing movement, whereas size had no impact. It will be interesting to see if the legalization of sports gambling across states results in any meaningful change to Moskowitz conclusion.

For my analysis, I intend to use data from the same source as Moskowitz in order to limit potential discrepancies in lines from differing sportsbooks. I have reached out to his main source, SportsInsights.com, as a part of the Action Network in hopes of acquiring a detailed dataset. This would include opening and closing prices for the Point Spread, Moneyline, and Over/Under for

the NFL, NBA, NHL, and MLB, the game's outcomes, as well as any other additional team or game information readily available. Once I have gained access to a suitable database, I will provide a summary statistic for the table and compare this to Moskowitz's dataset.

The next section of the paper intends to provide new literature on asset pricing theory by leveraging the sports betting laboratory to conduct analysis on contract pricing related to major news events. Many of the financial markets most studied and researched patterns deal with asset pricing related to reaction of new news in the market. For instance, academic researchers have conducted numerous studies on the phenomenon termed Post-Earnings-Announcement-Drift. Their findings of which demonstrate that a significant positive or negative earnings surprise has the tendency to lead to abnormal stock returns in the following trading days that drift in the direction of the surprise. This would suggest that investors underreact to the earnings announcement, which leads to the post-announcement drift. However, studies examining phenomena are faced issues discussed earlier, presence of the overall market risk premia, unidentifiable investor preferences, which makes it hard to emphatically conclude whether risk-based or behavioral models carry more weight. As such, I believe that I can provide novel information on this topic by utilizing sports betting markets to test for price changes following a major news event surrounding the contest. To begin, I will focus on looking at injury reports and evaluate what level of data this will provide. I plan on examining games with an injury report that caused a sizable move in the betting line, like the effects that an earnings surprise would instill. Then, having isolated these games, I will examine whether there are any mispricing effects once the game is played out. If there is a significant underreaction to the news, this phenomenon would partially help rationalize the behavioral activity demonstrated in the stock market and provide a better asset pricing model for capital markets.

Introduction to Sports Betting Markets:

Before giving a detailed account of the data used in this work, I shall provide a brief introduction regarding sports betting markets and the contracts used in this study. At a high level, sports betting markets enable individual agents to buy and sell various contracts which depend on some outcome in the game or season. This study, like Moskowitz, will examine the three most popular and heavily wagered contracts: point spread, moneyline, and over/under. To generalize these contracts for any game, let us consider two teams A and B, whose points scored are denoted as P_A, and P_B for A and B respectively.

The Point Spread then takes the following definition: $P_A - P_B = X$. In this case X would represent the Point Spread or simply the differential in points between teams. For example, if the spread between teams A and B is 5, i.e., $P_A – P_B = 5$, then any wager on the favorite team, A, would only pay off if team A wins by more than 5 points. Thus, anyone taking the opposite side would require Team B to win or lose by less than 5 points for the bet to pay off. In this specific case, if the game concludes with a point differential of 5 points between A and B, then the bets would be deemed a “push” and both sides are returned the principal. Furthermore, in the data the spread for a favorite will take the form of -X, or -5 for this example, while the underdog will be listed as +X, or +5.

Additionally, these contracts are established such that a wager on either team should take the form of a 50-50 wager, or coin toss. However, the sportsbook charge commission, also known as the vigorish, when setting the odds for the games. Thus, in order to win $100, one must place a $110 dollar bet, with the $10 difference representing this commission. Hence the payoffs for a standard bet would be: 210 when $y > X$, i.e., the team wagered upon “covers” the spread, 110 when the bet results in a push, and 0 if the bet is lost.

Next is the moneyline contract, which is simply a wager on the team to win the game. Unlike the point spread contract, which uses points to balance the opposing sides, a moneyline bet adjusts the payouts. For example, if team A is favored, then the moneyline bet will be listed as $-M_A$, implying that a bet of M_A dollars is needed to return $100 in winnings. On the contrary, the underdog will be listed at M_B dollars, which means that a $100 wager would pay out M_B dollars. Finally, the sportsbook sets the two values such that M_A is greater than M_B, with the difference representing the charged commission by the book.

This year's Superbowl provides a good look into how the point spread and moneyline bets work in practice. The Philadelphia Eagles deemed by the oddsmakers are listed as the favorites, hence anyone looking to place a moneyline wager on the Eagles can do so at -125 odds. Additionally, confident Eagles fans can choose to "lay" the spread and take the Eagles point spread contract at -1.5 for -110 odds, implying that a $110 Point Spread wager on the Eagles would win $100 if the spread is greater than 1.5 points. Chiefs' supporters then have access to the same point spread contract with the sportsbook allowing them to "take" the points at +1.5 for 110 odds. Additionally, if the individual thinks that the Chiefs can win the game outright, they could place a moneyline wager at +105 odds, implying that a $100 wager will win $105. In this example, the Point Spread sets the standard vigorish of 110-100 = 10, while the moneyline would be even greater at 125-105 = 20.

Last is the Over/Under contract, which unlike the Spread and Moneyline is not a wager on contest winner and loser but rather on the combined points scored between opponents. Thus, if the Point Spread is defined as $y = P_A - P_B$, then the Over/Under is similarly defined as $y = P_A + P_B$. Thus, in the data, you will see the Over/Under contract listed at a set number T, implying that those individuals taking the Over need more than T points to receive a payoff, whereas the

under-contract participants need less than T points. As in the case of the Point Spread, the Over/Under contract is balanced between the two sides such that this is roughly equivalent to a coin toss. Also, we have the same format as the Point Spread with a $110 bet resulting in a $210 payoff in the case of a win, $110 payoff in the case of a push, and $0 if the bet loses. Again the $10 difference between the amount wagered, $110, and the winnings $100 represents the book vigorish.

Thus, for the purposes of this work, the data used will consist only of these three types of sports betting contracts. It should be noted though that since the legalization of sports betting in many states across the United States that there has been a significant rise not only in the volume for these mainstream contracts but also in Prop Bets. These are side bets in a contest on much more specific events, including but not limited to, the over/under on the number of points, yards, rebounds, etc. a certain player will attain in a game, the coin toss, or even the Gatorade color dumped on the head coach of the winning team in the Super Bowl. While access to this data may present its own sets of challenges, I do see the possibility of future research using these more niche markets to compare pricing activity related to the standard Spread, Moneyline, and Over/Under contracts. It would be interesting to see if these markets, because of their smaller size, were less liquid and thus more susceptible to mispricing.

Lastly, in the primer, I would like to briefly discuss how the lines are initially set and adjusted, as this will be a focus when testing price movements in the underlying contracts. While there are certain markets which enable agents to trade the contracts directly with one another, most of the sports betting activity is conducted through sportsbooks. Like in financial markets, where investment banks and other brokers will intermediate trades by offering prices that they

will both sell and buy an asset, the sportsbook is acting as the intermediary between bettors by offering both sides prices at which they can enter the various contracts.

Thus, when the contracts for a contest are first released, the sportsbook sets an initial betting line or price with bookmaker's goal of balancing the odds such that money is placed evenly on both sides. To do this, the books employ computer algorithms and mathematical models factoring in a wide range of variables such as team power rankings, weather, injuries, etc. Additionally, once this initial betting line is released to the public, the betting limit, or amount that can be wagered upon the contest, is set low to prevent sharp bettors from seizing a potential pricing mistake. Hence, following the opening of the contract, the betting lines will continue to move up and down in reaction to betting volumes. Using the Superbowl example from above, if all the early betting volume came in on the Eagles Point Spread (-1.5), then the oddsmakers would adjust the line upwards to 2, and then 2.5, and so on, as they attempt to balance out the two sides. Doing so allows the Sportsbook to mitigate risk as they attempt to rake in the vigorish without exposing themselves to excessive risk. Additionally, if new information about the game's potential outcome is released, such as a sports injury, the betting line can move without being affected by volume.

Data:

For this work, data was collected from AusSportsBetting.com and OddsWarehouse.com. OddsWarehouse.com provides historical data on sports betting contracts, as well as team and game specific information for the NFL, NBA, NHL, and MLB from 2009-2023. (As of current iteration of this draft, I am awaiting the Princeton rush order to obtain oddswarehouse dataset). This includes opening and closing betting line prices for the Point Spread, Moneyline, and Over/Under contracts. However, the NFL is the only league with data on all three contracts. In

the case of the MLB and NHL, the point spread is always set at 0.5, 1.5, since these contests tend to be much more closely decided, hence the Moneyline acts as the primary market. Because Moskowitz also decided to drop these markets from his analysis, I see no need to acquire supplemental data for these markets. One difference of note though is that OddsWarehouse.com only has the Moneyline price for the NBA and not the Point Spread, which Moskowitz did include.

OddsWarehouse.com sources their data from several of the largest sportsbooks in the United States and Europe, which helps to eliminate potential outliers. This follows the same procedure as Moskowitz, in which he utilized the average of all sportsbooks' lines when they differed. Because this study is more interested in looking potential pricing anomalies due to behavior rather than a test of market efficiency, the focus is on what the prevailing line to the public was. Additionally, with the increased role of electronic trading and modelling, betting lines for the major markets, Point Spread, Moneyline, and Over/Under almost move identically across the various books (Moskowitz, 2021).[1] Hence, for the purposes of this paper, the OddsWarehouse.com data follows the same general collection methods as Moskowitz but enables access to data from 2013-2023. The data includes both regular season and playoff games and the date on which the contest was played. Basic team information, home field, and scores are included. Going forward, I will look to supplement the dataset with more game specific information such as weather, team information, etc. that can be used more for my event-driven tests.

[1] 1 As online sports gambling has continued to grow with the increased legalization in the United States there has been growing literature on "Line Shopping", in which bettors look for discrepancies in sports betting lines in small and relatively illiquid prop betting markets. A potential follow up study could look at these relatively illiquid markets and compare efficiency of these to the more standard markets that my paper will examine.

For this draft, since I do not yet have access to OddsWarehouse.com I am including data from AusSportsBetting on the NFL to draw a brief comparison to Moskowitz own data set. Table 1 presents summary statistics from AusSportsBetting. The data contains 7,320 betting contracts on 2,440 games from the years 2006-2023. It is important to note that the mean, standard deviation, and distribution values reported are of the contracts closing price. This represents the final state of the contests market and where most of the betting volume would be likely to occur. Additionally, all prices reported are from the perspective of the home team. Thus, it makes sense why the distribution at the 50th percentile is listed as a favorite instead of even odds as the books incorporate home field as an advantage into the price.

In general, despite a smaller dataset, the summary statistics generally align with those of Moskowitz. The mean values reported from AusSportsBetting are -2.0, -128.9, and 45.72 for the Point Spread, Moneyline, and Over/Under contracts respectively. In comparison the reported values from Moskowitz dataset are -2.6, -160.6, and 42.3. Overall, it appears that the data roughly aligns with Moskowitz, which gives credibility of the data from this one source. I anticipate that OddsWarehouse will demonstrate similar findings and enable me to go forward with data analysis on all four major sports leagues.

Table 1:
Summary Statistics of NFL Sports Betting Contracts

NFL, 2006-2023 2,440 Games; 7,320 Betting Contracts									
VARIABLES	mean	Sd	p1	p10	p25	p50	p75	p90	p99
PointSpread	-1.986	5.965	-16	-9.500	-6.250	-3	3	6	13
Moneyline	-128.9	337.6	-1,250	-437.7	-270.3	-152.7	132	220	500
OverUnder	45.72	4.277	37	40.50	42.75	45.50	48.50	51.50	56.50

Table 2:
Moskowitz Summary Statistics of NFL Sports Betting Contracts

Panel B: NFL 1985-2013 7,035 Games; 10,775 Betting Contracts									
VARIABLES	mean	sd	p1	p10	p25	p50	p75	p90	p99
PointSpread	-2.6	6.0	-15.5	-10.0	-7.0	-3.0	2.5	5.5	11.5
Moneyline	-160.6	208.0	-700.0	-370.0	-270.0	-174.0	-112.0	144.0	264.0
OverUnder	42.3	4.8	32.5	36.5	38.5	42.5	45.5	48.0	54.5

Methodology:

This section of the paper will look at performing the same Asset Pricing Tests as Moskowitz and compare differences between the results. First, I will provide a basic underlying guide to contract price movement and motivate a few potential hypothesis' that will be used in the analysis.

Literature Review:

(Notes: Section needs to be updated, but I am also wondering the importance of an in depth literature review if I am including some of this material in my introduction as motivation. Some feedback on how much work should be placed on giving a detailed explanation of related sources would be helpful.)

As alluded to previously, there have been many studies that have analyzed the behavior of Post-Earnings-Stock-Drift. Fama has even coined it the "Grandaddy of underreaction events".

Bernard and Thomas examined this famously in a 1989 study where they grouped stocks by the size of their respective earnings surprise. They then constructed a portfolio with the groupings in which they went long in stock with positive earnings surprises and short on the ones with negative. This strategy resulted in a statistically significant excess return of 18%.

Additionally, as mentioned earlier, a key study led by Yale Professor Tobias J. Moskowitz provides a large inspiration and rationalization for this paper to follow up on. Moskowitz makes the claim that asset pricing anomalies are well suited for analysis in the sports betting market because they lack exposure to systemic risk and have terminal values uncorrelated with betting activity. Moskowitz lays out the motivation for and rationale in depth in the paper but eventually decides to test for momentum, value, and size effects in sports betting markets because of their prevalence in the traditional finance industry. Ultimately, he concluded that sports contracts demonstrated momentum effects in their prices but that the transition costs in the form of the sportsbooks' cut or vigorish were too high to offer a profitable strategy.

Thus, this paper provides a solid starting point for this paper to build off in a few ways. The first main addition is that Moskowitz only examined Data up until 2013. Since then, the sports betting market in the United States had radically changed since the overturn of a law in 2018 that had previously outlawed sports gambling outside of Nevada. Since then, 31 states now have sports betting licenses with many offering an online option that streamlines the betting process onto a user's smartphone with the ability to place a bet whenever. This has resulted in increasing adoption of sports betting activity by the public as seen just from 2021 to 2022 as the number of people placing a bet increased from 20% to 25%. Furthermore, the total money wagered from 2018 to 2021 was $127 billion which resulted in nearly $8.9 billion in sportsbook revenue. Additionally, the major players in the U.S. market are now Fanduel and Draftkings who

together hold two-thirds of the market. This then presents an entirely different scene from 2013 and thus ought to provide a worthwhile examination of how the sports betting markets may have changed. More maturity and funds would suggest a more efficient market as the potential for arbitrage should be even tougher with more participants and online technology. However, many of the new gamblers are average citizens looking for a chance to win some money while enhancing their enjoyment of the game. This is vastly different from the finance industry where nearly all trading activity stems from institutions. Thus, with the less smart money, the increased size of the market may demonstrate different pricing activity from the previous decade.

Secondly, whereas Moskowitz centered on the behavioral effects related to momentum, value, and size, I hope to do an in-depth analysis of surprise news reports. I believe that the hardest part of the paper will be how to define what constitutes a big enough injury that it would be comparable to something like an earnings surprise for a stock. I will need to flush this out to eliminate bias and strengthen the analysis of the experiment. I believe that this is possible, and I will now begin the process of looking at the best available sports games and betting data to perform this experiment. Once conducted, the next major step will be determining to what extent the results are useful for drawing connections to asset pricing theory in the financial markets. While I don't anticipate a strict correlation between the two markets, I do believe that the behavior witnessed in reaction to major injuries surrounding a sporting event can provide a meaningful cross-analysis for the anomaly that is Post-Earnings-Announcement-Drift.

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