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Price movements and the prevalence of informed traders: The case of line movement in college basketball

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ABSTRACT

Recent research has hypothesized that a higher concentration of informed traders in a market implies that prices are more efficient. A reasonable next question is whether large price *movements* in markets with a relatively more informed clientele are more indicative of information realization. We find line movements in college basketball games of relatively low profile, denoted by the lack of a "power conference" team in the contest, are significantly more likely to be the result of information realization. This confirms that substantial price changes in markets with fewer ordinary traders are more (less) likely indicative of information flow (noise).

1. Introduction

Are changes in asset prices more indicative of information incorporation when trades are conducted within a group that is relatively more informed? Some evidence indicating support for this hypothesis has arisen in recent research. Consistent with this theory, Holden and Subrahmanyam (1992) derive a model describing how greater intensity in searching out mispricing results in quicker movement of prices to efficient levels. Building on the work of Badrinath, Kale, and Noe (1995) and Sias and

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Starks (1997), Boehmer and Kelley (2009) describe how stocks with greater institutional ownership are priced more efficiently. They detail the advantages available to institutions both in terms of uncovering unique information and interpreting underlying asset value. The intraday prices of those NYSE stocks with greater institutional ownership follow paths more consistent with random walk behavior, implying that underlying values are more accurately reflected by the prices of those stocks. Edmans (2009) demonstrates that outside blockholders are more apt to have useful information regarding stocks, and thus those firms with large blockholder presence are more likely to be priced correctly. Both of these papers give rise to the possibility that substantial price movements are less likely to be noise when a greater amount of informed trading is present.

Findings linking the efficiency of a marketplace to the quality of the information available regarding that market extend beyond stocks. In an integral piece implementing the sports betting markets Colquitt, Godwin, and Caudill (2001) describe how betting lines, which serve as prices for bettors, are more accurate for games which receive greater public attention. When a game involves larger profile teams, its line is substantially more likely to predict the final result, and gamblers are thus not able to systematically exploit any inefficiency.

Building off of the static model of Kyle (1985), Kitsul and Mahani (2011) note that frictions which slow the efficient pricing of assets are more impactful for the stocks of large firms due to the greater presence of passive, ordinary investors. Given the relative lack of trading by naive investors, prices for stocks of somewhat smaller firms may be more efficient. Again, the possibility arises that price movements of assets receiving less public interest are more likely to be reflective of information.

In the spirit of Colquitt et al. (2001), who study the efficiency of *prices*, we consider a unique approach to analyzing the impact of the concentration of informed traders within a market in determining the meaning of *price changes*. Namely, we study the movement of lines in the betting market for college basketball games. Gandar, Dare, Brown, and Zuber (1998)[1] demonstrate that the prices offered to the betting public by bookmakers are not always reflective of underlying value, even though bookmakers are experts in handicapping sports contests. This expertise allows the bookmaker to state an effective price for wagers on games, in the form of a line, but the presence of informed traders serves as an impetus, moving those prices to more efficient levels.

Research by Humphreys, Paul, and Weinbach (2010) reveals that sporting events with more publicity are more likely to realize noise in their betting markets. Avery and Chevalier (1999) describe how such noise can impact the prices of games offered by bookmakers. Ordinary bettors may be willing to overpay for wagers on preferred teams or to incorporate meaningless information into their evaluation of a game.

In this paper we consider whether the opening lines of college basketball games are worse predictors of contests than closing lines. Implementation of information may create a more efficient price for later wagers. Our greatest question is whether price shifts, in the form of line movements, are more likely to be indicative of information implementation when that market is concentrated with informed bettors. In more traditional financial markets it is known that *prices* are more efficient when informed trading is prevalent. Does this mean that sizable price *movement*s are more likely to be informative of underlying value when knowledgeable traders (such as institutional investors and block shareholders) more thoroughly concentrate in a market? We provide evidence investigating this claim via the betting markets.

The paper proceeds as follows: Section 2 formalizes the definitions of sports gambling terms and discusses the possible reasons for line movement. Section 3 notes the data sources. Section 4 presents the empirical results. Section 5 discusses the implications of the results and concludes.

2. Basketball lines and line movement

Bookmakers set point spreads, or "lines", in the most common form of handicapping basketball games. The point spread issued by the bookmaker (often a casino or internet company) establishes the "favorite" and the "underdog" of a game. The point spread serves as a correction based on the perceived

[1] Based on National Basketball Association data for the 1985–1986 through 1993–1994 seasons.

likelihood of each team winning a game. The favorite is considered more likely to win a game, and thus, the spread is instituted in order to place the two sides of a wager on more equivalent footing. A wager is graded based on subtracting the spread from the favorite's final score and comparing this adjusted figure to the final score of the underdog.[2] Whichever side then has the higher final score is the winning team of the "against the spread" wager. The team that wins an against-the-spread wager is said to have "covered" the game or the spread. Loosely, we may say that *after* the line is incorporated, the probability of covering should be nearly 50% for each team.[3]

After the initial or "opening" line is released by a bookmaker, bets may begin on a basketball game. Key to our study is the fact that bookmakers may adjust the spread of a game at any time and effectively offer a revised price to the betting marketplace. There are two primary reasons that a bookmaker may elect to do so: (1) the bookmaker has unexpectedly found an imbalance of wagered funds from ordinary, or "naive" bettors and desires to increase wagers on the underfunded side of a game, thus lowering its risk in a contest,[4] or (2) the bookmaker fears that informed or "sharp" bettors have superior insight regarding a contest, and the early wagers received thus convince the bookmaker to move the line in order to avoid further losses to such "wise guy" bettors.[5]

In reality, it is unlikely that one of these two factors would exclusively impact a bookmaker's decision on whether, or by how much, to move a line as there are numerous wagers from both sharp and ordinary bettors on each contest. Instead, bookmakers must evaluate the possible future wagers that may be received from both ordinary bettors and wise guys when making decisions regarding possible line movements. Sharp bettors and ordinary bettors may have similar opinions about a game, and thus, a line may move more rapidly in concordance with these shared preferences. Contrarily (and more likely), these effects may counter one another and keep a line at a given level, with informed and ordinary bettor money sharply divided.

The mix (or perceived mix) of naive and wise guy bets for a contest is a particularly interesting question to consider. If a large amount of money is wagered on a particular side of a game, for example on Team A (the favorite) at –3 points, and the bookmaker is willing to accept exposure to a loss because he is firmly convinced his chances of winning are greater than 50%, he will likely leave the spread in place. If, however, the bookmaker is less certain of his foresight in predicting a game's result because sharp bettors are predominantly playing Team A,[6] or if the bookmaker is unwilling to face the substantial losses possible should the uninformed (or "square") bets on Team A prevail, he may change the effective price of wagering on teams A and B. The bookmaker may move the spread (perhaps to "Team A –3.5" or "Team A –4") so that any future bets are more likely to be on Team B (now at +3.5 or +4 points, rather than +3). Such balancing of wagers will cause the commission (or "vigorish") charged by the bookmaker to more fully drive his/her profitability for the particular contest because future wagers may counterbalance some of the earlier "action" on Team A.[7]

[2] Thus, should Team A be a 5-point favorite against Team B, bettors of Team A will win if Team A prevails by more than 5 points. Bettors of Team B will win if Team B wins or if Team A prevails by 4 points or less. If Team A wins the game by exactly 5 points, the wager will result in a tie or "push".

[3] Levitt (2004), Paul and Weinbach (2007) and Krieger et al. (2013) demonstrate that bookmakers may intentionally skew lines slightly so that teams preferred by naive bettors are less than 50% likely to prevail in against-the-spread wagers.

[4] Unlike the post-wager shifting of odds in parimutuel betting, wagers that are placed at a certain line are locked into that line and evaluated accordingly; thus, sportsbooks may lose money on any given contest.

[5] Such line movement may be done in order to dissuade additional sharp bettors from capitalizing on a favorable line or may be done in order to stop the originally suspected sharp bettor from further exploiting a naive or "soft" line. There is a maximum amount which may be wagered in any one transaction, and thus, if a sharp bettor wishes to wager above this maximum amount, he must make multiple wagers. The bookmaker may elect to adjust the spread in between these separate transactions.

[6] Bookmakers, by recognition of account numbers (on the internet) or actual individuals (in person), and by the large amounts wagered, are often able to distinguish whether wagers are from sharps or ordinary bettors. The timing of wagers may also be informative. Sharp bettors may be particularly quick to wager on a contest soon after an attractive opening line is posted. (see Millman, 2001).

[7] Bettors must wager (and risk losing) $11 for each $10 they seek to win in a wager. This is often referred to as the "11-for-10 rule" of bookmaking. Therefore, by accepting an equal dollar amount of wagers on the two sides of a contest, bookmakers can claim a riskless profit. Setting lines to attempt to equalize these dollars is the traditional model of bookmaking. Alternatively, recent evidence exists that bookmakers are willing to assume some risk level in order to maximize expected profitability by accepting a disproportionate amount of dollars bet on teams perceived by the bookmaker to be less than 50% likely to win wagers (see Levitt, 2004, Paul and Weinbach, 2007 and Krieger et al., 2013).

We note a commonality between the two motivations for line movement (decreasing exposure and countering sharp players). In both cases, moving the spread of a game, while perhaps necessary in the bookmaker's opinion, is not ideal. A bookmaker would not set an opening line in hopes of having to adjust this line in the future. If intolerably high risk of a certain outcome, resulting from imbalanced betting, could have been avoided by setting a different opening line on a game, the knowledgeable bookmaker would have done so. If poor wagers against sharp players (without counteracting bets from ordinary players) could have been avoided by setting a different opening line, the knowledgeable bookmaker would have done so. Line movement is a defensive and undesirable exercise for the bookmaker. This is illustrated by the "middle" exposure that line movement creates for the bookmaker. For example, should the initial line for a game be Team A −7.5 and the line move to Team A −8.5, then relatively more bets will be placed on Team A at the initial price and relatively more bets will be placed on Team B at the later price. Should Team A win the underlying game by 8 points, the bookmaker will lose a disproportionate number of its wagers at both the initial *and* final prices. Clearly, it is not advantageous for a bookmaker to move a spread.

Our primary question, then, is what does it mean when a bookmaker acquiesces and does move the spread of a basketball game? More specifically, we consider the questions: how often do lines move? When a line moves, what does this say about the returns of the bookmaker? i.e., how likely is the bookmaker to lose the majority of bets it made at the initial line?[8] How much do lines move when such adjustments are carried out? Does the degree of movement indicate how likely bets are to win at the opening or closing line? Are some games more likely to see line movements than others? Are line movements in such instances more indicative of bookmaker error?[9]

3. Materials and methods

We consider these questions via the use of historical college basketball line information from sportsinsights.com. The historical opening (closing) lines available at sportsinsights.com denote the average of opening (closing) lines from six internet sportsbooks. Our sample period consists of all college basketball games beginning in the 2003–2004 regular season and lasting through the 2010–2011 regular season, ending in January of 2011.[10] All games featuring two Division I NCAA opponents, with opening and closing lines at sportsinsights.com, make up our initial sample.

Opening and closing lines for basketball games are compared in order to calculate the line movement of a contest. Throughout the day, lines may fluctuate multiple times and may reverse course after an earlier movement (future studies may consider the impacts of intraday movement), but our data still allows for considerable analysis. It is possible that new, relevant information may emerge after the opening line is set (for example, a player may become ill during the day of the game); however, as basketball lines are typically set on the morning of the day a game is played (as opposed to American football games which may have a valid line available for six days or more), the likelihood of such information unfolding, thus resulting in a line movement due to routine market efficiency, is relatively small.[11]

Our analysis is simple in its format. We consider basic sorts and statistical tests of proportions, we utilize a test for forecast accuracy introduced by Ashley, Granger, and Schmalensee (1980) and we estimate multivariate logistic regressions.

Our focus in this study is on men's NCAA Division I college basketball games. The relatively large number of participating teams allows for substantial statistical power and further segmentation of the

[8] The actual dollar gains and losses of bookmakers on individual games are proprietary in nature. However, the frequency of bets winning at initial lines when subsequent line movement exists gives a strong impression as to the consequences of errors in line making.

[9] As one example, Palmer (2010) notes that an NBA team with recent losses is more likely to have lines move away from it if it is an underdog or the visiting team.

[10] Difficulties in data collection preclude the use of the remainder of the 2010–2011 season, but informal observation yields no discernable difference in the interpretation of line movements from February 2011–April 2011.

[11] This belief is shared by previous studies of line movements, notably Gandar, Zuber, O'Brien, and Russo (1988) and Gandar et al. (1998).

Table 1
Line movement frequency of college basketball games.

$\lvert\Delta L\rvert$	N	Cumulative %
0.0	5424	21.21
0.5	8179	53.19
1.0	5678	75.39
1.5	3096	87.50
2.0	1637	93.90
2.5	774	96.93
3.0	390	98.45
>3.0	396	100.00
Total	25,574	

This table demonstrates the frequency of various line movements in men's NCAA basketball games starting with the 2003–2004 season through January of the 2010–2011 season. The line movement, denoted ΔL, is the value of the difference between the closing line of a game and its opening line. These lines are collected from sportsinsights.com and denote lines which were offered to bettors on the website pinnaclesports.com

sample into subsets for additional analysis. We also briefly consider some line movement trends in men's (NBA) and women's (WNBA) professional basketball games for comparison purposes. All pushes (tie bets) are omitted from our various samples.

4. Results

We present the frequencies of various line movements for college basketball games in Table 1.

It may be initially surprising to note how frequently opening lines of games are subsequently adjusted. The significant majority of college basketball games, over 78%, have some change in the spread between the opening and closing of the betting period.[12] The majority of these line movements are only by 0.5 points or 1 point, though a quarter of all college basketball games see line shifts greater than 1 point. These proportions do not vary substantially from season to season.

We next consider how frequently teams cover spreads when lines move in a manner indicating that the opening line of a contest might have underestimated the team's likelihood of prevailing. Put more plainly, if the spread of game Y moves from an opening line of Team A −2 versus Team B, to Team A −1.5 versus Team B, then Team B has seen line movement of 0.5 points in its direction. Conversely, if the line of game Z moves from an opening line of Team C −9 versus Team D, to Team C −10 versus Team D, then Team C has seen line movement of 1 point in its direction. In any game in which the opening and closing lines differ, line movement toward one team exists. Such a team is thus a stronger favorite, or less of an underdog, at the closing of betting than at the opening.

Allow X to be the set of teams with line movement in their direction and assume line movement is purely the result of bookmakers attempting to lower risk by balancing bets (i.e., all wagers are from ordinary bettors). If the opening line was efficient in incorporating information correctly, then X should cover opening lines 50% of the time, and cover the closing, inefficient spread, less than 50% of the time.[13] This implies the traditional, balanced book model of bookmaking, though the same conclusions are valid in a profit maximization setting. If, however, line movement is the result of bookmakers correctly fearing that teams from set X are more than 50% likely to cover the opening spread, as a significant amount of wagers on X emanate from wise guys, then X will cover more than 50% of all opening lines. In the case of line movement due to wise guy betting, approximately 50% of bets on X at the *closing line* should win (perhaps less given bookmaker preferences). The question of which of these explanations better describes the motivation of line movement is an empirical one.

[12] This is a conservative estimate as additional games might have had lines fluctuate throughout the day yet have identical opening and closing lines.

[13] Suppose the opening line is Team F −4 versus Team G. If heavy betting on Team F occurs, the bookmaker may move the line in an attempt to balance bets on the two teams. To induce increased betting on Team G, the line would have to increase (for example to Team F −5 versus Team G). If the opening line was correct, Team F would be less than 50% likely to cover the new spread, requiring a win by more than 5 points rather than by more than 4 points.

Table 2
Likelihood of covering college basketball spreads when lines move.

$\|\Delta L\|$	All	0.5	1.0	1.5	2.0	2.5	3.0	>3.0
% Cover open	54.7***	52.5***	54.7***	55.6***	57.8***	55.3***	60.0***	69.9***
% Cover close	50.0	50.4	50.4	49.1	49.6	47.7	51.4	48.4
Frequency	20,150	8179	5678	3096	1637	774	390	396

This table presents the percentage of occurrences in which a men's NCAA basketball team covers the opening and closing spread of a game in contests where the spread of a game shifts in the direction implying the team is a stronger favorite or less of an underdog. The results are shown based on the degree of line movement for the contest, as well as on an aggregated basis. ΔL is the movement in the spread toward the team, which becomes a greater favorite or smaller underdog through the course of the betting period. For example, if Team A was originally favored by 4 points over Team B in a game, and is a 5-point favorite at closing of betting for a contest, then Team A will be in the sample of games for which $\Delta L = 1.0$. As another example, if Team C was originally a 7-point underdog to Team D in a contest, and is a 6.5-point underdog at the close of betting for the game, then Team C will be in the sample of games for which $\Delta L = 0.5$. The games used in this study are from the 2003–2004 season through January of the 2010–2011 season. We track the percentage of instances in which wagers at the opening and closing lines of contests win and present significance levels for two-sided tests of the covering percentage being equal to 50%.

*** Denotes significance at the 1% level. These lines are collected from sportsinsights.com and denote average lines from six internet sports books. Games which push, relative to the given line, are excluded.

Table 2 presents the percentages of college basketball teams which cover opening and closing spreads based on the degree of line movement. Results for tests of the true percentage of spread covering being equal to 50% are also shown. The results demonstrate support for the theory that line movement is the result of sharp bettors recognizing opening lines, which offer profitable opportunities. For the full sample of college basketball games which have line movement, 54.7% of teams that have the line move in their direction cover the opening line. This is statistically significantly greater than 50% at the 1% level. Almost exactly half of teams with line movement in their direction cover closing spreads. This implies that line movement is unlikely to be purely a function of bookmaker attempts to balance the funds bet on the two sides of a contest.

The results are more pronounced for games with greater point spread movements. Teams with small line movements in their direction of only 0.5 points cover opening spreads 52.5% of the time. While this is significantly greater than 50% (in a two-sided test at the 1% significance level), bets on all such teams at the opening line would only break even for gamblers after incorporation of bookmaker commission, as a winning rate of 52.4% is necessary for a bettor to avoid long-term losses (Levitt, 2004). When bookmakers make greater initial errors in setting spreads, the profitability for early-moving wise guys jumps accordingly. 54.7% of all teams with a 1-point line movement in their direction cover opening spreads. The percentage increases to 55.6%, 57.8%, and 60.0% for the 1.5, 2.0, and 3.0-point cases, respectively. Significantly more (at the 1% level) than 52.4% of teams with line movement in their direction cover opening spreads for all cases, except the 0.5-point and 2.5-point instances. This indicates that the larger the initial reaction by bettors (and thus the subsequently larger moves in point spreads) the more likely the bookmaker is to suffer losses on those wagers placed at the opening line.[14] It is also more likely that the number of bets made at interim (still favorable) spreads will be greater when a spread must be moved further before reaching its closing level. Slightly less than half of wagers at closing spreads on teams with line movement in their direction are won when the shifts are by more than 1 point (with the exception of movements of exactly 3 points). While these percentages are statistically insignificant, this is perhaps indicative that bookmakers move lines more strongly when they are concerned that initial spreads were greatly mispriced.

We also apply a more formal test of opening versus closing line accuracy. Ashley et al. (1980) introduce the methodology, which is also used by Gandar et al. (1998). The following equation is estimated:

$$(\text{FEO} - \text{FEC}) = \alpha + \beta[(\text{FEO} + \text{FEC}) - (\text{MFEO} + \text{MFEC})] + \varepsilon \quad (1)$$

[14] The rare cases of updated information regarding player injuries, player eligibility, etc. are disproportionately likely to result in large line movements. Thus, caution should be utilized when interpreting the percentages of teams with large line movements, which cover opening spreads.

Table 3
Comparing forecast accuracy of college basketball opening and closing lines.

Season	N	MAFEO	MAFEC	MSFEO	MSFEC	α (p-value)	β (p-value)
2003–2004	2993	8.35	8.32	112.21	111.32	0.033 (0.068)	0.002 (0.158)
2004–2005	3097	8.44	8.37	114.67	112.12	0.070 (0.001)	0.008 (0.001)
2005–2006	3192	8.56	8.50	119.34	118.17	0.055 (0.015)	0.001 (0.443)
2006–2007	3407	8.54	8.51	126.76	125.29	0.033 (0.128)	0.004 (0.003)
2007–2008	3487	8.38	8.30	115.19	113.30	0.083 (0.001)	0.003 (0.070)
2008–2009	3449	8.43	8.38	114.01	112.63	0.051 (0.015)	0.003 (0.049)
2009–2010	3635	8.22	8.16	109.49	107.27	0.060 (0.006)	0.007 (0.001)
2010–2011	2314	8.39	8.34	114.79	112.61	0.052 (0.044)	0.008 (0.001)
All seasons	25,574	8.41	8.36	115.81	114.10	0.055 (0.001)	0.004 (0.001)

This table presents mean absolute and mean square forecast errors for opening and closing lines for men's college basketball games from the 2003–2004 season through January of the 2010–2011 season. Results are presented by season as well as on an aggregate basis. Lines are collected from sportsinsights.com and denote lines which were the average of those offered by six internet sports books. Estimates for the Ashley, Granger, and Schmalansee (AGS) test are also presented to determine if a statistical difference exists between the accuracy of opening and closing lines. N is the number of games where ΔL is not equal to 0. MAFEO is the mean of the absolute value of the opening line forecast error (i.e., the average of all |opening line − final score differential|). MAFEC is calculated similarly based on closing lines. MSFEO and MSFEC are calculated similarly but are based on the squaring of differentials between lines and final score differentials. Intercept and slope coefficient estimates, α and β, and their associated p-values are used to test the AGS null hypothesis that the difference between the mean square errors based on opening and closing lines, is zero. Rejection of this hypothesis and conclusion that closing lines are more accurate than opening lines requires both coefficients to be nonnegative and at least one of the coefficients to be significantly positive. p-values are based on two-sided hypothesis testing.

where FEO and FEC are individual game forecast errors of opening and closing lines, MFEO and MFEC are the mean forecast errors of these lines, and ε is an error term. The null hypothesis is that no difference exists between mean forecast errors of opening and closing lines. To reject this hypothesis and find that closing lines are more accurate than opening lines, estimates of both α and β must be positive, and at least one must be significantly positive. Additionally, we report values for MAFEO (MAFEC), the mean absolute forecast error based on opening (closing) lines, relative to realized game results. MSFEO (MSFEC), the mean square forecast error based on the opening (closing) line, relative to the realized game results, is shown as well.

The results shown in Table 3 demonstrate that closing lines are significantly better predictors of college basketball game outcomes than opening lines. The 2003–2004 season closing lines are more accurate at the 10% significance level, but all other individual seasons show significantly superior forecasting performance of closing lines at the 5% level or better. The results for the full sample are indicative of superior forecasting by closing lines at the 0.1% significance level. It does not appear that the movement of opening lines by bookmakers is simply an exercise done to lower risk when ordinary bettors display unexpected preferences. Strong support exists for the theory that line movements are largely due to bookmaker realization that initially "soft" lines should be moved in order to eliminate the advantages informed bettors held when betting began.

We next consider the question of whether bookmakers are more likely to offer self-confessed poor initial spreads in certain types of college basketball games. We separate our sample of college basketball games into two groups. The first group of games is the power conference sample. "Power conference" is an often-used description of United States collegiate sports leagues whose members are of notably high athletic profile. 73 U.S. universities with membership in six widely followed leagues are classified as members of power conferences.[15] A total of 346 American schools play NCAA men's Division I basketball. Any game which involves at least one power conference team is denoted a power conference game in our sample. All other games are denoted non-power conference games. This results in a sample breakdown of approximately 60% of college games classified as non-power conference.

In Table 4 we track the proportion of teams with line movement in their direction who cover the opening spreads of basketball games. This is done separately for power conference and non-power

[15] 12 from the Atlantic Coast Conference, 16 from the Big East Conference, 11 from the Big Ten Conference, 12 from the Big 12 Conference, 10 from the Pac 10 Conference, and 12 from the Southeastern Conference.

Table 4
Likelihood of covering opening basketball spreads in games where lines move.

	All moves	0.5	1.0	1.5	2.0	2.5	3.0	>3.0
NCAA power conference	53.8***	52.3**	54.3***	54.4***	56.6***	50.0	55.5	63.6***
Frequency	7996	3154	2249	1255	677	322	155	184
Profitability significance	**		*		**			***
NCAA non-power conference	55.1***	52.7***	55.0***	56.4***	58.6***	59.1***	63.4***	69.3***
Frequency	12,154	5025	3429	1841	960	452	235	212
Profitability significance	***		***	***	***	***	***	***
NBA	54.2***	51.9**	54.0***	56.9***	57.4***	58.5***	50.3	66.4***
Frequency	7178	3074	1990	981	470	258	167	238
WNBA	56.6***	52.1	57.2**	58.5**	59.0*	57.4	51.6	67.7***
Frequency	1045	349	271	142	105	54	31	93

No line movement	NCAA P	NCAA NP	NBA	WNBA
	19.7%	22.1%	22.9%	20.1%

This table presents the percentage of occurrences in which basketball teams cover the opening spread of a game in contests where the spread of a game shifts in the direction implying the team is a stronger favorite or less of an underdog. The results are shown based on the degree of line movement for the contest, as well as on an aggregated basis. Results are separated based on whether men's NCAA basketball games involve a team from a "power conference" or not. If a contest involves at least one team from the ACC, Big East, SEC, Big Ten, Big 12, or Pacific 10 conference then it is a power conference game. Other contests are classified in the "non-power conference" sample. For comparison, results of National Basketball Association (NBA) games and Women's National Basketball Association (WNBA) games are also shown. Men's NCAA games and NBA games are from the 2003 to 2004 season through January of the 2010–2011 season. WNBA games are for the entirety of the league's existence, from the 2005 through 2010 seasons. Lines are collected from sportsinsights.com and originally reflect the average of lines from six internet sports books. We track the percentage of instances in which wagers at the opening lines of contests win and present significance levels for two-sided tests of the covering percentage being equal to 50%. Additionally, significance levels for college basketball games for the two-sided test that lines are not equal to the profitability level of 52.4%, as shown by Levitt (2004), are given. The row labeled "Profitability significance" denotes these levels. The percentage of all games with no line movement is also given by league. These percentages are based on all games (games where the initial line resulted in a tied contest are not removed, unlike in the top portion of the table).
*, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

conference games. We delineate the results based on the degree of line movement. For comparison purposes, we also include winning frequencies against opening lines for teams with line movement in their direction in both men's (NBA) and women's (WNBA) professional basketball. It is interesting to note that, across all of the various basketball leagues, the relative frequencies of the various degrees of line movement are strikingly similar. More basketball games experience half-point line moves than zero line movement. One-point line movements are approximately as frequent as zero line movements, and larger line movements are decreasingly prevalent by movement size. Regardless of the basketball league, very similar types of line movements are conducted by bookmakers, to address bettors' preferences, between the opening of wagering and the actual games.

Table 4 suggests that college basketball teams with line movement in their direction are more likely to cover the opening spread of a game if the contest is a non-power conference game (55.1% versus 53.8% in power conference games). This discrepancy is statistically significant at the 10% level. Line movements in power conference games are just as frequent as in non-power conference games (in fact, while not significantly so, line movements are slightly more common in power conference games, as indicated at the bottom of Table 4). The significance level of the test of profitability (greater than 52.4% winning rate for teams with line movement in their direction) is stronger for the sample of non-power conference games (1%) than the sample of power conference games (5%). For each individual line movement degree, non-power conference teams are more likely to cover opening lines. This discrepancy is small in the case of a 0.5-point line movement (52.7% of non-power conference games result in teams with line movement in their direction covering opening lines, as opposed to 52.3% of power conference games), but the disparity grows as the line movement degree increases. Furthermore, for the non-power conference sample, tests of profitability for wagers on teams with line movement in their direction are significant at the 1% level for each ΔL. This is not the case for the power conference sample.

When lines shift by two points or more, teams with line movement in their direction perform very strongly, relative to opening lines, in non-power conference games. This may be evidence that bookmakers are more likely to badly misprice such games. As such games are of less interest to the general public, it is quite possible that a greater proportion of wagers in these games are made by informed, rather than ordinary bettors. Thus, line movement is more likely to be a concession by bookmakers that their wagering opponents have superior handicapping ability of the contest. Additionally, bookmakers of non-power conference games are more likely to offer inefficient lines due to unawareness. The advantage of an informed bettor in a non-power conference game may result not from superior handicapping of the contest, but from knowledge of situations (particularly player illness, eligibility, or injury status) of which an unwitting bookmaker is not aware. Such an oversight would be less likely in a higher profile game. Regardless of the specifics, the harm to the bookmaker results from an informational disadvantage. Such disadvantages are more apt to exist in lower profile games.[16]

Analogously, line movement in men's professional basketball games is less likely to be indicative of mispricing by bookmakers than similar line movement in women's professional basketball games. 56.6% of WNBA teams which have line movement in their direction prevail relative to the opening line, as opposed to 54.2% of NBA teams. This difference is statistically significant at the 10% level for the one-sided case.[17] The discrepancy is small for line movements of only 0.5 points (52.1% WNBA, 51.9% NBA) but increases for larger line movements, with the exception of the case of line movements of exactly 2.5 points. A similar effect to that described in the power versus non-power conference analysis may be at work. Lower public focus on WNBA games probably means that a larger proportion of wagers on such games come from bettors who are more informed than the bookmaker.

We further test whether the status of a college basketball game as "power conference" has predictive power of whether the team with line movement in its direction will cover the opening spread. This is accomplished via the following logistic regression specification:

$$\begin{aligned}\text{Logit (covers opening line)} &= \alpha + \beta_1(\text{non-power conference}) + \beta_2(\Delta L)\\ &\quad + \beta_3(\text{non-power conference} * \Delta L)\end{aligned} \tag{2}$$

non-Power conference is a dummy variable taking the value 1 when neither team in a college basketball game is a member of a power conference, and 0 otherwise. ΔL is the change in the line toward the team with the movement in its direction. A "success" in this specification occurs when the team with line movement in its direction prevails relative to the opening line. The results from the logistic regression specification are shown in Table 5.

Teams in non-power conference games are significantly (at the 10% level) more likely to cover opening lines when spreads move in their direction. This is in agreement with the result noted from the difference in proportions test in the discussion of Table 4. The non-power conference dummy coefficient's statistical significance increases to the 5% level when the degree of line change is additionally included as an independent predictor. ΔL is also highly significant. When the interaction term between the non-power conference dummy and ΔL is included, giving the full specification of Eq. (2), the degree of line movement coefficient remains strongly significant. Perhaps most interestingly, the interaction term's coefficient is positive and significant at the 5% level. Thus, the status of a game as a non-power conference contest is increasingly more impactful in predicting whether a team with

[16] Alternatively, rather than classifying college basketball games as "high profile" based on power conference membership, we consider games that include at least one team ranked in that week's Associated Press Top 25 poll to be high profile. We also consider classifying postseason (tournament) games, or games later in the season to be high profile. Our results are of a similar theme when we do so: line movements in lower profile games are more indicative of teams with the movement in their direction prevailing relative to opening lines. The statistical test results derived from segmenting the sample based on the power conference classification, however, are the strongest, in part due to the available sample sizes, and we thus emphasize these results.

[17] Relatively low statistical power is available in comparing NBA and WNBA results given that only recently have bookmakers offered spreads on WNBA games.

Table 5
Logistic regressions of covering opening lines when line moves.

Covers opening line	Coefficient	p-Value	Coefficient	p-value	Coefficient	p-value
Intercept	0.152	(0.001)	0.010	(0.728)	0.054	(0.142)
Non-power conference	0.052	(0.076)	0.057	(0.050)	−0.019	(0.689)
ΔL			0.123	(0.001)	0.085	(0.001)
Non-power conference* ΔL					0.068	(0.048)

This table presents logistic regression coefficients and p-values from modeling the probability of a men's NCAA basketball team covering the opening spread of a game for those contests in which the spread shifts in the direction implying the team is a stronger favorite or less of an underdog. Opening and closing lines from sportsinsights.com, originally the average of lines offered by six internet sports books, are utilized beginning in the 2003–2004 season through January of the 2010–2011 season. Non-power conference is a dummy variable which takes the value 0 if at least one of the teams in a contest affiliates with the ACC, Big East, SEC, Big Ten, Big 12, or Pac 10 conferences and 1 otherwise. ΔL is the movement in the spread toward the team, which becomes a greater favorite or smaller underdog through the course of the betting period. For example, if a team is a 5-point favorite at the opening line and a 6-point favorite at the closing line (or a 4-point underdog at the opening line and a 3-point underdog at the closing line), then $\Delta L = 1$.

opening line movement in its direction will cover the initial spread when the line movement is larger. This confirms the trend noted in Table 4.

5. Discussion and conclusion

Line movement in a basketball game is the result of a bookmaker's desire to decrease the betting on the side of a contest that has the line move in its direction. The bookmaker does this by offering to-be bettors of such a team an effectively higher price. The underlying motivation of the bookmaker may be concern that informed bettors are making bets with positive expected profitability at the original line, or the movement may simply reflect a bookmaker's desire to increase the wagers on the opposite side of a contest and thereby lower his/her exposure.

When a line does move, it is significantly more likely than not that the team with line movement in its direction will cover the opening line. This is most likely because, at least in some cases of line movement, certain bettors have superior ability to forecast game results than the bookmaker. Bookmakers, wary of the abilities of wise guy opponents, move lines in order to limit this exposure. In plainer speak, bookmakers recognize that the sharp bettor has superior ability, and to avoid taking the worst of further bets against sharp players, the bookmaker adjusts the line after the preferences of sharp bettors have been revealed via a bet.

Sharp bettors are frequently self-employed professional gamblers. The ability to maintain regular income from wagering in a system that charges commissions is rare, and thus the preferences of such bettors serve as powerful pieces of information to many handicappers. While casino and internet bookmakers are experts in line setting, they may question, on any individual game, if they are offering the most appropriate price possible. While it is not ideal to have to adjust the line of a game, the tool is available to the bookmaker.

Before this tool is implemented, however, the bookmaker may suffer substantial losses due to poorly set lines. In the Las Vegas casino sportsbook setting, for example, maximum betting limits of $5000 for NBA basketball games and $3000 for college basketball games are common. While these maximums may not strike one as particularly large, initially, it should be noted that one or two wagers will often not be enough to convince a bookmaker to move a spread, and thus, significantly greater exposure may result to a bookmaker than the maximum bet amount.[18] From the perspective of the wise guy, a multitude of casinos and internet books exists, allowing the wise guy to shop for the most favorable price, and even if one bookmaker's line does move in response to sharp betting, other opportunities to bet at the desired line may still exist.[19]

[18] While these amounts are the posted maximum bets, management at books may approve, or "key" additional amounts at its discretion.

[19] Both informed bettors and books can track line movements instantaneously, and bookmakers at one sports book may elect to shift a line without receiving wagers on a game, simply because a fellow bookmaker has shifted his price. Not all

As previously discussed, not all cases of line movement by bookmakers are in response to concern that wise guys have superior information. The bookmaker may instead simply be seeking to lower risk exposure by shifting the line.[20] In the case of an accurate bookmaker facing only naive bettors, teams with line movement in their direction should not cover more than 50% of opening lines because those lines were the best possible estimate of a game's outcome. While classifying bettors by knowledge/information level illustrates the concerns of bookmakers in regards to line movement, segmenting bettors into distinct ordinary and informed classes is overly simplistic. A continuum of ability exists through the betting population, and bettors that one might routinely classify as "ordinary" can be relatively informed if the bookmaker provides a poorly handicapped opening line. As the bookmaker would not knowingly produce such an opening line, but will always be cognizant of the possibility of a mistake, it is probably most realistic to state that all line movements are conducted in part due to simple risk management and in part due to efforts to protect against the possibility that bettors are able to place wagers with expected profitability.

The varying mix of relatively ordinary and sharp bettors for different types of contests is the most interesting question to us. The evidence supports the reasonable proposition that line movements in games with relatively low profile are more indicative of defensive action by bookmakers fearful of wagers from wise guys. The ordinary gambling public is most likely to have (uninformed) opinions regarding games involving teams frequently on television, games featuring larger schools with more vivid athletic cultures, and games with meaningful implications for championship play. Our proxy for this higher profile status is membership, by at least one participant, in a power conference.

Who would be interested in wagering on a game featuring relatively *low profile* schools with limited media coverage? Disproportionately, the answer is those bettors who feel they have an advantage over the bookmaker in handicapping the contest. Line movement in such contests is considerably more likely to result from the fear of bookmakers that the initial price offered was inaccurate. This information is then incorporated into betting lines. The fact that line movements in low profile games are relatively more likely to be indicative of information impacts, and relatively less likely to be the result of noise from naive bettors, supports the theory that substantial price movement is more meaningful when savvy traders make up a greater proportion of a market.

After revisions, we see that closing lines for non-power conference games (like power conference games) are fairly accurate in predicting the final result, i.e. both sides of wagers are about equally likely to win, after factoring in the spread. For line shifts of over 0.5 points, wagers placed at the opening line on teams with line movement in their direction are not only significantly likely to win, they are significantly more likely than the profitability mark of 52.4% to win. Teams with line movements in their direction are, furthermore, more likely to cover opening lines when the profile of the game is low, and large line shifts are more likely to be evidence of early susceptibility to sharp bettors.

One "bookmaker" is typically a staff of a few expert handicappers who work for a casino or internet company. This staff has dozens of daily professional and amateur athletic contests to handicap. The bookmaker also offers odds on numerous "futures" bets whose payoffs will be determined at the end of major sporting events, and these futures prices must be monitored constantly. Bookmakers have incentives to offer lines as quickly as possible, and on as many contests as possible, in order to attract volume which, typically, will be profitable for their employers given the bookmaker's relative expertise and the commission charged to bettors. If, however, bookmakers spread themselves too thin and offer prices on contests about which they are relatively uninformed, or if bookmakers offer lines without fully researching a particular contest, then losses may be taken, particularly to sharp bettors.[21] Given

bookmakers, however, are likely to react to a line shift from a peer in identical fashion; thus, the informed bettor will likely have the opportunity to place wagers totaling many times the maximum bet allowed by any one bookmaker, even if his initial wager causes the opposing bookmaker to shift the line.

[20] However, Humphreys et al. (2013), based on data from the 2007 college basketball season, do not find that line movements are designed to balance books. This would lead further credence to the belief that line shifts are designed to respond to sharp bettors.

[21] A recent Business Week article by Eric Spitznagel (April 11–17, 2011) discusses a number of sharp bettors who have consistently profited from wagering on WNBA games. Given the relatively low interest in betting on such games from the general public, setting lines in WNBA games may be a dangerous exercise for bookmakers with limited time to devote to the process.

time and effort restrictions, it is reasonable that bookmakers would concentrate their work on those games which garner a large amount of public attention. A small mistake on a high profile game may be more damaging than a large mistake on a low profile game (particularly given that maximum betting limits exist on contests and that line movements are possible for the bookmaker). Thus, a bookmaker's time management, given that he will handicap all possible games, may be entirely reasonable.

But why would bookmakers offer *any* prices on contests for which their only opponents may be bettors with superior information? The exercise is largely done for reputation's sake. A sportsbook is better able to advertise itself if it may credibly argue that it offers lines on every imaginable contest in relatively short order. The downside potential in handicapping low profile contests with few naive bettors is considerable, however. Sports gambling is growing in popularity,[22] and increased profitability is available to bookmakers on many contests. The willingness to accept bets when the *opposition* is relatively well informed, however, may directly impact a bookmaker's bottom line. The reputational gain from such bookmaking is more questionable.

Regardless of the wisdom of a bookmaker's decision to handicap all possible games, we are fortunate that they do so. Their willingness results in an excellent environment to uniquely study what the prevalence of informed traders implies about price movements. The findings of Boehmer and Kelley (2009), Edmans (2009), and Kitsul and Mahani (2011) suggest that prices are more efficient when equities have more institutional ownership, more blockholders, and lower market participation by ordinary investors, respectively. In the wake of these papers, it is reasonable to consider the possibility that substantial price movements are indicative of information, and not noise, when knowledgeable traders populate the marketplace. More work needs to be done on the link between price movements and the makeup of a marketplace for traditional assets, but our evidence provides independent support that, in a market more concentrated with informed participants, there is a greater likelihood that price shifts are indicative of information.

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[22] Merrill Lynch and PricewaterhouseCoopers estimate that worldwide sports gambling revenues easily exceed $100 billion currently and will continue to increase. Estimates exceed $500 billion by 2015.

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