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Symposium

An Empirical Examination of the Parimutuel Sports Lottery Market versus the Bookmaker Market

Jaiho Chung* and Joon Ho Hwang†

A sports lottery in Korea presents a unique opportunity for comparing a parimutuel-type sports lottery market against a bookmaker market outside the realm of horse racing. Using two- and three-game soccer final-score betting in the sports lottery market in Korea, which features matches in the English Premier League, we compare winning payoffs in this parimutuel-type sports lottery against corresponding payoffs from an established bookmaker market in the United Kingdom. We find that for outcomes with relatively high payouts (that is, lower-probability events), winning bets placed in the sports lottery market have greater payoffs than corresponding bets placed in the bookmaker-based market. However, the opposite is true for outcomes with relatively low payouts (that is, higher-probability events). Results suggest that participants in the sports lottery market tend to bet more toward high-probability events than the amount implied by the bookmaker's odds. Results also suggest that the favorite-longshot bias is still present in the bookmaker market, even when there is less threat of privately informed bettors than in horse racing.

JEL Classification: G14, L83

1. Introduction

Market mechanisms under which sports betting takes place can be categorized into two major types: a bookmaker system and a parimutuel market system. In a bookmaker-based system, the bookmaker posts odds and charges a commission (also called “vigorous” or “juice”) for placing a bet. In this type of market, bettors (or “punters”) are promised a fixed payoff according to the odds that are posted at the time they make their bets. In the parimutuel betting system, there are no bookmakers, and the payout from a specific outcome is inversely related to the aggregate amount wagered on that outcome relative to the aggregate amount bet across all outcomes. Therefore, the payout will not be determined until all bets are submitted. In this

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study, we use a unique data set in the parimutuel-type Korean sports lottery market and examine the joint efficiency of the parimutuel sports lottery market and the bookmaker market.

Sports betting markets have been used in many studies as a way of testing market efficiency (see Sauer 1998; Vaughan Williams 1999; and Paton, Siegel, and Vaughan Williams 2009 for reviews). A widely documented anomaly against market efficiency in the sports betting market is the favorite-longshot bias. The favorite-longshot bias, first shown in the horse race betting market, states that horses with lower odds (higher probability of winning) tend to win more frequently than projected by their odds, while horses with higher odds (lower probability of winning) tend to win less frequently than indicated by their odds. In a parimutuel market structure, this suggests that favorites are underbet while longshots are overbet (see Ziemba and Hausch 1984; Thaler and Ziemba 1988; and Paton, Siegel, and Vaughan Williams 2009 for reviews).¹

Most horse tracks in the world operate as a parimutuel system (the system is called the totalisator in the United Kingdom, Australia, and New Zealand),² whereas horse tracks in the United Kingdom, Ireland, and Australia also employ bookmaker-based systems. Researchers have examined market efficiency between these two different types of market structures for horse tracks. Gabriel and Marsden (1990, 1991), Bruce and Johnson (2000), and Peirson and Blackburn (2003) compare returns in the British horse track for bets made in the parimutuel (“tote”) market and bets made with the bookmaker. Gabriel and Marsden (1990, 1991) examine winning bets in two markets under the situation where tote bettors had restricted information on current odds due to the absence of mechanical or electronic tote boards during the year of their sample period. They find that the level of winnings from successful bets in the parimutuel market is larger than that in the bookmaker market. Bruce and Johnson (2000) examine all bets made in the two markets under full odds information available for the tote bettors and find that the favorite-longshot bias is strong in the bookmaker market but not in the parimutuel market. Peirson and Blackburn (2003) also find similar results in British racetracks and note that profit maximization by bookmakers and efficient behavior by bettors can cause the difference between the two markets.

For sports betting other than horse racing, most markets are bookmaker based, with the exception of betting pools and some sports lotteries. Therefore, almost all previous studies on sports betting outside of horse racing are based on a bookmaker market, and none of these studies examines efficiencies across different market structures.³

In this study, we use a unique data set in the parimutuel-type Korean sports lottery market to ascertain whether there is a significant difference in winning payoffs between this parimutuel sports lottery market and the bookmaker-based market. In the Korean sports lottery market,

¹ On the other hand, there is also some evidence of a reverse favorite-longshot bias for betting markets in some Asian horse tracks (Busche and Hall 1988) and in other sports, such as baseball and hockey (Woodland and Woodland 1994, 2001).

² In the United Kingdom, the brand of the totalisator is the “tote.” In Australia, Tabcorp Holdings, through the privatization of the Victorian Totalisator Agency Board (TAB) in 1994, is the major operator of the totalisator. We thank the referee for providing us with this information.

³ With regard to studies that examine sports betting markets outside of horse tracks, Zuber, Gandar, and Bowers (1985); Gandar et al. (1988); Dare and MacDonald (1996); and Gray and Gray (1997) investigate the National Football League (NFL) betting market; Camerer (1989) and Brown and Sauer (1993) study the National Basketball Association (NBA) betting market; Woodland and Woodland (1994) examine the Major League Baseball (MLB) betting market; and Woodland and Woodland (2001) investigate the National Hockey League (NHL). There are also numerous studies on soccer betting, including Pope and Peel (1989); Forrest and Simmons (2000); Forrest, Goddard, and Simmons (2005); and Graham and Stott (2008).

odds are determined by the parimutuel method, and current odds are readily available on its website, which allows participants to monitor odds on a real-time basis. Among the various betting opportunities that are offered by the Korean sports lottery system, we focus on “soccer special triple” and “soccer special double,” where participants who pick the correct final scores of a predetermined three- or two-game soccer lottery win the share of the betting pool. For instances where the Korean sports lottery features games in the English Premier League, the odds on the final score of these three (or two) games are available on major bookmakers, such as the online betting website of William Hill PLC. Using data from 34 sports lotteries for 86 English Premier League matches between 2005 and 2008, we compare the return on winning bets placed in the parimutuel-type Korean sports lottery market to the corresponding return on a bet placed in the U.K. bookmaker-based market.

We find notable differences in the realized return between these two markets. For example, a \$1.00 bet on the final score of 1:0, 2:0, and 0:3 for matches between Bolton and Manchester United, Arsenal and Wigan, and Middlesbrough and Aston Villa, played on November 25, 2007, paid an amount of \$6605.20 in the Korean sports lottery market, compared to \$2028.00 in the U.K. bookmaker market. However, another \$1.00 bet on the final score of 2:1, 1:1, and 1:2 for matches between Arsenal and Tottenham, Fulham and Wigan, and Middlesbrough and West Ham on December 22, 2007, paid only \$92.90 in Korea’s sports lottery market, compared to \$585.00 in the U.K. bookmaker-based market. These discrepancies in winning payouts between two markets are surprising since current odds on both markets are accessible to participants in the Korean sports lottery market. We find that for low-payout outcomes (games that turn out as many have expected), the Korean sports lottery market returns lower payouts compared to the corresponding payoffs in the bookmaker-based market. The reverse relationship is found for high-payout outcomes (games that do not turn out as many have expected). Overall, our results suggest that the two markets are not jointly efficient.

Our main contributions are twofold. First, to the best of our knowledge, this is the first study to provide an empirical examination of a parimutuel sports lottery market relative to a bookmaker market.⁴ Some sports lotteries, such as Pro-line, operated by the Ontario Lottery and Gaming Corporation in Canada, are organized as bookmaker-based, fixed-odds systems and do not have a corresponding parimutuel market to compare against. For parimutuel-type sports lotteries such as The New Football Pools or Brittens National Pools in the United Kingdom or Sports Action in the United States, the lack of information on current odds or on the final payoff data make it impossible to compare the return against a bookmaker-based market.⁵ The sports lottery market in Korea, which provides current odds information to all participants and *ex post* payout information for their events, provides a unique opportunity for us to examine the parimutuel-type sports lottery market against the bookmaker market.

Second, given that the sports lottery, which we investigate, operates as a parimutuel market, this is also the first study to empirically test the joint efficiency of the parimutuel

⁴ Metrick (1996) analyzed 24 cases of National Collegiate Athletic Association (NCAA) basketball tournament betting pools, which function similarly to a sports lottery. However, he did not examine the efficiency of the betting pool against the bookmaker market.

⁵ In Europe, many countries operate their own sports lottery (for example, Svenska Spel in Sweden), most of which are governed by the European State Lottery and Toto Association. For a study of football (soccer) pools in the United Kingdom, see Forrest (1999).

market and bookmaker-based market outside the realm of horse tracks.⁶ In horse racing, studies (for example, Crafts 1985 and Shin 1992) note that private inside information is believed to be prevalent, and Shin (1991, 1992) argues that the bookmakers worsen the odds for longshots to guard against bettors with inside information, thereby causing the favorite-longshot bias in the bookmaker market. In comparison to horse race betting, betting on the final score of a soccer game would see many fewer cases of insider traders. For example, even if someone has inside information on a player's physical condition, the insider trader is unlikely to predict the final score of the game with high accuracy because of the larger proportion of the unpredictable component ("luck") present in the correct score betting. Therefore, it is interesting to see whether the favorite-longshot bias would still exist in the bookmaker market relative to the parimutuel market when bookmakers are faced with less threat of privately informed bettors. Our results suggest that the bias still exists in the bookmaker market.

Our study is not without limitation. Since we compare the parimutuel market and the bookmaker market on the basis of only winning bets, we do not intend to test the market efficiency in *each* of the two markets. Rather, we test the joint efficiency of these two markets and look only for the *relative* extent of bias across these two markets.

The article is organized as follows: Section 2 introduces the Korean sports lottery market and the U.K. bookmaker market. Section 3 explains the different market structures and mechanisms between the two markets, while section 4 compares the payoffs from the Korean sports lottery market against those from the U.K. bookmaker-based market. Section 5 analyzes these results with respect to the existence of the favorite-longshot bias. Section 6 provides some additional analyses, including the comparison against betting exchanges and tests of alternative specifications of the model, and section 7 concludes the article.

2. The Korean Sports Lottery Market and the U.K. Bookmaker Market

Korean Sports Lottery Market

In Korea, the only government-sanctioned and legalized sports betting markets outside of on-track betting are Sports Toto, which is structured as a parimutuel market, and Sports Proto, which is structured as a bookmaker market.⁷ In this study, our reference to Korean sports lottery refers to the parimutuel-type Sports Toto.

⁶ As for theoretical models that compare the parimutuel and bookmaker markets, Ottaviani and Sørensen (2005) model the equilibrium in each of the two markets under the presence of privately informed bettors. In doing so, they extend Shin (1991, 1992) by introducing *ex post* competition among bookmakers. Koch and Shing (2008) argue that the coarse grid odds offered by the bookmaker worsen the odds for the longshot, whereas odds are almost continuous in the parimutuel market; this results in the favorite-longshot bias in the bookmaker market but not in the parimutuel market. Vaughan Williams and Paton (1998) propose a general theory of explaining the bias using transaction costs, the extent of public information, and the consumption benefit from betting. Ottaviani and Sørensen (2008b) provide an overview of the theoretical explanations for the bias, including those based on the misestimation of probabilities, market power of informed bettors and uninformed bookmaker, preference for risk, heterogeneous beliefs, and limited arbitrage by informed bettors.

⁷ As for the two types of lottery, Sports Toto and Sports Proto, the football fixtures offered therein and the rules of the lottery are different, thereby making it impossible to conduct any market efficiency comparison between the two types of sports lottery.

Participants in the Korean sports lottery can make their bets offline through licensed betting offices, which are equipped with online terminals, or directly purchase online through the Korean sports lottery website (www.betman.co.kr).⁸ To bet online, the participant must register online for free using his national identification number and fund his account through electronic bank wire. In contrast, the identity of the participant is not checked when betting through licensed offline betting offices.

Participants of the Korean sports lottery can purchase multiple entries within the maximum wager limit of 100,000 Korean Won (approximately US\$100). Real-time odds are available on the Korean sports lottery website. Unlike in horse tracks where odds are rounded down, odds in the Korean sports lottery market are rounded off to the first decimal point.⁹ At the end of the event, participants who correctly predict the outcome of the games offered in the lottery share the prize pool in proportion to their bets, net of taxes. The prize pool consists of 50% of the total amount of money wagered for the event. If there are no winners for a specific round of sports lottery, the prize money is carried forward and added to the prize pool for the next event. In our analysis of the Korean sports lottery market, there was one occasion where there were no winning ticketholders. We exclude that event and the following one from our sample of data.

Among the different types of bets offered in Sports Toto, we focus on betting events called soccer special triple and soccer special double, where the corresponding odds of these events can also be found in overseas bookmaker markets. In soccer special triple (double), participants try to pick the correct final score (out of six available choices of 0, 1, 2, 3, 4, and 5 or more goals for each team) of a predetermined three (two) soccer matches.

Soccer special triple and soccer special double are offered once or twice a week for the Korean K-League games and the English Premier League matches during their respective seasons. Betting was also offered for international matches, such as games in the 2006 World Cup and Euro 2008. We use only English Premier League games as our sample of analyses and exclude Korean K-League and international matches. This is because the established bookmaker market that we use in this study is based in the United Kingdom and would therefore provide the best benchmark for games in the English Premier League for our analyses of the sports lottery market. Our choice of the U.K. bookmaker's odds as the benchmark is not without potential problems, as these odds may be biased and not represent a perfect indicator of the likelihood of each outcome. However, given that our sample consists of games in which the U.K. bookmaker is likely to have an informational advantage in setting the odds, the bookmaker's odds in the United Kingdom can provide a reasonable forecast of the outcome.¹⁰ Our objective is to examine how the odds that are generated from the parimutuel sports lottery

⁸ As of September 2008, the website is accessible only in Korea and is closed to access from foreign IP addresses. When we asked the customer representative the reason for the limited access, we were told that it was for the protection of user information and website security. Also mentioned were plans for opening up the website to access from outside of Korea; however, the exact date of opening was not determined at the time of the discussion. A reading of the bulletin board of users suggests that participants who reside outside of Korea are able to indirectly access the site using Korean proxy servers.

⁹ Busche and Walls (2001) argue that the rounding down of odds in horse tracks, known as breakage, can be a cause of the favorite-longshot bias because breakage imposes a proportionately larger cost on favorites than on longshots. We do not have such a problem in our sample as odds are rounded off rather than rounded down.

¹⁰ Direct evidence that the Korean sports lottery participants are using information from the U.K. bookmaker market comes from the user bulletin board of the Korean sports lottery website. In the bulletin board, we were able to observe numerous posting of the current U.K. bookmakers' odds information by the website users.

market differ from those posted by the bookmaker and examine the relative extent of the bias between the two markets.

With regard to the above objective, we exclude games in the Korean domestic league because the U.K. bookmaker may have informational disadvantage. We exclude events that feature international matches because all of them include a game in which the Korean national team is playing, where a skewed betting behavior due to bettors' sentiment is likely to occur in the Korean betting market.

An average soccer special triple lottery in our sample attracted 154,427 participants for an average bet amount of 4907 Korean Won (approximately US\$4.91) per participant. The size of soccer special triple was smaller, attracting 14,588 participants on average, with the average bet amount of 4697 Korean Won (approximately US\$4.70) per participant.

U.K. Bookmaker Market

To find the corresponding odds for the same event in the bookmaker market, we use a major U.K.-based bookmaker, William Hill PLC. The website of William Hill PLC (<http://www.williamhillplc.com>) states that the company employs over 16,000 people in the United Kingdom and Ireland and is licensed and regulated in the United Kingdom. Its shares have been trading on the London Stock Exchange since 2002, and the company is included in the Financial Times and London Stock Exchange 250 index. Its website attracts customers from over 150 countries and currently has over 300,000 active online customers. It also has over 2250 offline betting shops across the United Kingdom and Ireland, making it the largest operator in the United Kingdom in terms of the number of betting shops. Therefore, bettors in the U.K. bookmaker market can place their wagers through the bookmaker's website or through betting shops. To bet online, participants can open an account at the bookmaker's website free of charge and fund their account using methods such as bank wire, credit card, or third-party payment service such as PayPal, NETeller, or Moneybookers. Similar to the case of the Korean sports lottery, the identity of the participant is typically not checked when betting takes place at offline betting shops.

The maximum amount of winning by a customer varies depending on the type of event. For wagers placed for games in the English Premier League, the maximum winning per day is £1 million. Therefore, much more money can be wagered at the U.K. bookmaker's market compared to the Korean sports lottery market, where the maximum wager is 100,000 Korean Won (approximately US\$100 or £65).¹¹

3. Comparison of Market Structures

Market Operating Hours

Betting in the Korean sports lottery market opens at 9:30 A.M. (Korean standard time) on Thursday for the upcoming weekend matches and closes 10 minutes before the start of the first match. The corresponding U.K. bookmaker market opens earlier than the Korean sports

¹¹ A scan of the online user forum revealed that some participants are betting with greater stakes, such as 1 million Korean Won (approximately US\$1000 or £650). This is possible because the identity of the purchaser is not recorded when wagering takes place through an offline vendor, and therefore the participant can place multiple wagers across different vendors.

lottery market, typically about one week before the start of the match. Once the Korean sports lottery market is open for these matches, both markets stay open until the Korean sports lottery market closes. The U.K. bookmaker market closes just before the start of each match. In our article, both the Korean sports lottery market odds and the U.K. bookmaker market odds represent final odds in their respective market. There may be some concern about comparing odds based on the final odds in each market because of the time gap between the closing time of the Korean sports lottery market and that of the U.K. bookmaker market. These concerns can be addressed by considering the following. First, bookmaker odds may change during the last 10 minutes before the start of the first match. However, after most information becomes available to the public, such as the weather, starting lineup of players, and so forth, there would be little change in the U.K. bookmaker odds within that time frame. A second concern may be that, if there is a big time gap between the closing time of the Korean sports lottery market and the kickoff time of the second match (and third match in the case of the three-game lottery), then the final odds from the Korean sports lottery market may not incorporate all relevant information for these second or third matches. However, for the three-game lottery, 32 matches out of 54 matches (59.26%) in our sample had the same kickoff times for the first, second, and third matches offered in the sports lottery. As for the two-game lottery, 22 out of 32 matches (68.75%) had the same kickoff times between the first and the second match. For some lotteries that featured matches with different kickoff times, the second and third matches are within only a couple of hours from the first match offered in the sports lottery. Therefore, we believe the above concern will not be driving our results.

Tax and the Calculation of After-Tax Payoffs

The quoted odds in the Korean sports lottery market are stated in a pre-tax payout amount. For quoted odds greater than 100, a 22% tax is automatically levied on the difference between the winning payouts and the bet amount. The actual winning payoff is paid out after the tax has been taken out. For example, if the participant of the Korean sports lottery market places a wager of 1000 Korean Won and wins the lottery with quoted odds of x , which is greater than 100, then her after-tax payoff will be $(1000x - 1000) \times (1 - 0.22) + 1000$. Therefore, the corresponding after-tax winning payout odds can be calculated as follows:

$$\frac{(1000x - 1000) \times (1 - 0.22) + 1000}{1000} = 0.78x + 0.22. \quad (1)$$

The next equation summarizes the relationship between the after-tax odds and the quoted odds in the Korean sports lottery market:

$$\begin{aligned} \text{After-tax odds} &= 0.78 \times \text{quoted odds} + 0.22; & \text{if quoted odds} > 100 \\ \text{After-tax odds} &= \text{quoted odds}; & \text{if quoted odds} \leq 100. \end{aligned} \quad (2)$$

Contrary to the tax situation in the Korean sports lottery market, bettors of William Hill PLC do not pay any tax on their winnings. Instead, only the bookmaker is charged with tax, called gross profits tax (GPT), which is based on the net revenue of the bookmaker. Therefore, from the standpoint of the bettors, the following payout equation applies to the outcomes in the U.K. bookmaker market:

$$\text{After-tax odds} = \text{quoted odds}. \quad (3)$$

Readers can refer to Paton, Siegel, and Vaughan Williams (2002) for more information on betting taxation in the United Kingdom.

Participants' Access to the Other Market

In general, for participants in each market, the ability to participate in the other market is difficult due to the following restrictions. For the Korean bettors, they are restricted from betting in the overseas market due to government restrictions. Specifically, they cannot fund their account using conventional methods such as credit cards or bank wire since the Korean government blocks transactions to foreign gambling sites. For the U.K. bettors, they are restricted from betting in the Korean market because the Korean sports lottery is closed to participation by foreigners or anyone accessing from a foreign IP address.

Finding a way to participate in the other market is not impossible, though. One way of participating in the other market is by placing a local representative who works as an agent in the other country. However, as this would incur a large transaction cost, we believe it is generally the case that bettors do not participate in the other market.

Since prices in different markets are likely to converge with each other if bettors are allowed to participate in both markets without any trading cost or restriction, we think that our setting where bettors are not able to participate in the other market presents a better environment in which to compare the prices determined in each market.

4. Results

Table 1 shows the results for the Korean sports lottery, which featured games in the English Premier League. We retrieve data from www.betman.co.kr, and the final sample consists of 34 sports lotteries for 86 English Premier League matches between 2005 and 2008.¹² Even with a pre-tax payout ratio of only 50%, a sizable amount of money is bet on the sports lottery market in Korea.¹³ As can be seen from Table 1, the three-game lottery market, with an average total bet amount of 755,898,461 Korean Won (approximately US\$755,898), constitutes a much bigger market than the two-game lottery market. We conjecture that the greater participation for the three-game lottery market compared to the two-game lottery market is because investors are drawn to the higher payout, in spite of the lower probability of winning. Table 1 shows that the mean (median) payout on the winning ticket is 6114.6 (532.4) times the amount bet for the three-game lottery and 234.0 (60.0) times the wagered amount for the two-game lottery.

To examine whether any discrepancies exist in the winning payoffs between the parimutuel sports lottery market in Korea and the bookmaker market in the United Kingdom, we

¹² No lotteries were offered in 2006 for matches in the English Premier League. For the two-game lottery, it started offering games in the English Premier League from 2007.

¹³ The pre-tax payout ratio of 50% implies that the expected pre-tax return for all bets at the aggregate level is 50%. For an individual bettor, the participation decision will depend on his or her assessment of the expected return after observing other participants' selections and the resulting odds in the sports lottery pool. For example, if the bettor observes that a specific outcome is underbet by a significant amount, the bettor will decide to participate in the sports lottery. We thank the referee for pointing this out.

Table 1. Results of the Korean Sports Lottery

		Game 1			Game 2		
Year	Date	Home Team	Away Team	Score	Home Team	Away Team	Score
Panel A: Three-game lottery							
2005	Aug 13	Everton	Man Utd	0 2	Aston Villa	Bolton	2 2
2005	Sep 18	Liverpool	Man Utd	0 0	Blackburn	Newcastle	0 3
2007	Oct 20	Arsenal	Bolton	2 0	Fulham	Derby	0 0
2007	Oct 27	Man Utd	Middlesbrough	4 1	Tottenham	Blackburn	1 2
2007	Nov 03	Arsenal	Man Utd	2 2	Fulham	Reading	3 1
2007	Nov 12	Tottenham	Wigan	4 0	Man Utd	Blackburn	2 0
2007	Nov 25	Bolton	Man Utd	1 0	Arsenal	Wigan	2 0
2007	Dec 02	Portsmouth	Everton	0 0	Wigan	Man City	1 1
2007	Dec 09	Middlesbrough	Arsenal	2 1	Tottenham	Man City	2 1
2007	Dec 16	Derby	Middlesbrough	0 1	Portsmouth	Tottenham	0 1
2007	Dec 22	Arsenal	Tottenham	2 1	Fulham	Wigan	1 1
2008	Jan 20	Fulham	Arsenal	0 3	Tottenham	Sunderland	2 0
2008	Jan 31	Chelsea	Reading	1 0	Everton	Tottenham	0 0
2008	Feb 03	Portsmouth	Chelsea	1 1	Tottenham	Man Utd	1 1
2008	Feb 10	Derby	Tottenham	0 3	Everton	Reading	1 0
2008	Feb 24	Fulham	West Ham	0 1	Liverpool	Middlesbrough	3 2
2008	Mar 02	Birmingham	Tottenham	4 1	Fulham	Man Utd	0 3
2008	Mar 22	Tottenham	Portsmouth	2 0	Middlesbrough	Derby	1 0
Mean							
Median							
Minimum							
Maximum							
Panel B: Two-game lottery							
2007	Oct 20	Arsenal	Bolton	2 0	Fulham	Derby	0 0
2007	Oct 27	Man Utd	Middlesbrough	4 1	Tottenham	Blackburn	1 2
2007	Nov 03	Arsenal	Man Utd	2 2	Fulham	Reading	3 1
2007	Nov 12	Tottenham	Wigan	4 0	Man Utd	Blackburn	2 0
2007	Nov 25	Bolton	Man Utd	1 0	Arsenal	Wigan	2 0
2007	Dec 02	Portsmouth	Everton	0 0	Wigan	Man City	1 1
2007	Dec 09	Middlesbrough	Arsenal	2 1	Tottenham	Man City	2 1
2007	Dec 16	Derby	Middlesbrough	0 1	Portsmouth	Tottenham	0 1
2007	Dec 22	Arsenal	Tottenham	2 1	Fulham	Wigan	1 1
2008	Jan 20	Fulham	Arsenal	0 3	Tottenham	Sunderland	2 0
2008	Jan 31	Chelsea	Reading	1 0	Everton	Tottenham	0 0
2008	Feb 03	Portsmouth	Chelsea	1 1	Tottenham	Man Utd	1 1
2008	Feb 10	Derby	Tottenham	0 3	Everton	Reading	1 0
2008	Feb 24	Fulham	West Ham	0 1	Liverpool	Middlesbrough	3 2
2008	Mar 02	Birmingham	Tottenham	4 1	Fulham	Man Utd	0 3
2008	Mar 22	Tottenham	Portsmouth	2 0	Middlesbrough	Derby	1 0
Mean							
Median							
Minimum							
Maximum							

This table shows the results for the two types of Korean sports lottery, “soccer special triple” (three-game lottery) and “soccer special double” (two-game lottery). In the three (two)-game Korean lottery, participants need to pick the correct final score for three (two) predetermined football matches. For our study, we limit lotteries to those that feature English Premier League games. The after-tax winning payouts are stated in multiples of the bet amount, after the deduction of a tax of 22% for winnings whose quoted odds were greater than 100. The total bet amount is shown in Korean Won, where 1000 Korean Won are equivalent to approximately US\$1. Panel A shows the results for the three-game lottery. Panel B shows the results for the two-game lottery.

Table 1. Extended

Game 3			After-Tax Winning Payout	Total Bet Amount
Home Team	Away Team	Score		
Middlesbrough	Liverpool	0 0	2086.5	1,551,239,000
Man City	Bolton	0 1	5664.7	2,132,140,000
Middlesbrough	Chelsea	0 2	198.5	515,507,900
Sunderland	Fulham	1 1	286.4	488,752,200
Middlesbrough	Tottenham	1 1	1577.6	509,572,800
Bolton	Middlesbrough	0 0	2266.1	579,813,500
Middlesbrough	Aston Villa	0 3	6605.2	494,523,000
Reading	Middlesbrough	1 1	635.8	487,055,400
Bolton	Wigan	4 1	9620.4	611,740,700
Fulham	Newcastle	0 1	429.0	536,675,200
Middlesbrough	West Ham	1 2	92.9	551,584,600
Reading	Man Utd	0 2	199.1	831,048,200
Man Utd	Portsmouth	2 0	188.1	889,009,500
Blackburn	Everton	0 0	306.4	738,088,100
Middlesbrough	Fulham	1 0	132.4	662,848,100
Newcastle	Man Utd	1 5	10,677.6	561,243,200
Middlesbrough	Reading	0 1	68,745.1	810,836,000
Newcastle	Fulham	2 0	351.3	654,494,900
			6114.6	755,898,461
			532.4	595,777,100
			92.9	487,055,400
			68,745.1	2,132,140,000
			42.7	47,547,000
			75.0	55,017,700
			136.3	64,872,000
			171.9	71,677,600
			82.3	63,293,000
			68.0	60,920,500
			94.4	77,529,000
			51.9	64,517,500
			16.2	68,218,800
			36.8	80,604,700
			35.2	82,657,400
			41.4	74,071,900
			34.1	70,411,800
			321.4	55,490,300
			2505.1	87,345,000
			30.8	73,911,800
			234.0	68,630,375
			60.0	69,315,300
			16.2	47,547,000
			2505.1	87,345,000

construct the after-tax payoffs from winning bets in each market. For the Korea sports lottery market, we need to account for the 22% tax that is levied on winnings with quoted odds greater than 100. Therefore, as illustrated in Equation 2, the after-tax payoff on the winning bet i in the Korean sports lottery market is as follows:

Table 2. Comparison of Average Winning Bets

	Number of Observations	Sports Lottery	Bookmaker	Difference
Panel A: Three-game lottery				
All events	18 (54 games)	6114.6 (15,993.0)	2166.6 (3150.3)	3948.0 (−14,477.5)
Lotteries with win payouts less than the median win payout of 532.4	9 (27 games)	242.7 (108.3)	535.6 (309.7)	−292.9*** (311.1)
Lotteries with win payouts greater than the median win payout of 532.4	9 (27 games)	11,986.6 (21,585.5)	3797.6 (3874.0)	8188.9** (20,120.5)
Panel B: Two-game lottery				
All events	16 (32 games)	234.0 (610.4)	146.6 (167.1)	87.3 (460.7)
Lotteries with win payouts less than the median win payout of 60	8 (16 games)	36.1 (10.4)	58.6 (10.5)	−22.5** (13.7)
Lotteries with win payouts greater than the median win payout of 60	8 (16 games)	431.8 (841.9)	234.6 (205.0)	197.2 (653.5)

This table shows the average after-tax winning payout stated as a multiple of the bet amount for the Korean sports lottery market and for the corresponding payoff from the bookmaker market of William Hill PLC. Panel A shows the results for a three-game Korean sports lottery, where participants need to pick the correct final score for three predetermined football matches that are played in the English Premier League. Panel B shows the results for a two-game lottery. Standard deviations are in parentheses. The significant differences are indicated at 5% and 1% levels by ** and ***, respectively, using a Wilcoxon matched-pairs signed rank test.

$$\begin{aligned} s_i &= 0.78 \times p_i + 0.22 && \text{if quoted odds } p_i > 100 \\ s_i &= p_i && \text{if quoted odds } p_i \leq 100. \end{aligned} \tag{4}$$

We retrieve corresponding final odds of the English Premier League games from the website of William Hill PLC. In the bookmaker market, odds for the final score are posted for each game. Therefore, if we note m_{ki} as the posted odds for the k th soccer match, the corresponding odds for the winning bet i are as follows:¹⁴

$$\begin{aligned} m_i &= m_{1i} \times m_{2i} \times m_{3i} && \text{for the three-game bet} \\ m_i &= m_{1i} \times m_{2i} && \text{for the two-game bet.} \end{aligned} \tag{5}$$

Table 2 shows the average winning payoffs and the accompanying standard deviations from the two markets. For a \$1.00 bet, the average payout in the three-game (two-game) Korean sports lottery market is \$3948.00 (\$87.30) greater than the corresponding payout in the U.K. bookmaker market. The Wilcoxon matched-pairs signed-rank tests indicate that the differences in the average winning payouts between two markets are not significant at conventional levels. This is surprising given that the Korean sports lottery market pays out only

¹⁴ Bettors in the bookmaker market can make this form of bet, which is known as “trebles” or “parlay,” where multiple bets must all win for the winnings to be collected.

50% of the total bet amount and further levies 22% tax for winning payouts with quoted odds of over 100, which applies to all cases in our three-game lottery sample. By comparison, as we show later, the average commission charged by the bookmaker is 28.1%. While these differing circumstances lead us to expect significantly higher winning payouts in the U.K. bookmaker market, our results show that this is not the case. Rather, the results in Table 2 show that the sports lottery market yields higher, although statistically insignificant, average winning payouts compared to identical bets made with the bookmaker.

The comparison of winning payouts between the sports lottery market and the bookmaker market reveals drastic differences between the two markets once we divide our sports lottery sample into two groups: one where the after-tax winning payout is less than the median and the other where the after-tax winning payout is greater than the median. For the former subset, winning payouts from the sports lottery market are significantly less than the corresponding payouts from the bookmaker market for both the three-game lottery (panel A) and the two-game lottery (panel B). For winning payouts greater than the median payout, the sports lottery market exhibits significantly higher return than the bookmaker market in the case of the three-game lottery. For the two-game lottery, the difference is statistically insignificant at conventional levels. These results, taken as a whole, suggest that participants in the Korean sports lottery market tend to bet too much (little) on outcomes with higher (lower) probabilities of occurrence than the amount suggested by the bookmaker's odds. Given the 50% payout rate in the Korean sports lottery market, the way to rationalize participation in this market is to expect for a customer to bet on a high-odds outcome in hopes of winning a fortune. If this rationale holds, outcomes that are higher (lower) than average should result in relatively lower (higher) payoffs than the corresponding payouts in the bookmaker market. Interestingly, however, our results show that the opposite is true.

To better gauge the relationship between the odds set in the Korean sports lottery market against those set in the U.K. bookmaker market, we run a regression analysis where the dependent variable is the winning payout in the Korean sports lottery and the right-hand side variable is the corresponding payout from the U.K. bookmaker market. Since our sample consists of games in the English Premier League, under the null hypothesis that the bookmaker's odds are not biased, these odds should be the best unbiased estimates of the odds that are set in the Korean sports lottery market.

We therefore estimate the following regression:

$$s_i = \alpha + \beta \cdot m_i + \varepsilon_i. \quad (6)$$

In Equation 6, ε_i is assumed to be an $N(0, \sigma^2)$ error term, and s_i and m_i represent the winning payoffs from the sports lottery market and the corresponding payoffs from the bookmaker market, respectively, where the specific construction of each variable was explained in Equations 4 and 5.

The regression results are shown in Table 3. The R^2 of the regression is only 31% for the three-game lottery market and 85% for the two-game lottery market.¹⁵ This shows that the odds quoted by the U.K. bookmaker are a better predictor of the odds in the Korean sports lottery market for the two-game lottery market, in which the pool is smaller, than in the larger three-game lottery market.

¹⁵ By way of comparison, Gabriel and Marsden (1990) show an R^2 of 0.193 in their study of horse tracks.

Table 3. Regression of Winning Bets in the Parimutuel Sports Lottery against Corresponding Bets in the Bookmaker Market

Dependent Variable: Winning Odds from the Sports Lottery Market	Right-Hand Side Variable: Corresponding Payout from the Bookmaker Market	
	Posted Odds	Fair Odds
Panel A: Three-game lottery		
Slope	2.83** (1.05)	1.34** (0.50)
Intercept	−9.06 (3954.19)	−9.06 (3954.19)
R ²	0.31	0.31
F value	7.19**	7.19**
Panel B: Two-game lottery		
Slope	3.37*** (0.38)	2.05*** (0.23)
Intercept	−260.36*** (82.11)	−260.36*** (82.11)
R ²	0.85	0.85
F value	80.37***	80.37***

This table shows the results of an ordinary least squares regression where the dependent variable is the after-tax payout from the winning sports lottery ticket and the independent variable is the corresponding payoff from the bookmaker market of William Hill PLC. In the first column of the results, the payoff from the bookmaker market is calculated using the quoted odds. In the second column of the results, we use fair odds = (quoted odds) * (1.281) to account for the 28.1% average commission charged by bookmakers for the correct final-score betting. The procedure for calculating the average commission is shown in the Appendix. Panel A shows the results for the three-game Korean lottery, where participants need to pick the correct final score for three predetermined football matches that are played in the English Premier League. Panel B shows the same results for the two-game lottery. Standard errors are in parentheses. F values are for testing the null hypothesis of intercept = 0 and slope = 1. Significant coefficients and F values are indicated at 5% and 1% levels by ** and ***, respectively.

For both the two-game and three-game markets, the slope of the regression is greater than unity, along with the negative intercept.¹⁶ Consistent with the result of Table 2, the slope of the regression implies that for outcomes with smaller payouts, winning payoffs in the Korean sports lottery market are less than the corresponding payoffs from the bookmaker market in the United Kingdom. However, for outcomes with larger payouts, winning payoffs in the Korean sports lottery market are greater than the corresponding payoffs from the bookmaker market in the United Kingdom. The negative intercept of the regression shows that the aggregate payout in the Korean sports lottery market is less than the payout in the U.K. bookmaker market. In the Korean sports lottery market, the payout ratio is 50% of the total wager pool, and an additional 22% tax is levied on winnings with quoted odds greater than 100. In the bookmaker market, on the other hand, tax is not charged to the winning ticketholder. Rather, tax is levied to the bookmaker, who in turn charges a commission that is incorporated into the quoted odds.

To examine whether the two-game lottery and the three-game lottery show different betting behavior (for example, participants in the three-game lottery may overbet longshots in hopes of winning a big jackpot, compared to participants in the two-game lottery), we tested for the difference in the slope of our regression between the two types of lottery using the Wald test. Results show that the difference in the slope coefficient between the two types of lottery is not statistically significant at conventional levels. Therefore, although the three-game lottery market attracts more participants than the two-game market, as shown in Table 1, we do not

¹⁶ If we restrict the intercept to be zero in the linear regression, the coefficients of the slopes are 2.82 for the three-game lottery and 2.57 for the two-game lottery, and both are still significantly greater than unity.

find support for the different betting behavior between the participants of the two-game lottery and those of the three-game lottery.

So far, we have compared the winning payout of the Korean sports lottery market against the corresponding payout of the bookmaker using its quoted odds. However, since bookmakers charge a certain amount of commission as noted above, the “fair” odds for a bet should be greater than the quoted odds. As an example of the difference between quoted odds and fair odds, let us consider the case where the bookmaker posts odds of 1.90 for event A and odds of 2.00 for event B, where events A and B are mutually exclusive and span the universe of all outcomes. Then the fair odds are

$$\frac{\frac{1}{1.9} + \frac{1}{2}}{\frac{1}{1.9}} = 1.95$$

for event A and

$$\frac{\frac{1}{1.9} + \frac{1}{2}}{\frac{1}{2}} = 2.05$$

for event B. Therefore, a clever parimutuel bettor will compare the expected payout in the parimutuel market to the fair odds in the bookmaker market and place a bet for an outcome whose payout in the sports lottery market is greater than the fair odds that are generated from the bookmaker market. If the payout difference between the two markets varies between smaller payouts and larger payouts even after the bookmaker’s commission has been accounted for, the result will provide stronger evidence that two markets are not jointly efficient.

Therefore, in our analysis below, we take into account the average bookmaker’s commission of 28.1% that is charged on the final-score betting. The procedure for calculating the average bookmaker’s commission is illustrated in the Appendix. The use of the average commission for all possible outcomes is under the null hypothesis that the bookmaker’s odds are not biased across different odds of final-score bets, and therefore the same amount of commission is charged across different outcomes.¹⁷ We then make the comparison based on this measure of the after-commission fair payout, which is calculated as 1.281 times the posted odds for each game. Therefore, in Equation 6, if m_{ki} is the posted odds for the k th soccer match, the corresponding fair odds in the bookmaker market for the winning bet i are as follows:

$$\begin{aligned} m_i &= m_{1i} \times (1.281) \times m_{2i} \times (1.281) \times m_{3i} \times (1.281) \\ &= m_{1i} \times m_{2i} \times m_{3i} \times (1.281)^3 \quad \text{for the three-game lottery} \quad (7) \\ m_i &= m_{1i} \times (1.281) \times m_{2i} \times (1.281) = m_{1i} \times m_{2i} \times (1.281)^2 \quad \text{for the two-game lottery.} \end{aligned}$$

The results in Table 3 show that even with the fair odds of the bookmaker, the estimated slope is greater than unity, along with a negative intercept. This implies that for outcomes with higher (lower) probabilities of occurrence, bettors in the Korean sports lottery market overbet

¹⁷ The bookmaker’s commission can vary for different types of bets. However, for the specific type of bet (the correct final score bets) we are examining, the null hypothesis is that the bookmaker’s commission is the same across different odds. We thank the referee for pointing this out.

(underbet) these outcomes relative to the fair probabilities that are suggested by the bookmaker's odds even after accounting for their commissions.

5. Favorite-Longshot Bias

Our comparison between the parimutuel sports lottery market in Korea and the bookmaker market in the United Kingdom allows us to compare the extent of the favorite-longshot bias between the two markets. Since we are examining only winning bets, we do not intend to assess the *absolute* magnitude of the favorite-longshot bias for *each* market. Nonetheless, we can compare the *relative* extent of the bias between two markets. Specifically, our empirical results can contribute to the following aspects of the favorite-longshot bias.

First, as for the comparison between different market structures, previous studies have found that the favorite-longshot bias exists, with some exceptions, for both the parimutuel and bookmaker markets. The evidence for the parimutuel market is shown in studies such as Ali (1977) and surveyed in Thaler and Ziemba (1988) for racetracks in the United States, where longshots are found to be overbet relative to favorites. More recently, Ottaviani and Sørensen (2008a) theoretically show that the extent of the bias depends on the amount of private information in the market. For the bookmaker market, one of the widely accepted theories for observing the favorite-longshot bias is that bookmakers trim the odds on longshots relative to favorites to protect themselves from the existence of informed bettors (Shin 1991, 1992). Vaughan Williams and Paton (1997) find empirical support for the above argument in U.K. horse tracks.

Our results in Tables 2 and 3 show that for higher-odds (lower-odds) outcomes, bookmakers are posting odds that are lower (higher) than those found in the parimutuel market. Therefore, for our sample of soccer betting, we find that the favorite-longshot bias is relatively more severe in the bookmaker market when compared to the parimutuel market. Even though bookmakers are less likely to encounter bettors with inside information in the case of correct-score betting in soccer games compared to the case of horse racing, our results imply that bookmakers are still reducing the odds on longshots. Therefore, our results suggest that the threat of traders with inside information is not the sole reason why bookmakers exhibit the favorite-longshot bias.

As for the parimutuel market, it exhibits a *reverse* favorite-longshot bias relative to the bookmaker market. Ottaviani and Sørensen (2008a) show in their model that when signals contain little information and there is aggregate uncertainty about the final distribution of bets due to noise, there will be a reverse favorite-longshot bias in the parimutuel market. As bets made on predicting the final scores of two- or three-game soccer matches are less likely to contain material information compared to other types of bets, such as bets on a team to win for a single soccer match or bets in horse racing, our results show empirical support for Ottaviani and Sørensen (2008a).

Second, with regard to cross-country comparison, there is evidence that horse tracks in Europe show a strong favorite-longshot bias, whereas Asian markets show a reverse favorite-longshot bias; see Busche and Hall (1988) for evidence in the Hong Kong racetrack betting market, Busche (1994) for Hong Kong and Japanese racetracks, and Coleman (2004) for a survey. Our results show that this differing pattern in the betting behaviors for European and Asian participants extends to betting markets outside of horse racing. As mentioned by Busche and Hall (1988) and Coleman (2004), it is puzzling why participants in different countries

demonstrate different betting behaviors. These can be due to different factors such as the market power of market makers, patterns of gambling behavior, cultural factors, or attitudes toward risk.¹⁸ For example, Asian bettors, compared to European bettors, may be relatively more risk averse or have a tendency to underestimate the chances of low probability events, which results in Asian bettors overbetting the favorites and thereby causing the reverse favorite-longshot bias.¹⁹ While uncovering the exact reason for this diversity is beyond the scope of this article, we believe it is an interesting topic for future research.

6. Additional Tests

Betting Exchanges

Our categorization of the betting market follows from studies like Coleman (2004), which categorize betting markets into bookmaker-based markets and parimutuel markets. However, sports betting exchanges can be considered another category of betting markets. In the betting exchange market, participants in the market can act as bookmakers by submitting their own prices through the Internet; see Smith, Paton, and Vaughan Williams (2006) for a study on betting exchanges. In this subsection, as an additional analysis, we examine the winning payoffs between the sports lottery market and the betting exchange market.

Data on betting exchanges are from Betfair.com, one of the major betting exchanges in the United Kingdom. Data from Betfair.com have time-stamped odds for games played in 2007 and 2008.²⁰ We extracted odds for each game at two different time periods: one for the last transaction odds before the closing time of the Korean sports lottery and the other for the last transaction odds before the starting time of the match.

In Betfair.com, since odds are available for scores of three or fewer goals by both teams (other outcomes are under the “any unquoted” category of bets), there are no corresponding odds for outcomes with high scores of more than three goals by either team. As a result, we are able to collect betting exchange samples for 33 matches.

As for the correlation coefficient between the betting exchange odds and the bookmaker’s final odds, it is 0.95 when we use the betting exchange odds right before the start of the match. Second, the correlation coefficient of the two markets is 0.94 when we use the last transacted betting exchange odds before the Korean sports betting market closes. Therefore, the odds at the bookmaker market and those at the betting exchanges are highly correlated with each other.

To examine the relationship in the winning payoff odds between the sports lottery market and the betting exchange market, we follow a similar method as the case of the bookmaker market. Specifically, for each winning payoff odds in the Korean sports lottery market, we construct corresponding odds in the betting exchange market, as in Equation 6.

¹⁸ We thank the referee for pointing this out.

¹⁹ Snowberg and Wolfers (2008) argue that the favorite-longshot bias is based on bettors’ perception of overestimating the chances of low-probability events. More recent studies on explaining the different degrees of favorite-longshot bias include Peel and Law (2009) and Bruce et al. (2009). Paton, Siegel, and Vaughan Williams (2009) provide a nice review of these recent research studies.

²⁰ We thank Adrian Murdock and Michael Robb at Betfair.com for providing us with the data.

Table 4. Regression of Winning Bets in the Parimutuel Sports Lottery against Corresponding Bets in the Betting Exchange Market

Dependent Variable: Winning Odds from the Sports Lottery Market	Right-Hand Side Variable: Corresponding Payout from the Betting Exchange	
	Odds at Sports Lottery Closing Time	Odds at Kickoff
Slope	1.12 (0.09)	1.07 (0.09)
Intercept	−258.00** (109.98)	−240.68* (125.44)
R^2	0.89	0.85
F value	172.83***	127.45***

This table shows the results of an ordinary least squares regression where the dependent variable is the after-tax payout from the winning sports lottery ticket, and the independent variable is the corresponding payoff from the betting exchange market of Betfair.com. In the first column of the results, the payoff from the betting exchange market is calculated using betting exchange odds for the last transaction before the Korean sports lottery closing time. In the second column of the results, the payoff from the betting exchange market is calculated using betting exchange odds for the last transaction before the start of the match. Standard errors are in parentheses. F values are for testing the null hypothesis of intercept = 0 and slope = 1. Significant coefficients and F values are indicated at 10%, 5%, and 1% levels by *, **, and ***, respectively.

We then estimate the following regression:

$$s_i = \alpha + \beta \cdot n_i + \varepsilon_i, \tag{8}$$

where ε_i is assumed to be an $N(0, \sigma^2)$ error term, and s_i and n_i represent the winning payoffs from the sports lottery market and the corresponding payoffs from the betting exchange market, respectively.

The result of the regression is provided in Table 4. For our analysis between the sports lottery market and the betting exchange market, we do not distinguish between the two- and three-game lottery markets because of the small number of betting exchange data available that corresponds to the three-game lottery market. This is because for us to find the corresponding betting exchange data for the three-game sports lottery, all three games must end with three goals or less. In the first column of the results, the payoff from the betting exchange market is calculated using betting exchange odds for the last transaction before the Korean sports lottery closing time. In the second column of the results, the payoff from the betting exchange market is calculated using betting exchange odds for the last transaction before the start of the match.

Results in Table 4 show that the intercept of the regression is significantly negative, but the coefficient of the slope is not significantly different from 1. The negative intercept reflects the low payout ratio of the Korean sports lottery market compared to the U.K. betting exchange market. More importantly, since the slope coefficient is not statistically different from unity, the previously noted favorite-longshot bias in the relationship between the Korean sports lottery market and the U.K. bookmaker market is not observed in the relationship between the Korean sports lottery market and the U.K. betting exchange market. The result suggests that the favorite-longshot bias (reverse favorite-longshot bias) present in the U.K. bookmaker market (Korean sports lottery market) relative to the Korean sports lottery market (U.K. bookmaker market) is more likely to be caused by the difference in the market structure between the parimutuel market and the bookmaker market, rather than by the difference in the location of the betting market.

Alternative Specifications of the Regression

For the robustness of our results, we run alternative specifications of the regression model.²¹ The relationship of the winning payoff between the Korean sports lottery market and the U.K. bookmaker market may be nonlinear as opposed to linear and begin at the origin rather than having a negative intercept. If participants in the sports lottery market overbet longshots in hopes of winning a big jackpot, the odds for higher payoff outcomes would be lower in the sports lottery market compared to the bookmaker market. This implies that for higher odds, odds in the sports lottery market will increase at a decreasing rate relative to odds in the bookmaker market. Therefore, in the nonlinear regression of the sports lottery odds against the bookmaker odds, we add a logarithm term interacted with a greater-than-median payoff dummy. Conversely, for the lower payout outcomes, odds in the sports lottery market may increase at an increasing rate relative to odds in the bookmaker market. Therefore, we allow for a square term interacted with a less-than-median payoff dummy. The specification of the nonlinear regression model is as follows:

$$s_i = \alpha + \beta_0 \cdot m_i + \beta_1 \cdot D_1 \cdot m_i^2 + \beta_2 \cdot D_2 \cdot \log(m_i) + \varepsilon_i. \quad (9)$$

In the above equation, s_i is the winning payout from the Korean sports lottery market, as shown in Equation 4, and m_i is the corresponding payoff from the U.K. bookmaker market, as shown in Equation 5. In panel A of Table 5, D_1 is a dummy variable that takes a value of 1 for outcomes with payoffs greater than the median payoff in our sample. D_2 is a dummy variable that takes a value of 1 for outcomes with payoffs less than the median payoff in our sample. In Model 1 and Model 2, we consider only the nonlinear term, and in Model 1 and Model 3, we restrict the intercept to be zero. Results in panel A show that the coefficients of the logarithm of the bookmaker odds for less-than-median payouts are significant in Models 1 and 2. However, their significance disappears once we include the linear term in Models 3 and 4. Therefore, once we account for the linear relationship between the Korean sports lottery market and the U.K. bookmaker market, there is little additional explanatory power of nonlinear terms.

In panel B of Table 5, we test for the different betting behavior between the two lottery markets, in which participants in the three-game lottery may overbet longshots in hopes of winning a big jackpot. Therefore, D_1 in Equation 9 represents the three-game lottery dummy, and D_2 represents the two-game lottery dummy. Results in panel B are very similar to those of panel A. That is, the relationship between the Korean sports lottery market and the U.K. bookmaker market seems to follow a linear relationship. Also, we do not find support for the possibly different betting behavior between the participants in the two-game lottery and those in the three-game lottery, even if we account for nonlinearity.

7. Conclusion and Discussion

This study examined the winning payoffs from a sports lottery market in a parimutuel wagering form. Apart from the fact that the sports lottery market has not been empirically examined, previous research on the comparison between parimutuel markets and bookmaker markets was confined to the horse racing market. In studies of horse tracks, the threat of

²¹ We thank the referee for suggesting the analyses on the alternative specifications of the regression.

Table 5. Alternative Specifications for the Regression of Winning Bets in the Parimutuel Sports Lottery against Corresponding Bets in the Bookmaker Market

Right-Hand Side Variables	Model 1	Model 2	Model 3	Model 4
Panel A: Nonlinear relationship based on the level of payout				
Bookmaker odds			2.70*** (0.86)	2.68*** (0.89)
(Bookmaker odds) ² × (greater-than-median payout dummy)	0.06 (2.57)	0.84 (3.01)	−0.50 (2.29)	−0.29 (2.70)
Log (bookmaker odds) × (less-than-median payout dummy)	2.61*** (0.88)	3.13** (1.33)	0.24 (1.09)	0.39 (1.49)
Intercept		−1613.51 (3100.37)		−427.04 (2786.81)
Adjusted R ²	0.17	0.11	0.35	0.29
F value	4.44**	2.96*	7.03***	5.54***
Panel B: Nonlinear relationship based on the type of lottery market				
Bookmaker odds			2.76*** (0.85)	2.74*** (0.87)
(Bookmaker odds) ² × (three-game lottery dummy)	0.49 (2.19)	0.96 (2.38)	0.06 (1.93)	0.21 (2.12)
Log (bookmaker odds) × (two-game lottery dummy)	2.45*** (0.86)	2.97** (1.31)	0.12 (1.05)	0.30 (1.43)
Intercept		−1613.31 (3002.08)		−501.15 (2673.29)
Adjusted R ²	0.15	0.09	0.35	0.29
F value	4.05**	2.62*	6.98***	5.50***

This table shows the results of alternative specifications of regression where the dependent variable is the after-tax payoff from the winning sports lottery ticket, and the independent variable is the corresponding payoff from the bookmaker market of William Hill PLC. The specification of the nonlinear regression model is $s_i = \alpha + \beta_0 \cdot m_i + \beta_1 \cdot D_1 \cdot m_i^2 + \beta_2 \cdot D_2 \cdot \log(m_i) + \varepsilon_i$, where s_i is the winning payout from the Korean sports lottery market as shown in Equation 4, and m_i is the corresponding payoff from the U.K. bookmaker market as shown in Equation 5. In panel A, D_1 is a dummy variable that takes a value of 1 for outcomes with payoffs greater than the median payoff in our sample. D_2 is a dummy variable that takes a value of 1 for outcomes with payoffs less than the median payoff in our sample. In panel B, D_1 represents the three-game lottery dummy and D_2 represents the two-game lottery dummy. Standard errors are in parentheses. Significant coefficients and F values are indicated at 10%, 5%, and 1% levels by *, **, and ***, respectively.

private inside information faced by the bookmaker has been one of the widely accepted explanations for the favorite-longshot bias that is observed in the bookmaker market.

In our sample of correct-score betting of English Premier League soccer games that is offered by the Korean sports lottery market, participants can monitor real-time odds in the sports lottery market and have access to odds that are quoted by the bookmaker at the same time for the same event. This presents a unique opportunity for comparing the parimutuel sports lottery market against the well-established bookmaker-based system for events where inside information is likely to be less pervasive than in horse racing.

We find that for winning bets with relatively low payouts, the Korean sports lottery market yields lower payouts compared to corresponding payouts in the U.K. bookmaker market. The reverse is true for winning bets with relatively high payoffs. When we regress the winning payoff resulting from the Korean sports lottery market against the corresponding payoff from the U.K. bookmaker-based market, the slope of the regression is significantly greater than unity. Overall, our results suggest that bookmakers still exhibit favorite-longshot bias even when the threat of inside traders is smaller than in horse racing. Conversely, participants in the parimutuel sports lottery market in Korea show a reverse favorite-longshot bias relative to the U.K. bookmaker market.

As a final note, since our study considers only winning bets, the results are not conclusive but only suggestive. We hope that our study can serve as a building block for studying the efficiency of the sports lottery market. A further test of market efficiency of each market by using bets that span all combinations of outcomes and analyzing the distribution of betting ratios over various outcomes is left for possible future research.

Appendix: Calculation of Bookmakers' Commission for Correct Final-Score Betting

To calculate the fair odds in the bookmaker market, we need to incorporate the bookmaker's commission into the quoted odds. However, we cannot directly compute the bookmaker's commission because the quoted odds on final scores do not span the universe of all possible outcomes.²² However, under the null hypothesis that the bookmaker's odds are not biased, we can assume that the commission is the same for all outcomes. Then we can make use of the odds on the over/under total goals that are scored in a game. First, by using the odds on the over/under total score, we calculate the probability that the final score will be less than or equal to the specified total goals. At www.williamhillplc.com, odds are available for less than two goals scored, exactly two goals scored, and more than two goals scored for each game.

Let us denote the odds on less than two goals scored as U , the odds on exactly two goals scored as E , and the odds on more than two goals scored as O . The probability that the total goals scored will be two or less is

$$\frac{(1/U)+(1/E)}{(1/U)+(1/E)+(1/O)}.$$

Now, there is a finite number of cases of the final score where the total goals scored is less than or equal to two. If we define S_i as the quoted odds of the final score being $i \in \{(1, 0), (2, 0), (0, 0), (1, 1), (0, 1), (0, 2)\}$ and denote the bookmaker's fractional commission by C , then the fair odds of the final score being i is $S_i \cdot (1 + C)$ and the corresponding fair probability of the final score being i is $1/[S_i \cdot (1 + C)]$.

To find the value of C , we can solve for C in the following equation:

$$\sum_i \frac{1}{S_i \cdot (1 + C)} = \frac{(1/U)+(1/E)}{(1/U)+(1/E)+(1/O)}.$$

Using 20 matches between August 16, 2008, and August 25, 2008, we find that the average commission $C = 28.1\%$.

²² This is because no odds are available for unusually high scores such as 7-4, 5-5, or 8-0, even though they have non-zero chances of occurrence.

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