Inter-Market Arbitrage in Betting*

Egon Franck, Erwin Verbeek**, Stephan Nüesch

forthcoming in *Economica*

(Version: January 2012)

We show that a combined bet at the bookmaker and at the bet exchange market yields a guaranteed positive return in 19.2% of the matches in the top-five European soccer leagues. Moreover, we find that all considered bookmakers frequently offered arbitrage positions, and that they experienced, on average, negative margins from these postings. Our findings indicate that bookmakers set prices not only by optimising over a particular bet, but also by taking the future trading behaviour of their customers into account. We discuss the implications for the literature on the relationship between betting market structure and informational efficiency.

---

* This article is based on a chapter of the second author's 2009 dissertation.

** Corresponding author: University of Zurich, Department of Business Administration, Plattenstrasse 14, CH-8032 Zurich, email: erwin.verbeek@business.uzh.ch, phone: +41 44 634 29 61

Introduction

Arbitrage is typically defined as 'the simultaneous purchase and sale of the same, or essentially similar, security in two different markets for advantageously different prices' (Sharpe and Alexander, 1990; cited in Shleifer and Vishny, 1997, p.35). The efficient market hypothesis relies to a large extent on the assumption that any arbitrage opportunity is exploited quickly once it appears. Smith et al., (2005, p.160) regard it as 'the purest form of weak form inefficiency', when price differences permit riskless arbitrage.

Thus far, all empirical papers that have addressed arbitrage in betting have concentrated on arbitrage strategies in a single market setting. The traditional forms of betting are the pari-mutuel system and the bookmaker setting. Hausch and Ziemba (1990) and Edelman and O'Brian (2004) showed that for a small number of cases positive returns can be achieved in pari-mutuel betting by spreading stakes across different betting pools. However, risk-free arbitrage is not feasible in pari-mutuel betting because the payout ratio depends on the final betting volumes placed on each possible outcome and is, therefore, not determined ex ante. By contrast, in the bookmaker market the payout ratio on a winning bet is tied to the initially taken odds and does not depend on subsequent price changes. Empirical studies that tested the arbitrage condition in bookmaker betting discovered some opportunities for arbitrage when the number of bookmakers analysed was sufficiently large (see Pope and Peel, 1989; Dixon and Pope, 2004; Vlastakis et al., 2009). Alongside the traditional market settings, exchange betting has emerged in recent years as a novel market mechanism. Exchange betting differs from the traditional betting markets in that bettors can not only *buy* bets (bet *on* a given outcome to occur), but they can also *sell* bets (bet *against* a given outcome to occur). On an online platform, individuals can either be *suppliers* of liquidity by offering betting volume at certain odds (i.e., submitting *limit orders*), or they can be *demanders* of liquidity by directly placing bets at these odds (i.e., submitting *market orders*). That way, the odds are determined in a continuous double-auction process that matches supply and demand. Wolfers and Zitzewitz (2004), in their survey article on prediction markets, conclude that the prices for the same underlying asset at two major exchange markets

(*Tradesports* and *World Bet Exchange*) 'co-move very closely, and opportunities for arbitrage [...] are virtually absent' (p. 116).

This paper is the first to analyse *inter-market* arbitrage in the betting industry by combining bets at the bookmaker market and the exchange market. We collected the odds posted by ten major bookmakers and matched them with the corresponding odds traded at the *Betfair* platform. *Betfair* is a well-known betting exchange that claims to organise 90% of all exchange-based betting activity worldwide (Croxson and Reade, 2008). Our data set covers 11,933 soccer matches played in the top-five European leagues (the English *Premier League*, the French *Ligue 1*, the German *Bundesliga*, the Italian *Serie A* and the Spanish *Primera Division*) during seven seasons (2004/05 to 2010/11). Our analysis reveals 102 intra-market arbitrage opportunities in which price differences among bookmakers exceed commissions. Essentially this form of arbitrage involves betting on the three possible outcomes (i.e., home team win, draw, away team win) with more than one bookmaker, such that the sum of odds probabilities corresponding to the three outcomes sums to less than unity. Inter-market arbitrage is, however, far more likely. We find 2,287 inter-market arbitrage opportunities yielding an average return of 1.4%. Thus, for more than one in six matches, an optimal combination of odds from a bookmaker and odds traded at the bet exchange platform yields a positive return independent of the match's outcome.

An obvious reason why the inter-market hedging strategy enables more arbitrage opportunities than the intra-market strategy is that there are lower trading costs involved with the former. Bet exchange companies charge significantly lower commissions since they take no counterparty risk. Whereas the average bookmaker commission in our sample is 11.3%, the commission at the considered bet exchange platform lies between 2.0% and 5.0%, depending on the client's betting activity. Furthermore, placing a bet on all possible outcomes of an event is no longer necessary to hedge against the uncertainty of the underlying outcome: a bettor can simply buy favourable odds from a bookmaker and sell them directly on the bet exchange platform.

Another reason for the numerous inter-market arbitrage opportunities is that price differences are more pronounced across markets than within markets. Empirical studies (e.g., Smith et al., 2006; Smith et al., 2009; Franck et al., 2010) have shown that bet exchange odds perform better than bookmaker

odds in predicting the outcome of sporting events. This paper confirms these previous findings. Inter-market arbitrage opportunities mostly arise from inefficiently low-priced bookmaker bets (over-favourable odds) that the bettor can sell at a higher price (lower odds) on the bet exchange platform. A detailed analysis shows that when exploiting inter-market opportunities, bettors gain 1.6% on the bookmaker position (normal return on a bookmaker bet is -11.3%) and lose -0.2% on the hedging position from the bet exchange (normal bet exchange return is -2.5%) on average. Regression analyses support the finding that the bet exchange market outperforms the bookmaker market in terms of informational efficiency.

The literature offers different explanations for bookmaker mispricing. Shin (1991; 1992; 1993), for example, argues that bookmakers skew the odds in order to hedge against the threat of bettors endowed with superior information. According to his theory, bookmakers decrease the odds on low-probability outcomes where the risk of insider knowledge is particularly harmful. Moreover, recent papers show that bookmakers can increase profits by systematically setting 'wrong' odds to take advantage of sentimental bettor preferences. Bettors are considered as biased by sentiment if demand spreads unevenly across the possible outcomes of an event even though odds represent true probabilities. One source of sentimental betting behaviour documented in soccer is team popularity (Forrest and Simmons, 2008; Franck et al., forthcoming). Given sentimental preferences and thus unequal betting volumes, bookmakers balance their liabilities by decreasing the odds on the bet with comparatively higher betting volume and by increasing the odds on the opposing bet (Kuypers, 2000; Levitt, 2004). Alternatively, if elasticity of demand is sufficiently high, Franck et al. (forthcoming) show that risk-neutral bookmakers can profit from offering not less but more favourable odds for bets with high sentimental betting volume.

Whereas these arguments rationalise bookmaker mispricing, they do not fully explain price differences between the bookmaker market and the bet exchange. It is not evident why bettor sentiment or the threat of inside knowledge should not equally bias prices at the exchange market. Bettors who place limit orders at the exchange platform may have similar pricing considerations to those of a bookmaker.

In this paper we venture the argument that bookmakers do not simply optimise over a particular bet, but take the expected future trading behaviour of their customers into account. They deliberately decrease prices (increase odds) relative to the true outcome probability from time to time as part of their promotional activities to acquire new customers, even though they suffer negative average margins from these bets.

There are structural differences between the two market settings that may cause differences in the pricing considerations of the market's traders. Whereas the market participants remain anonymous at the bet exchange, at the bookmaker market their identities are revealed. Bettors have to make specific investments to trade with a given bookmaker but not if they trade with anonymous suppliers of limit orders at the bet exchange. Thus, bettors face switching costs between different bookmakers. Switching costs include the time and money to open and manage an online account, to transfer money from or to the account, and the time to get accustomed to the webpage and to the procedure of placing bets. Once acquired, bettors may stick with a given bookmaker and place bets even under unfavourable terms. Additionally, in contrast to a limit order submitter, a bookmaker is able to manage his customer portfolio and capitalise on their future trading behaviour. Bookmakers have the technical means to gather information on the trading behaviour of each of their clients and to identify skilled bettors or arbitrageurs, and they reserve the right to segment their customer base ex post by limiting maximum stakes or closing accounts. These differences in market structure serve as an explanation for the persistent frequency of inter-market arbitrage opportunities over the last seven years for each bookmaker in our data sample.

The article is structured as follows. Section I introduces the theoretical background for arbitrage betting within and between the two market mechanisms. In Section II, we present the empirical findings on both intra- and inter-market arbitrage opportunities. In Section III, we investigate the extent to which each market contributes to inter-market arbitrage opportunities. Section IV concludes and discusses implications for the literature on the relationship between market structure and informational efficiency in the betting industry.

I. Theoretical Background

A betting market is a simple speculative market, where contracts on some future cash flow are traded. The direction of the cash flow is tied to the outcome of a given event—in our context, the outcome of a soccer match. In fixed-odds betting, the size of the cash flow is determined by the odds.[1] Although the odds may change over time, the size of the bettor's claim is tied to the initially taken odds and does not depend on subsequent price changes. There are two distinct market mechanisms for fixed-odds betting: the bookmaker and the bet exchange market.

The bookmaker market is the most popular form of sports gambling. Here, the odds are unilaterally determined by the bookmaker and published a few days before the match starts.[2] Bettors can place their bets at these odds while the bookmaker takes the opposite position. In European online sports betting, the odds are typically represented as 'decimal odds', which determine the payout ratio on a winning bet. Thus, for each possible outcome e of a sporting event, the bookmaker i posts his odds $o_{i,e}$. At these odds, the bettor can place a wager that the outcome of the match will actually occur. The bettor's expected return on this bet is

$$E[\pi_{i,e}] = \varphi_e(o_{i,e} - 1) + (1 - \varphi_e)(-1) = \varphi_e o_{i,e} - 1\,, \tag{1}$$

where φ_e is the true probability of the outcome e to occur. As we set the stake of the bet to unity, (-1) is the bettor's net return in case the match's result is not e (a losing bet), and the bettor's net return in case the match's result is e (a winning bet) is $(o_{i,e} - 1)$. The inverse of the posted decimal odds $\frac{1}{o_{i,e}}$ can be interpreted as the bookmaker's probability for the underlying

[1] Contrary to fixed-odds betting, in pari-mutuel betting, the bettor's claim is tied to the volumes placed on each outcome of the event at the moment the market is closed. The betting volumes on all possible outcomes are aggregated and then distributed to the winners according to their relative stakes. Therefore, the bettor's claim is not ex ante fixed but depends on the incoming betting volumes. Pari-mutuel betting is still common in horse racing but is becoming less important compared to fixed-odds betting.

[2] The bookmakers actually have the right to adjust odds after the market has opened, but they rarely do so (Forrest et al., 2005).

match outcome to occur.[3] For a given match, the probabilities of all possible events sum up to greater than one because the bookmaker's commission or 'overround' is already included in the odds, thus $\sum_e \frac{1}{o_{i,e}} \geq 1$. The average bookmaker's commission in our sample ranges between 10.9% (*B365* and *Gamebookers*) and 14.1% (*Interwetten*).

In the bet exchange market, it is not the bookmaker but other bettors who take the opposite side of a contract. Thus, individuals can directly trade the bets with each other on a platform where they post the odds under which they are willing to place a bet *on* or *against* a given outcome. The latent demand for bets is collected and presented in an order book that publicly displays the most attractive odds with the corresponding available volumes. The bettor has the choice either to submit a limit order and wait for other participants to match his bet or to submit a market order and directly match already offered bets. As a result, there is a continuous double auction process taking place on the platform. If bettors with opposing opinions agree on a price, their demands are automatically translated into a transaction. Therefore, the odds traded at a bet exchange are not determined by a market intermediary, i.e., the bookmaker, but are the result of a continuous matching of supply and demand. The provider of the platform typically charges a commission fee on the bettors' net profits. The commission fee of *Betfair*, for example, ranges between 2% and 5% percent depending on the individual's annual betting activity.

Once a bet on the outcome e of a given event has been matched, the traders hold a contract on some future cash flow. The size of the cash flow is determined by the agreed odds $o_{ex,e}$, and the direction of the cash flow depends on the actual outcome of the underlying event combined with the position a given bettor holds. He can either hold the 'long position' or the 'short position'. If a bettor goes long, he bets that the outcome e will occur. The expected return in that case is similar to wagering at the bookmaker market with the exception that the commission fee c $(0 < c < 1)$ on his net winnings

[3] The betting audience often uses the term 'prices' and 'odds' interchangeably. In line with most related academic articles, we mean by the price of a bet the reciprocal of its odds.

has yet to be included. Hence, the bettor's expected return on a *long position bet* with agreed odds $o_{ex,e}$ is

$$\begin{aligned} E\left[\pi_{ex,e}^{long}\right] &= \varphi_e\left(o_{ex,e}-1\right)(1-c)+(1-\varphi_e)(-1) \\ &= \varphi_e\left[o_{ex,e}(1-c)+c\right]-1\,. \end{aligned} \tag{2}$$

As already mentioned, Equation (2) is similar to Equation (1) except that the commission fee c is charged on the winning bet, whereas the bookmaker's commission is already included in the offered odds.

Alternatively, if a bettor goes short, he bets that the outcome e will *not* occur. The expected return on a *short position bet* with $o_{ex,e}$ is

$$\begin{aligned} E\left[\pi_{ex,e}^{short}\right] &= \varphi_e(-1)+(1-\varphi_e)\frac{1}{o_{ex,e}-1}(1-c) \\ &= \frac{1-c}{o_{ex,e}-1}-\varphi_e\left[\frac{1-c}{o_{ex,e}-1}+1\right]. \end{aligned} \tag{3}$$

As Equation (3) denotes the opposite market position to Equation (2), the expected return when going short also depends on the actual outcome probability φ_e and the traded odds $o_{ex,e}$, which appear inversely in the equation. Thus, the return on a short position bet, holding φ_e constant, decreases in $o_{ex,e}$.

Next, we examine the composition of arbitrage opportunities in the betting market. An arbitrage bet requires buying a contract at one price and contemporaneously selling the same or equivalent contract at a higher price. The stakes placed on each side have to be chosen such that the return on the combined bet does not depend on the actual outcome of the match. We denote a combined bet fulfilling this condition a *hedged bet*. An *arbitrage opportunity* arises if the price difference exceeds the commissions involved. In order to overcome these commissions, the arbitrageur must seek favourable selling conditions offered by other bookmakers (intra-market arbitrage) or by the betting exchange market (inter-market arbitrage).

First, we consider *intra-market arbitrage*. Since at the bookmaker market a bet can exclusively be placed on a given outcome to occur, to 'sell' a bet requires going long in each complementary outcome of the event. Thus, the arbitrageur has to wager a proportion s_e of his overall stake on each outcome of the match. To overcome the commissions, he has to select the most favourable odds $\bar{o}_e = \max_i(o_{i,e})$ from a set of bookmakers $i = \{1,2,..,I\}$. His expected return on the combined bet is then

$$E[\Pi^{intra}] = \sum_e \varphi_e \bar{o}_e s_e - \sum_e s_e \,. \tag{4}$$

To hedge this bet, the stakes s_e have to be spread over the outcomes such that the probability φ_e in the return equation can be dropped. Therefore, the bettor must choose stakes that are inversely proportional to the odds. This implies that the payoff is constant over all possible outcomes of an event, thus $\bar{o}_e s_e = const.\ \forall e$. Since we are interested in the return, we set the overall stake to unity, so that $\sum_e s_e = 1$. These two conditions are jointly fulfilled if the proportion of a one unit wager placed on each outcome of the match is

$$s_e^* = \frac{1}{\bar{o}_e} \frac{1}{\sum_e \frac{1}{\bar{o}_e}} \,. \tag{5}$$

Equation (4) for the return on the intra-market hedged bet then reduces to

$$\Pi^{intra} = \frac{1}{\sum_e \frac{1}{\bar{o}_e}} - 1 \,. \tag{6}$$

If the differences between the odds from the involved bookmakers are larger than the associated commissions, the intra-market hedged bet yields a positive return. Hence, an intra-market arbitrage opportunity arises if

$$\sum_e \frac{1}{\bar{o}_e} < 1 \tag{7}$$

holds.

Next, we examine *inter-market arbitrage*, where we include the possibility of placing wagers at the exchange market to hedge a bet. There are two different ways to hedge a bet in the inter-market arbitrage case. The arbitrageur can take the long position on a given outcome at the exchange market or bookmaker market and can bet on all contrary outcomes, effectively reselling his contract. We will refer to this method as the *long position inter-market arbitrage* strategy. An alternative is to go short at the exchange market in order to 'sell' the contract bought at the bookmaker market. We define this method as the *short position inter-market arbitrage* strategy.

The former strategy is very similar to the intra-market arbitrage case. The arbitrageur bets on all possible outcomes at the most advantageous odds. The only exception is that he seeks favourable odds not only from the bookmaker market but also from the exchange market. Hence, he places his bets on $\bar{\bar{o}}_e = \max\left[\bar{o}_e,\ \left(o_{ex,e}(1-c)+c\right)\right]$. Analogously to Equation (6), the return on the *long position inter-market hedged bet* is

$$\Pi_{long}^{inter} = \frac{1}{\sum_e \frac{1}{\bar{\bar{o}}_e}} - 1\,. \tag{8}$$

A somewhat more elegant way to realise potential inter-market arbitrage returns is to directly sell a bet at the exchange market. Exchange markets offer the possibility to place a bet not only *on* a certain outcome (a *long position bet*) but also *against* the outcome (a *short position bet*). Thus, the *short position inter-market arbitrage* strategy involves buying a contract at the bookmaker and selling the same contract at a more favourable price at the bet exchange market. The expected return of this arbitrage strategy is

$$E\left[\Pi_{short}^{inter}\right] = s_{short,e}\left[\frac{1-c}{o_{ex,e}-1} - \varphi_e\left(\frac{1-c}{o_{ex,e}-1}+1\right)\right] + s_e\left[\varphi_e\bar{o}_e - 1\right]. \tag{9}$$

The stakes at the bet exchange, $s_{short,e}$, and at the bookmaker market, s_e, have to be balanced according to the following two conditions *(i)*

$$s_{short,e}\left[\frac{1-c}{o_{ex,e}-1}+1\right]=s_e\bar{o}_e=const.\ \forall e\ , \tag{10}$$

and *(ii)*

$$s_e=1-s_{short,e} \tag{11}$$

in order to hedge the bet. Therefore, the proportion of a one-unit wager placed at the exchange market is

$$s^*_{short,e}=\frac{\bar{o}_e}{\bar{o}_e+\frac{1-c}{o_{ex,e}-1}+1}. \tag{12}$$

At the bookmaker market, it is simply

$$s^*_e=1-s^*_{short,e}\ . \tag{13}$$

The expression for the return on the *short position inter-market hedged bet* then reduces to

$$\Pi^{inter}_{short}=\max_e\left(\frac{\bar{o}_e\left(o_{ex,e}-c\right)}{\bar{o}_e\left(o_{ex,e}-1\right)-c+o_{ex,e}}-1\right). \tag{14}$$

Even though the short position inter-market arbitrage strategy actually allows hedged bets on the event level (in our context a home win, a draw, or an away win), it does not make sense to place more than one hedged bet on the same match. Instead, we assume that the bettor only goes for the most attractive short position hedged bet of a particular match. In doing so, the return on a short position inter-market hedged bet is positive if

$$\bar{o}_e>\frac{\left(o_{ex,e}-c\right)}{1-c} \tag{15}$$

holds for at least one outcome of the match. Hence, a short position inter-market arbitrage opportunity arises if the most attractive odds from the

bookmaker market exceed the corresponding short position odds, i.e., odds requested on the selling side, from the exchange market after adjustment for the charged commission. Condition (15) is intuitive: the arbitrageur requires high odds from the bookmaker because he bets on the outcome to occur at this market. On the exchange market, he needs low odds because he places a short bet that yields a higher payout ratio the lower the odds.

II. Arbitrage Opportunities in European Soccer Betting

Data

We examine the betting market for European soccer matches. Our data covers the top-five leagues (the English *Premier League*, the French *Ligue 1*, the German *Bundesliga*, the Italian *Serie A* and the Spanish *Primera Division*). These five leagues have a market share of over 50% in the European soccer market and are estimated to have generated combined revenues of GBP 7.2 billion in 2009. Average match attendance varied from 20,100 in the French *League 1* to 42,500 in the German *Bundesliga* during the 2009/10 season (Jones, 2010).

The sports betting industry is composed of a multitude of bookmakers and several bet exchange platforms. Whereas in the pre-internet period, bets were placed over the counter, online wagering has become very popular in recent years. In 2010 the online sports betting market had an estimated turnover of more than GBP 6 billion (*H2 Gambling Capital,* 2011).

We collected the odds of ten well-known bookmakers (*B365*, *Blue Square*, *Bwin*, *Gamebookers*, *Interwetten*, *Ladbrokes*, *Sportingbet*, *Stan James*, *VC Bet* and *William Hill*) available at *football-data.co.uk*, where odds are recorded on Friday afternoons for weekend matches and on Tuesday afternoons for midweek matches. We merged the bookmaker odds with corresponding bet exchange odds traded at *betfair.com*. *Betfair* is the leading bet exchange platform for sports betting. In 2010 *Betfair* processed 5.7 million trades per day, and 823,000 active customers generated a yearly revenue of GBP 306 million (see *corporate.betfair.com*). The webpage *data.betfair.com* makes historical *Betfair* odds available as a cross-sectional dataset on a match-event-odds

level. This implies that every single quote ('ODDS') that was traded during a given match (e.g., *Manchester United* versus *Liverpool*) and for a certain event (i.e., home win, draw, away win) is one observation. For each of these odds we observe the points in time when there was a transaction for the first time ('FIRST˙TAKEN') and for the last time ('LAST˙TAKEN'), the number of individual transactions ('NUMBER˙BETS') and the volume matched ('VOLUME˙MATCHED'). The match and event can be identified by the variables 'FULL˙DESCRIPTION', 'SELECTION' and 'SCHEDULED˙OFF'. The variable 'FULL˙DESCRIPTION' includes the name of the home team, the away team and the league, the variable 'SELECTION' indicates whether the quote concerns a home win, draw or away win bet, whereas the variable 'SCHEDULED˙OFF' is a time stamp for the match start.

We merged the two data sets based on the home team name, the away team name and the match date. As team names and the date format in the *Betfair* dataset are rather inconsistent, the *Betfair* data had to be cleaned first. After data cleaning we were able to merge information from 93% of all the matches played during seven seasons (2004/05 to 2010/11), a total of 11,933 matches.

As the *Betfair* odds may change over time prior to match start as a result of the double-auction process taking place at the platform, we have to make sure to collect odds that were valid at the same time the bookmaker odds were recorded at the webpage *football-data.co.uk* (i.e., Friday afternoons for weekend matches and Tuesday afternoons for midweek matches). The dataset from *data.betfair.com* is cross-sectional and not longitudinal; it does not include information about the odds at any time during the trading period at *Betfair*. However, we know the point in time when a given quote was traded for the first time and the last time during the pre-play period. Accordingly, we dropped all odds that were traded for the *first* time *after* bookmaker odds were recorded at *football-data.co.uk* and all odds that were traded for the *last* time *before* bookmaker odds were recorded.[4] After that, all remaining odds could possibly have been valid at the point in time when the bookmaker odds

[4] As previously mentioned, *football-data.co.uk* states that: 'Betting odds for weekend games are collected Friday afternoons, and on Tuesday afternoons for midweek games.' We assume that *(i)* afternoon is at 4pm, *(ii)* Saturday and Sunday matches start at 3pm, and that *(iii)* all other matches start at 8pm.

were collected. However, these odds differ only slightly for a given match-event, having an average standard deviation of 0.146. To select the relevant quote from the subsample of potential odds, we make use of the information about the betting volume placed on a given quote. We simply pick the odds that were most intensively traded in terms of betting volume because these odds are most likely to have been available at the relevant point in time.[5] We test the robustness of our results in two ways. First, we run our analyses using the volume-weighted average of the potential *Betfair* odds. The main findings do not change in any significant way using this alternative procedure (see Tables A1 and A2 in the Appendix of this paper). Second, we calculate the returns of the hedged bets using the least favourable *Betfair* odds, i.e., the *lowest* odds to calculate the returns of the *long position inter-market hedged bets* (see Equation 9) and the *highest* odds to calculate the returns of the *short position inter-market hedged bets* (see Equation 14).[6] While the frequencies of inter-market arbitrage opportunities decreases compared to our baseline specification for obvious reasons, they are still substantial (see Table A3 in the Appendix of this paper).

The data selection is rather conservative with respect to detecting arbitrage opportunities. First, by choosing soccer, the most popular European sport, we consider only intensively traded bets (for more detailed information on liquidity issues we refer to Subsections *Liquidity at the bet exchange* and *Liquidity at the bookmaker market*). Sports that receive less media attention and for which less information is publicly available are likely to evoke more disagreement among bookmakers and bet exchange platforms and to provide more opportunities for arbitrage. Second, we compare the odds at only one specific point in time. This means that we simulate a very simple hedging strategy by which the arbitrageur checks the odds of a given match only once. The number of arbitrage opportunities would be expected to increase substan-

---

[5] The *Betfair* quote that is most heavily traded is expected to have been available the longest during the pre-play period and, therefore, is most likely to have been available at the relevant point in time. Moreover, the procedure of selecting the quote with the highest betting volume assures that these odds were highly liquid and no weight is assigned to pre-play odds on which only few bets were placed.

[6] Noteworthy, the selection of these odds allows for a significant increase of arbitrage opportunities compared to our baseline specification by using them the other way round, i.e., the *lowest* odds to calculate the returns of the *short position inter-market hedged bets* and the *highest* odds to calculate the returns of the *long position inter-market hedged bets*.

tially if the whole trading period is monitored. Third, in addition to the match odds analysed here, bettors can also wager on a variety of more specific bets, such as bets on the correct score, the half time score, sending offs, the final rank order in the championship tournament, or handicap (i.e., placing a bet on or against the event that a particular team wins with more than one or two goals in advance). Obviously, the inclusion of different sorts of betting contracts tends to increase the number of arbitrage opportunities. However, it lies beyond the scope of this paper to provide an exhaustive collocation of different arbitrage strategies. We prefer to concentrate on the most popular bets, for which arbitrage opportunities should be least likely.

Results

In the following, we calculate the returns of the hedged bets as outlined in the Section *Theoretical Background*. We include a maximum commission fee c of 5% that is charged on net winnings from the *Betfair* position. Table 1 presents our findings.

[Insert Table 1 about here]

The first column in Table 1 contains the average returns of the three different hedged bets for all matches, whereas the second column displays the cases with an arbitrage opportunity, defined as hedged bets with a positive return. The upper block gives the average returns and frequency of the *intra-market* arbitrage bets, when the hedged bets are constructed using only the odds of the ten different bookmakers. The average return on all hedged bookmaker bets is -3.9%, which is considerably higher than the average bookmaker return of -11.3%, but it is still negative. Out of 12,782 matches, we find 102 arbitrage opportunities with an average return of 0.9%. This is one arbitrage opportunity per 125 matches, or 0.8%. The frequency of intra-market arbitrage opportunities in our sample is higher than the value of 0.5% found by Vlastakis et al. (2009) in their sample of 12,841 soccer matches covering 26 different countries. One reason of the higher percentage of arbitrage opportunities in our sample is that we compare the odds of ten different bookmakers, whereas Vlastakis et al. (2009) included only five different bookmakers.

The middle and lower blocks in Table 1 summarise the returns of hedged bets when considering both bookmakers' odds and the odds traded at *Betfair*.

With the *long position inter-market* strategy, the average return is -2.4% when betting on all matches. 5.0% of the matches offered an arbitrage opportunity with an average return of 1.7%. When adopting the *short position inter-market strategy*, the average return increases to -0.7% when betting on all matches. For 19.2% of the matches the return on the short position hedged bet is positive and yields an arbitrage opportunity with an average positive return of 1.4%.

Figure 1 illustrates the density functions of the returns on the hedged bets when following the three different arbitrage strategies to give a more comprehensive picture of returns on hedged bets.

[Insert Figure 1 about here]

The *inter-market arbitrage* strategy is far more attractive than the *intra-market arbitrage* strategy. The distributions of returns yielded by following one of the inter-market arbitrage strategies are shifted to higher return values in comparison with the distribution of returns when combining only bookmaker bets. Furthermore, Figure 1 confirms the finding in Table 1 that the *short position inter-market* strategy offers the highest potential for arbitrage. Not only are the returns less negative at the low end of the distribution, but also the area under the curve on the positive side is the largest of all three arbitrage strategies.

Liquidity at the bet exchange

Market liquidity at the bet exchange is a crucial issue to consider when testing the practical relevance of the arbitrage opportunities documented in our sample. If the inter-market arbitrage opportunities appeared only in low liquidity events, betting volume from arbitrage bettors would quickly move the price at the bet exchange, and therefore limit the degree to which bettors can make arbitrage profit. As we observe the number of transactions and the volumes placed at *Betfair*, we can explicitly analyse the connection between market liquidity and inter-market arbitrage.[7]

In a first simple step, we investigate whether the average pre-play liquidity for matches with arbitrage opportunities is above or below the average

[7] We observe the number of transactions and the volumes that were actually traded at the given odds. These figures are likely to correlate positively with the market's liquidity (i.e., the availability of limit orders).

pre-play liquidity for all matches. We find that the average amount of money traded in the pre-play period is GBP 378,266 for all matches, but GPB 588,134 for matches that present an inter-market arbitrage opportunity. The same pattern appears when comparing the number of bets placed. While the average number of bets placed when all matches are considered is 2,167, 2,978 is the average number of bets placed on matches that offer an arbitrage opportunity. Thus, inter-market arbitrage opportunities seem to primarily concern high liquidity matches and not low liquidity matches.

Next, we take a look at the volume and number of bets that was traded at the specific *Betfair* odds we used to calculate the arbitrage returns documented above.

[Insert Table 2 about here]

The results shown in Table 2 reinforce the conclusions reached above: matches yielding a positive short-position hedged return have higher liquidity (GBP 125,270 and 324 bets) on average than the average for all matches (GBP 64,907 and 245 bets). If we restrict our sample to arbitrage opportunities with a betting volume higher than GBP 10,000, we lose only 609 or 26.6% of the arbitrage opportunities. To give a more comprehensive picture of the low liquidity bets (i.e., bets with a trading volume of less than GBP 10,000), Figure 2 depicts the cumulative density function of betting volumes.

[Insert Figure 2 about here]

The dashed line in Figure 2 represents all matches in the sample, and the solid black line represents the subsample of matches that offer an arbitrage opportunity. Figure 2 illustrates that less than 5% of the arbitrage opportunities have liquidity below GBP 1,000, 13% below GBP 5,000. As the dashed line is always above the solid black line, we see that the low liquidity matches are less frequent when there is an arbitrage opportunity.

Liquidity at the bookmaker market

The provision of sufficient liquidity is one of the main advantages of dealer markets compared to auction markets (see, e.g., Madhavan, 2000). Theoretically, the bookmakers accept unlimited betting volume at the odds they publish. In practice, however, bookmakers have defined limits for single bets and/or maximum winnings in their general terms and conditions. The

maximum winnings vary between GBP 9,000 per bet (*Interwetten*, *Bwin*) and GBP 2,000,000 per day (*William Hill*).

An even more relevant restriction is that bookmakers can cancel bets or limit stakes after they have been placed on the basis of, for example, technical problems, suspicion of fraud, or, most importantly, suspicion of arbitrage betting. All ten bookmakers considered in this paper explicitly reserve the right to cancel bets ex post, limit stakes and close customer accounts at any time without giving any reasons. The terms and conditions include statements like:

> 'The company reserves the right to exclude users from participating in any of the matches of *bwin International Ltd.* at its discretion' (*Bwin*, 2010).
>
> 'We reserve the right to refuse part or all of a bet' (*Ladbrokes*, 2011).
>
> 'If [...] we become aware that You have placed bets and/or played online games with any other online provider of gambling services [...] then we shall have the right to suspend Your Account' (*William Hill*, 2010).

Two bookmakers (e.g., *William Hill, B365*) explicitly confirmed that they limit stakes whenever they identify a bettor as an arbitrageur.[8] Arbitrage betting is no longer attractive if stakes are tightly limited. Ex post bet cancellations prevent risk-free arbitrage betting because the return on the hedged bet is no longer independent of the match's actual outcome if one side of the arbitrage bet is lost after the other has already been placed.

Nevertheless, arbitrage betting (or at least the lure of 'risk-free' profits) seems to be relevant in practice. The identification of arbitrage opportunities in sports betting has become the business concept of several service providers having sounding names like: *U can't lose*, *Rebel Betting* or *Arb Hunters*. They sell information on arbitrage opportunities to customers who buy access to their service. For a price between 10 GBP and 179 GBP per month a customer receives information on arbitrage opportunities via restricted webpage access, email, or text message. Obviously, the arbitrage service providers

---

[8] A semi-professional arbitrage bettor reported to have been stake-limited by *Gamebookers*, *Interwetten* and *William Hill*. The threat of stake limitation seems to be common knowledge among semi-professional bettors. Several online blogs and review pages such as *surebetmonitor.com* make explicit suggestions to avoid being stake limited. For example, they suggest not to place unrounded stakes, e.g. GBP 5,897, or not to bet on 'palps'. The arbitrage community uses the term 'palps' for totally wrong odds that the bookmakers intentionally set in order to catch arbitrage bettors.

largely ignore the practical limitations of arbitrage betting (e.g., stake limits) when advertising their services. In some cases, they at least give advice on how to circumvent being stake-limited by the bookmakers. *Sports Arbitrage World* for example suggests not to 'bet the maximum stakes', not to 'make frequent withdrawals' or not to 'immediately start betting indiscriminately on any and all sports' (*Sports Arbitrage World*, 2011).

III. Inter-Market Price Differences and Informational Efficiency

As demonstrated in the previous Section, the European sports betting market as a whole does not satisfy the weak-form efficiency assumption since inter-market arbitrage opportunities are quite frequent. Theoretically, inter-market arbitrage opportunities may arise from pure noise or from different levels of informational efficiency in the two betting markets. If the former holds true, then price differences between the markets are non-systematically related to the observed outcome of a match. This means that the two market settings may frequently disagree about the probability of a match's outcome, but neither outperforms the other in terms of average prediction accuracy, and therefore, the two markets can be considered as equally contributing to the existence of arbitrage opportunities. In the latter case, the price differences, and thus arbitrage opportunities, are caused by one specific market posting odds that are less efficient on average, while the other market's predictions tend to be closer to the observed outcome probabilities. In this Section, we study the comparative efficiency of the different market settings to examine whether one of the two market settings can be identified as enabling inter-market arbitrage opportunities.

Descriptive statistics of the comparative efficiency

The expected return on a bet is a function of the true outcome probability and the posted odds (see Equations (1), (2) and (3)). The relationship between the true probability and the posted odds must translate into observed returns: if a bet is efficiently priced, the odds already incorporate all available

information relevant to the outcome, and, therefore, the observed return is not systematically associated with inter-market price differences.

We now set out to test this conjecture for both market settings. We concentrate on *short position inter-market arbitrage* opportunities and split up hedged bets into their components, that is, the bet *on* the outcome to occur at the bookmaker market on one side, and the short bet *against* the outcome to occur at the exchange market on the other side. We calculate the bettor's return on the positions of the different markets from which the hedged bets are derived. According to the efficiency hypothesis, the returns on these positions should not depend on the existence of an arbitrage opportunity as a signal of inter-market price differences. If the two markets are equally efficient, then the price differences that enable arbitrage opportunities are unsystematically distributed over the true outcome probability, and the bookmaker and the *Betfair* position should similarly contribute to the observed arbitrage opportunities. Put differently, sometimes the bookmaker odds may turn out to be 'too high', and sometimes the *Betfair* odds may turn out to be 'too low', but on average both market settings yield equally efficient prices. If, on the other hand, the odds of the exchange market (bookmaker market) are closer to the efficient level than the odds of the bookmaker market (exchange market), then we expect that bets at the bookmaker market *on* the outcome (the bets at the exchange market *against* the outcome) should perform abnormally well, that is, relatively better when arbitrage opportunities exist. Table 3 presents the average return on the bookmaker position and the average return on the *Betfair* position whenever we identified a short position inter-market arbitrage opportunity.

[Insert Table 3 about here]

The return derived from the *short position inter-market arbitrage* opportunities is accumulated on the bookmaker position, whereas the *Betfair* position serves as (costly) hedging. This finding gives the impression that, on average, the bookmakers' odds are too high—rather than the bet exchange odds being too low—in the case of an arbitrage opportunity.

However, the returns on the bookmaker position and the return on the *Betfair* position are not directly comparable because the stakes placed at each of the different markets are not equal. In order to hedge against the outcome of the match, the stakes were spread according to Equations (12) and (13). In

the following, we drop the idea of optimal hedging and place a one-unit wager at each of the two positions and calculate its ex post return. Table 4 presents the results.

[Insert Table 4 about here]

The first column reports the returns when wagering on all matches and the second column represents the cases for which an inter-market arbitrage opportunity exists. As we select the bookmaker with the highest odds and the event with the highest short position inter-market hedged return in the first panel in Table 4, the bettor's average return on these bets is slightly positive (0.4%). The average return on these bets at the betting exchange is lower (-2.5%). In order to study the relative efficiencies of the two different betting market mechanisms, we compare the average return on the bets on all matches (first column) with the average return on bets for which an arbitrage opportunity exists (second column). The absolute deviation from the average return is more pronounced at the bookmaker market than at the bet exchange. The average returns on the bet exchange position increase from -2.5% to -1.1%, whereas the average returns on the bookmaker position increase from 0.4% to 7.5%. Thus, if bettors place their entire stakes at the bookmaker market, instead of hedging against the outcome at the bet exchange, whenever inter-market arbitrage was possible, then they could have substantially increased their expected returns.

One could argue that this result may be driven by the simple fact that the bookmaker position is composed of the extreme odds of ten different bookmakers and therefore is more likely to be less efficient. In order to control for this issue, we recalculate the average returns using the odds of a random bookmaker[9] instead of selecting the most attractive bookmaker odds. The results are presented in the second panel of Table 4. Our previous findings from the upper panel are not sensitive to this specification. Again, when considering a single randomly chosen bookmaker, the absolute deviation from average returns is more pronounced at the bookmaker market than at the bet exchange. If bets are only placed when an arbitrage opportunity exists, then the bookmaker return improves from -3.8% to 7.0%, whereas the return on the

[9] For each match, we randomly pick one bookmaker from the set of all bookmakers that are offering bets.

bet exchange market improves to a lesser extent, increasing from -2.5% to 0.6%. Hence, inter-market arbitrage opportunities appear to serve as a signal of biased bookmaker odds.

Regression results of the comparative efficiency

Thus far, the differences in prices between the two markets have been reduced to a simple dichotomous signal: whether an arbitrage opportunity exists or not. We next test the robustness of our results if the entire range of price differences is taken into account. We therefore examine how well the odds of a given market are able to forecast the outcome of a match and test whether the prediction accuracy can be improved by the additional information of the price difference between the two markets. If a betting market is efficient, the odds fully reflect all relevant information, so that there is no better predictor of the outcome's true probability than the posted odds themselves. Therefore, no other source of information is able to improve the prediction accuracy of the market's odds. Adapted to our context, the difference in prices between the two betting markets (as an available source of information) does not increase the prediction accuracy of an efficient market.

To get a market's forecast for a match outcome, we transform the odds into implicit probabilities. The implicit probability is simply the inverse of the odds adjusted for a possible commission included in the odds.[10] Thus,

$$p_{ex,e} = \frac{1}{o_{ex,e}} \frac{1}{\sum_e \frac{1}{o_{ex,e}}} \tag{16}$$

is the implicit probability of a match outcome predicted by the exchange market, and

$$p_{i,e} = \frac{1}{o_{i,e}} \frac{1}{\sum_e \frac{1}{o_{i,e}}} \tag{17}$$

[10] In the case of the bookmaker, this is the already mentioned overround. The odds traded at *Betfair* can contain an overround as well, because they are determined by the market participants trading bets with each other. The average bookmaker overround in our sample is 11.3%, whereas the average overround at *Betfair* is 0.6%.

is the implicit probability of a match outcome predicted by the bookmaker market. If a betting market is efficient, then the implicit probability is the best available approximation of the true outcome probability, and the price of a parallel market does not provide any information that is not already present in the market. If, however, the price of the parallel market is able to improve the forecasts on the actual outcome beyond the posted odds, then the efficiency hypothesis is rejected for the betting market concerned. We test the efficiency hypothesis of the bookmaker market by running the following regression on match outcomes e:

$$Prob(outcome_e) = \alpha + \beta_1 p_{i,e} + \beta_2 \Pi^{inter}_{short\,i,e} + \varepsilon_{i,e} \ . \tag{18}$$

The bookmaker is randomly selected from the pool of available bookmakers for each match. Analogously, we test the efficiency of the bet exchange odds by estimating the following equation:

$$Prob(outcome_e) = \alpha + \beta_1 p_{ex,e} + \beta_2 \Pi^{inter}_{short\,i,e} + \varepsilon_{i,e} \ . \tag{19}$$

The binary dependent variable $outcome_e$ takes the value 1 if the match's observed outcome was actually the outcome of a given bet; otherwise it takes the value 0. The variable $\Pi^{inter}_{short\,i,e}$ is the return on a short position hedged bet as defined by Equation (14) in Section I, except that it is calculated specifically for the given outcome e and bookmaker i.[11] The return on the short position hedged bet is, as we have outlined in Section I, independent of the actual outcome of the match. It is a continuous variable that represents the deviation of prices between the two markets.[12] In order to circumvent the problem that the bets are not independent, but nested within matches, we estimate the effects separately for each of the bets on the three possible outcomes

[11] In Section I, the return on *a short position hedged bet* was defined as the optimal alternative from the set of all outcomes of a match and the set of all available bookmakers. Following the short position arbitrage strategy, hedged bets are available on the outcome level because the same bet bought at the bookmaker market can be sold at the betting exchange.

[12] Another possibility would be to directly introduce the odds of the two parallel markets into the model. A potential problem of that procedure is high multicollinearity between the two variables. By using the return on the hedged bet as the explanatory variable, we circumvent this issue.

of a match, i.e., the bet on the home team winning, the bet on a draw and the bet on the away team winning.[13] As we assume that the error term follows a standard normal distribution, we derive our coefficients from a maximum likelihood estimation of a probit model. The marginal effects, the standard errors and the levels of significance are presented in Table 5.

[Insert Table 5 about here]

Whereas the returns on the hedged bet help explain the true outcome probabilities at the bookmaker market, they do not have any additional explanatory power in the case of the bet exchange. The odds traded at *Betfair* already reflect the available relevant information. At the bookmaker market, the return on the hedged bet contains additional explanatory power beyond the implicit probabilities of the bookmaker odds. The results in Table 5 reveal a significantly positive correlation between the outcome variable and the return on the hedged bet. This implies that if the odds posted by the bookmaker are higher than the odds traded at *Betfair* after being adjusted for commission (see Condition 15), the bookmaker odds are on average too high and the implicit probabilities (prices) are too low with respect to the actual outcome probability.

Overall, we demonstrate that the price differences between the two markets are not due to noise. Instead, the bet exchange market clearly outperforms the bookmaker market in terms of informational efficiency, which is in line with recent results by Smith et al., (2009) and Franck et al., (2010).[14] Thus, inter-market arbitrage opportunities emerge as a result of the different informational efficiency of the offered odds at the two betting markets.

Intentional price deviations as part of the bookmaker's promotional activities

Basically, there are two explanations for the lower informational efficiency of the bookmaker odds in comparison to the odds traded at the bet exchange. First, bookmakers may be less informed about the true outcome probabilities

[13] An alternative approach would be to run a pooled regression and include both dummy variables for each bet and interaction terms. This procedure leads to virtually the same results.

[14] Spann and Skiera (2009) find that a virtual stock exchange platform (*bundesligaboerse.de*) and the bookmaker *Oddset* perform equally well in terms of predicting German soccer match outcomes. However, the exchange platform they analyse does not operate with real money.

and/or unable to process and incorporate the relevant information into the odds. The alternative explanation is that bookmakers may intentionally set inefficiently high odds from time to time.

If the first hypothesis holds, one would expect arbitrage opportunities to have diminished with time provided that bookmakers learn from the past. In Table 6 we present the number and likelihood of arbitrage opportunities as well as the average return on the bookmaker position from arbitrage bets for each bookmaker and broken down by season.

[Insert Table 6 about here]

Table 6 reveals that every bookmaker provided short-position inter-market arbitrage opportunities in every season of our sample. It can be seen that neither the likelihood of arbitrage bets nor the average return on the bookmaker position in the case of arbitrage opportunities have systematically decreased over time. The frequency of arbitrage opportunities remains surprisingly stable for most bookmakers. Nine of the ten bookmakers experienced negative average margins from the odds that enabled arbitrage opportunities (i.e., positive returns for the bettors). Thus, the bookmakers have not generally improved the efficiency of their posted odds, even though they ought to be aware that the bet exchange predictions have been closer to the true outcome probabilities in the past. Real-time pricing data from bet exchanges and (online) bookmakers are publicly available on the internet, and price-monitoring software facilitates checking the odds available at different bookmakers' and exchanges' websites on a high-frequency basis. Bookmakers either employ in-house software to do so or buy the services from third parties such as *betgenious.com* or *txodds.com*. As the respective price on a rival bet exchange market is among the most obvious sources of information to be considered in the pricing decision of the bookmakers, it is implausible that arbitrage opportunities arise due to ignorance (except technical and human mistakes). Therefore, we conclude that the bookmakers intentionally distort odds in some cases. Following this argument, the obvious question is: why would bookmakers intentionally offer odds that enable arbitrage opportunities and lead to negative expected margins?

We hypothesize that bookmakers frequently offer over-favourable odds allowing positive average returns for bettors as an element of their promotional activities to attract new customers. Initially, the bookmakers bear negative

expected margins from these bets, but in the longer run, they may benefit from a higher customer base. Casual bettors, once acquired, tend to stick with a given bookmaker even though more favourable terms are available elsewhere.

Our argument is based on the structural differences between the bookmaker market and the bet exchange. The identities of the buyer and the seller remain mutually anonymous at the bet exchange platform, whereas they are revealed in the bookmaker market. First, we analyse this difference between the two market structures from the perspective of the liquidity demander (i.e., the submitter of market orders at the bet exchange and the bettor at the bookmaker market). Second, we address the issue from the liquidity supplier's perspective (i.e., the submitter of limit orders at the bet exchange and the bookmaker at the bookmaker market).

Since limit orders and market orders are matched by pools and not by individuals at the bet exchange, the identity of the liquidity provider is unknown to the liquidity demander. At the bookmaker market, the bettors obviously know with whom they trade. In contrast to trading with different limit order submitters at the exchange platform, bettors are required to invest specifically in order to trade with different bookmakers. The initial investments necessary to wager with a given bookmaker include the time and money to open and manage an account, the documentation required to withdraw winnings and the time to get used to a bookmaker's specific webpage and to the procedure of placing bets. Whereas it is usually rather easy to open an account and to deposit money, bookmakers often complicate the withdrawal of money by requiring copies of identity cards or bank accounts. Furthermore, some bookmakers (e.g., *William Hill*, *Ladbrokes*) charge administration fees if bettors have not placed bets within a certain time period. These specific investments imply that bettors have to bear additional costs if trading with different bookmakers instead of just a single one. Therefore, bookmakers can profit from new clients in the longer run, as many bettors do not swiftly change to another bookmaker, and place bets even at unfavourable odds.[15] Document analyses and in-depth interviews with senior executives of

[15] Even though a particular bet is a standardised product, it is an empirical fact that the elasticity of demand for an individual bookmaker is not infinitely high. Otherwise bookmakers, as mere price takers, would have to set equal prices to those at the bet exchanges,

the betting industry confirm that over-generous odds are part of the online and offline advertisements ahead of the matches that aim to attract new customers. The annual report of *Ladbrokes*, one of the two big players in the English bookmaker market, publishes cost per acquisition figures of between GBP 91 in 2006 and GBP 156 in 2009. These numbers include not only online and offline recruitment expenditures but also so-called 'promotions and bonuses netted from revenues' (*Ladbrokes*, 2010). Andrew Lyman, senior executive of *William Hill*, concedes: '[...] some of our pricing is done as a loss leader to attract customers'. Thus, negative average margins when offering an inter-market arbitrage opportunity are attributed to the overall marketing budget.

Information on the identity of the counterpart-trader is what differentiates the bet exchange from the bookmaker market. This applies not only to the demander of liquidity, but also to the supplier of liquidity. Suppliers of limit orders at the exchange platform do not have proprietary bases of customers who made specific investments to trade with them. Bookmakers, on the other hand, have an established customer portfolio, which they can cultivate to some extent. As online wagering requires the bettors to register, bookmakers can keep track of the entire trading history of their accounts and create bettor profiles. Most bookmakers reserve the explicit right to use cookies, log files, clear gifs, and/or third parties to create customer profiles in their terms and conditions. Any software that the bookmakers use to track other bookmaker's odds and the odds traded at bet exchange platforms is likely to be integrated into their customer database. Thus bookmakers can identify arbitrageurs who only (or mostly) bet on their overly favourable odds. In such situations, as mentioned in the previous Section, the bookmakers reserve the right to close the customers' account or to restrict their maximum stakes to an amount that makes betting unattractive. Moreover, customer profiling enables the bookmakers to segment their customer portfolio ex post by keeping profitable leisure bettors and discriminating against unprofitable skilled bettors.

---

which is not consistent with our empirical finding of numerous inter-market arbitrage opportunities. Furthermore, the bookmakers would have to set equal prices to those at all the other bookmakers, which is not consistent with our empirical results either: the bookmaker odds for the same underlying contract have an average standard deviation of 0.185, and we even find some intra-market arbitrage opportunities (see Table 1).

To sum up, there are important institutional differences between the bookmaker market setting and the bet exchange market. Bettors at the exchange platform trade with an anonymous counterparty, whereas the identities of the liquidity demanders and the liquidity suppliers do matter in the bookmaker market because bettors face switching costs between different bookmakers, and because the bookmaker can track each of his bettors' trading history. These institutional differences influence the pricing considerations of the market participants. Suppliers of limit orders at the exchange platform set their prices to optimise over a particular bet. Bookmakers, in turn, are able to optimise over the entire expected trading activity of their customer portfolio. This explains why inter-market arbitrage opportunities have remained a frequent phenomenon over the last seven years for every bookmaker in our data sample.

IV. Conclusion

We show that in the gambling industry inter-market arbitrage opportunities between bookmakers and the bet exchange market arise very frequently. In our sample of the top-five European soccer leagues, we identified an arbitrage opportunity in 19.2% of all matches. These arbitrage opportunities do not arise from random price differences between the two markets, but are the result of different levels of informational efficiency. Specifically, most arbitrage opportunities emerge when a bookmaker offers inefficiently low-priced bets that can be sold for a comparatively higher price at the bet exchange. Rather than the bet exchange market, it is the bookmakers who give rise to the arbitrage opportunities.

The paper contributes to the recent discussion on how market structure affects information efficiency in betting markets (see Bruce and Johnson, 2005; Sung and Johnson, 2010; Franck et al., forthcoming). Consistent with previous empirical work (e.g., Smith et al., 2006; Smith et al., 2009; Franck et al., 2010) we find that the odds at the bookmaker market are less efficient than those at the bet exchange market. Moreover, we show that bookmakers are willing to accept negative margins by posting more favourable odds than the rival bet exchange market, even though price transparency is high. They frequently take a loss by not incorporating the odds from the rival bet ex-

change market—as one of the most obvious sources of information—into their price setting decision.

The literature proposes different explanations of why bookmakers deviate from efficient prices. Shin (1991; 1992; 1993) points out that bookmakers skew the odds because they are facing an adverse selection problem in which some bettors may be trading on the basis of superior information. Bookmakers may also deviate from efficient prices to take advantage of sentimental bettor preferences (Kuypers, 2000; Levitt, 2004; Forrest and Simmons, 2008; Franck et al., forthcoming).

Focusing on bookmakers as market makers, these considerations do not fully explain why we frequently find substantial price differences between the bet exchange market and the bookmaker market for the same underlying contracts. It is not clear a priori why submitters of limit orders at the exchange platform should have different pricing considerations than bookmakers. To date, no theory is available that models price reactions caused by the threat of private information or sentimental preferences at the bet exchange market.

We argue that bookmakers set their prices to optimise profits in the long term, rather than over each individual bet. This idea is based on what ultimately differentiates bookmakers from bet exchange platforms: bookmakers are not trading against anonymous submitters of market orders as at the exchange platform; they can keep track of the trading behaviour of each customer and take their entire future trading behaviour into account. Thus, bookmakers may post overly favourable odds to attract new customers. Initially, they have to bear negative expected margins from these bets. But in the longer term the bookmakers seem to benefit from a higher customer base. Some of the acquired clients may contribute to the bookmaker's future winnings, because they face switching costs and place bets even under unfavourable conditions. As the bookmakers can profile each client's trading history and are able to discriminate against skilled bettors by closing their accounts or restricting their maximum stakes, the remaining customer base may be an even more 'profitable deal'.

This practice of 'hidden price discrimination' has not been investigated in the literature so far. Yet, it has important consequences for future research in the field because it changes the way the bookmaker's price setting decision must be modelled and, as a result, how price anomalies in the market are in-

terpreted. Studies addressing price anomalies in the betting industry have so far implicitly assumed that first, the bookmaker's odds represent an optimal decision for every single bet given the available information about the true outcome probability and the nature of demand, and that second, virtually any market order has to be fulfilled at the given odds. Our findings indicate that bookmakers optimise in the long term, and they are able to segment the market to some extent by refusing to serve clients identified as unprofitable skilled bettors such as arbitrageurs.

References

Bwin (2010): General terms and conditions http://help.bwin.com/General/Legal/general˙tac.aspx#limits˙of˙payment accessed February 2, 2010.

Bruce, A. C. and Johnson, J. E. V. (2005): Market ecology and decision behaviour in state-contingent claims markets. *Journal of Economic Behavior and Organization,* **56**, 199-217.

Croxson, K. and Reade, J. (2008): Information and efficiency: goal arrival in soccer betting. *Working paper*, Oxford University.

Edelman, D. and O'Brian, N. (2004): Tote arbitrage and lock opportunities in racetrack betting. *The European Journal of Finance,* **10**, 370-378.

Dixon, M. and Pope, P. (2004): The value of statistical forecasts in the UK association football betting market. *International Journal of Forecasting,* **20**, 697-711.

Franck, C., Verbeek, E., and Nüesch, S. (2010): Prediction accuracy of different market structures - bookmakers versus a betting exchange. *International Journal of Forecasting,* **26**, 448-459.

Franck, C., Verbeek, E., and Nüesch, S. (Forthcoming): Sentimental preferences and the organizational regime of betting markets, *Southern Economic Journal*.

Forrest, D., Goddard, J., and Simmons, R. (2005): Odds-setters as forecasters: the case of English football. *International Journal of Forecasting,* **21**, 551-564.

Forrest, D., Simmons, R. (2008): Sentiment in the betting market on Spanish football. *Applied Economics,* **40**, 119-126.

Hausch, B., and Ziemba, W. (1990): Arbitrage strategies for cross-track betting on major horse races. *Journal of Business,* **63**, 61-78.

H2 Gambling Capital (2011): Global gambling data service. http://www.h2gc.com/, accessed August 18, 2011.

JONES, D. (2009): *Safety in numbers: annual review of football finance. Report*, Manchester: Sports Business Group at Deloitte.

KUYPERS, T. (2000): Information and efficiency: an empirical study of a fixed odds betting market. *Applied Economics*, **32**, 1353-1363.

LADBROKES (2010): Annual report and accounts 2009 Ladbrokes, http://investors.ladbrokesplc.com/-reports; accessed May 21, 2010.

LADBROKES (2011): Website Terms and Conditions. http://help.ladbrokes.com/display/4/kb/article.aspx?aid=2665, accessed June 10, 2011.

POPE, P. AND PEEL, D. (1989): Information, prices and efficiency in a fixed-odds betting market. *Economica,* **56***,* 323-341.

SHLEIFER, A. ANDVISHNY, R. (1997): The limits of arbitrage. *Journal of Finance,* **52**, 35-55.

SHARPE, W. AND ALEXANDER, G. (1990): *Investments. 4th Edition.* Englewood Cliffs, NJ: Prentice Hall.

SHIN, H. A. (1991): Optimal betting odds against insider traders. *Economic Journal,* **101***,* 1179-1185

SHIN, H. A. (1992): Prices of state contingent claims with insider traders, and the favourite-longshot bias. *Economic Journal,* **102***,* 426-435.

SHIN, H. A. (1993): Measuring the incidence of insider trading in a market for state-contingent claims. *Economic Journal,* **103***,* 1141-1153.

SMITH, M., PATON, D. AND VAUGHAN WILLIAMS, L., (2005): An assessment of quasi-arbitrage opportunities in two fixed-odds horse-race betting markets. in: Vaughan Williams, L. (ed.): *Information efficiency in financial and betting markets*. Cambridge: Cambridge University Press, 159-171.

SMITH, M., PATON, D. AND VAUGHAN WILLIAMS, L., (2006): Market efficiency in person-to-person betting. *Economica,* **73**, 673-689.

SMITH, M., PATON, D. AND VAUGHAN WILLIAMS, L., (2009): Do bookmakers possess superior skills to bettors in predicting outcomes? *Journal of Economic Behavior and Organization,* **71***,* 539-549.

Sports Arbitrage World (2011): I have heard that bookmakers quickly limit traders. http://support.sportsarbitrageworld.com/index.php?˙m=knowledgebase&˙a=viewarticle&kbarticleid=58, accessed August 18, 2011

Spann, M. and Skiera, B. (2009): Sports forecasting: a comparison of the forecast accuracy of prediction markets, betting odds, and tipsters. *Journal of Forecasting,* **28***,* 55-72.

Sung, M. and Johnson, J. E. V. (2010): Revealing weak-form inefficiency in a market for state contingent claims: the importance of market ecology, modelling procedures and investment strategies. *Economica,* **77***,* 128-147.

Verbeek, E. (2009): *Information efficiency in speculative markets*, Ph.D. Dissertation, University of Zurich.

Vlastakis, N., Dotsis, G. and Markellos, R. (2009): How efficient is the European football betting market? Evidence from arbitrage and trading strategies. *Journal of Forecasting,* **28***,* 426-444.

William Hill (2010). Terms and conditions. http://williamhill-lang.custhelp.com/cgi-bin/williamhill˙lang.cfg/php/enduser/std˙adp.php?p˙faqid=6719; accessed February 2, 2010.

Wolfers, J. and Zitzewitz, E. (2004): Prediction markets. *Journal of Economic Perspectives*, **18**, 107-126.

TABLES & FIGURES

Table 1
Arbitrage Opportunities in European Soccer Betting

	All matches	Arbitrage opportunities
Intra-market:		
Return on the hedged bets	-0.039 (0.017)	0.009 (0.016)
Observations	12,782	102
Percentage		0.8%
Long position inter-market:		
Return on the hedged bets	-0.024 (0.017)	0.017 (0.035)
Observations	11,933	593
Percentage		5.0%
Short position inter-market:		
Return on the hedged bets	-0.007 (0.017)	0.014 (0.028)
Observations	11,933	2,287
Percentage		19.2%

Note: The table gives an overview on arbitrage bets in the European soccer betting market. It can be seen that the intra-market strategy (upper block) is less attractive than inter-market arbitrage. The short position arbitrage method (lower block) exhibits thereby even higher potential in terms of number of arbitrage opportunities than the long position inter-market method (middle block). Standard deviations of positive returns are given in parentheses.

Table 2

Total Amount of Money and Total Number of Bets Traded at Betfair

	All matches	Arbitrage opportunities	
		all	> GBP 10,000
Total amount of money traded (in GBP)	64,907 (187,261)	125,270 (275,765)	169,029 (310,587)
Total number of bets executed	245 (302)	324 (386)	411 (412)
Observations	11,933	2,287	1,678

Note: The table gives an overview on the liquidity at the specific bet exchange prices used to calculate the arbitrage returns documented in the paper (standard deviations in parentheses). It can be seen that the liquidity of matches with an arbitrage opportunity (middle column) is not below but above average liquidity (left column), and lies above GBP 10,000 in more than 70% of the cases (right column).

Table 3

The Composition of Returns of Short Position Arbitrage Bets

	Arbitrage opportunities
Return of arbitrage bets	0.014 (0.028)
- Return on the bookmaker position	0.016 (0.461)
- Return on *the Betfair* position	-0.002 (0.461)
Observations	2,287

Note: The table summarises the returns (standard deviations in parentheses) on short position arbitrage bets (first row) and the returns on the positions from which they are derived; the bet *on* the outcome at the bookmaker market (second row) and the short bet *against* the outcome at the exchange market (third row). It can be seen that the net return derived from the arbitrage opportunities is accumulated on the bookmaker position, whereas the *Betfair* position serves more as (costly) hedging.

Table 4

Descriptive Statistics of the Comparative Efficiency

	All matches	Arbitrage opportunities
Most attractive bookmaker:		
- Return on the bookmaker position	0.004 (1.620)	0.075 (1.681)
- Return on the *Betfair* position	-0.025 (0.849)	-0.011 (0.998)
Observations	11,933	2,287
Random bookmaker:		
- Return on the bookmaker position	-0.038 (1.529)	0.070 (1.780)
- Return on the *Betfair* position	-0.025 (0.849)	0.006 (0.948)
Observations	11,933	653

Note: The table summarises the returns (standard deviations in parentheses) of the markets' positions placing one unit stakes. This is done for the bookmaker offering the highest odds (first panel) and a randomly chosen single bookmaker (second panel). The returns are calculated for all matches (first column) and for the cases offering an inter-market arbitrage opportunity (second column). It can be seen that the returns on both positions deviate from their average level in the case of an arbitrage opportunity, but the return on the bookmaker position deviates to a larger extent compared to the return on the *Betfair* position.

Table 5

The Markets' Comparative Efficiency using Multivariate Probit Regressions

Dependent variable: outcome of a bet (0/1)	Bets on a home win	Bets on a draw game	Bets on an away win
Random bookmaker			
Implicit probability	1.206 ***	1.386 ***	1.094 ***
	(0.033)	(0.105)	(0.031)
Return on the hedged bet	1.175 ***	0.912 **	0.982 ***
	(0.197)	(0.286)	(0.177)
Observations	11,933	11,933	11,933
Pseudo-R^2	0.085	0.013	0.093
Betfair			
Implicit probability	1.110 ***	1.186 ***	1.003 ***
	(0.031)	(0.091)	(0.029)
Return on the hedged bet	0.132	-0.278	0.102
	(0.197)	(0.297)	(0.175)
Observations	11,933	11,933	11,933
Pseudo-R^2	0.085	0.013	0.095

Note: The table presents the marginal effects of multivariate probit regressions that explain the observed outcome (win or loss) of bets on a home win (first column), bets on a draw game (second column) and bets on an away win (third column). The explaining variables are the probabilities for these outcomes implied by the odds of a randomly chosen bookmaker (upper block) and of the exchange market (lower block) and the return on the short position hedged bet as a measure of inter-market price difference. The robust standard errors are given in parentheses. ***, **, * denotes significance at the 0.1% , 1%, 5% level respectively. It can be seen that, in contrast to the exchange market, the odds of the bookmaker market do not contain all information rendered by the inter-market price differences.

Table 6

Arbitrage Opportunities by Bookmaker and by Season

		All seasons	Season						
			2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
B365	- # of arbitrage opportunities	720	61	71	71	113	145	112	147
	- % of arbitrage opportunities	6.0%	3.9%	4.7%	4.0%	6.3%	8.1%	6.4%	8.3%
	- Return on the bookm. pos.	0.059	0.180	-0.013	0.048	-0.073	0.209	0.021	0.029
		(1.826)	(1.598)	(2.062)	(1.759)	(1.623)	(2.260)	(1.743)	(1.559)
BS	- # of arbitrage opportunities	390	.	.	.	64	115	91	120
	- % of arbitrage opportunities	5.5%	.	.	.	3.6%	6.4%	5.2%	6.8%
	- Return on the bookm. pos.	-0.012	.	.	.	-0.160	-0.058	-0.003	0.102
		(1.523)	.	.	.	(1.152)	(1.388)	(1.294)	(1.935)
B&W	- # of arbitrage opportunities	604	97	95	79	87	76	75	95
	- % of arbitrage opportunities	5.1%	6.2%	6.3%	4.5%	4.9%	4.2%	4.3%	5.4%
	- Return on the bookm. pos.	0.091	-0.019	0.220	0.147	0.018	0.075	0.145	0.063
		(1.765)	(1.377)	(1.919)	(1.745)	(1.609)	(1.740)	(1.506)	(2.286)
GB	- # of arbitrage opportunities	532	70	52	56	95	96	63	100
	- % of arbitrage opportunities	4.5%	4.5%	3.4%	3.2%	5.3%	5.4%	3.6%	5.7%
	- Return on the bookm. pos.	0.022	0.185	0.093	-0.119	-0.036	-0.074	0.180	-0.004
		(1.515)	(1.680)	(2.089)	(1.414)	(1.357)	(1.324)	(1.579)	(1.390)
IW	- # of arbitrage opportunities	814	79	89	85	110	141	130	180
	- % of arbitrage opportunities	6.8%	5.1%	5.9%	4.8%	6.2%	7.9%	7.5%	10.2%
	- Return on the bookm. pos.	0.001	0.189	-0.091	-0.043	-0.060	0.026	-0.015	0.015
		(1.250)	(1.093)	(1.126)	(1.010)	(1.323)	(1.358)	(1.302)	(1.316)
LB	- # of arbitrage opportunities	478	42	52	60	60	79	58	127
	- % of arbitrage opportunities	4.0%	2.7%	3.4%	3.4%	3.4%	4.4%	3.3%	7.2%
	- Return on the bookm. pos.	0.015	0.141	0.371	-0.065	-0.114	-0.155	0.223	-0.068
		(1.610)	(1.577)	(2.166)	(1.319)	(1.543)	(1.196)	(2.200)	(1.410)
SB	- # of arbitrage opportunities	416	58	58	59	77	73	41	50
	- % of arbitrage opportunities	3.5%	3.8%	3.8%	3.3%	4.3%	4.1%	2.4%	2.9%
	- Return on the bookm. pos.	0.002	0.124	0.058	0.005	-0.026	-0.108	0.217	-0.183
		(1.610)	(1.590)	(2.153)	(1.623)	(1.271)	(1.473)	(1.817)	(1.418)
SJ	- # of arbitrage opportunities	895	.	70	104	133	238	158	192
	- % of arbitrage opportunities	8.6%	.	4.6%	5.9%	7.5%	13.3%	9.1%	10.9%
	- Return on the bookm. pos.	0.051	.	0.423	-0.127	-0.133	0.180	0.065	-0.032
		(1.762)	.	(2.056)	(1.500)	(1.381)	(2.143)	(1.680)	(1.525)
VC	- # of arbitrage opportunities	607	.	54	54	82	95	75	247
	- % of arbitrage opportunities	5.9%	.	3.6%	3.1%	4.6%	5.3%	4.3%	14.1%
	- Return on the bookm. pos.	0.005	.	-0.026	-0.218	0.029	0.124	-0.166	0.058
		(1.936)	.	(2.220)	(1.431)	(1.613)	(2.596)	(1.444)	(1.909)
WH	- # of arbitrage opportunities	513	51	43	45	36	90	69	179
	- % of arbitrage opportunities	4.5%	3.3%	2.8%	2.5%	2.8%	5.0%	4.0%	10.1%
	- Return on the bookm. pos.	0.064	0.156	0.036	-0.279	-0.277	0.271	0.252	0.022
		(1.715)	(1.652)	(1.823)	(1.257)	(1.184)	(2.312)	(1.856)	(1.470)

Note: The table presents the number and percentage of arbitrage opportunities, as well as the bettor's return (standard deviations in parentheses) on the bookmaker position of these arbitrage bets for each single bookmaker in the sample (rows) and broken down by season (columns). It can be seen that neither the frequency of arbitrage opportunities nor the bookmakers' loss of margin caused by the arbitrage opportunities have generally decreased during the seven year period of the data sample.

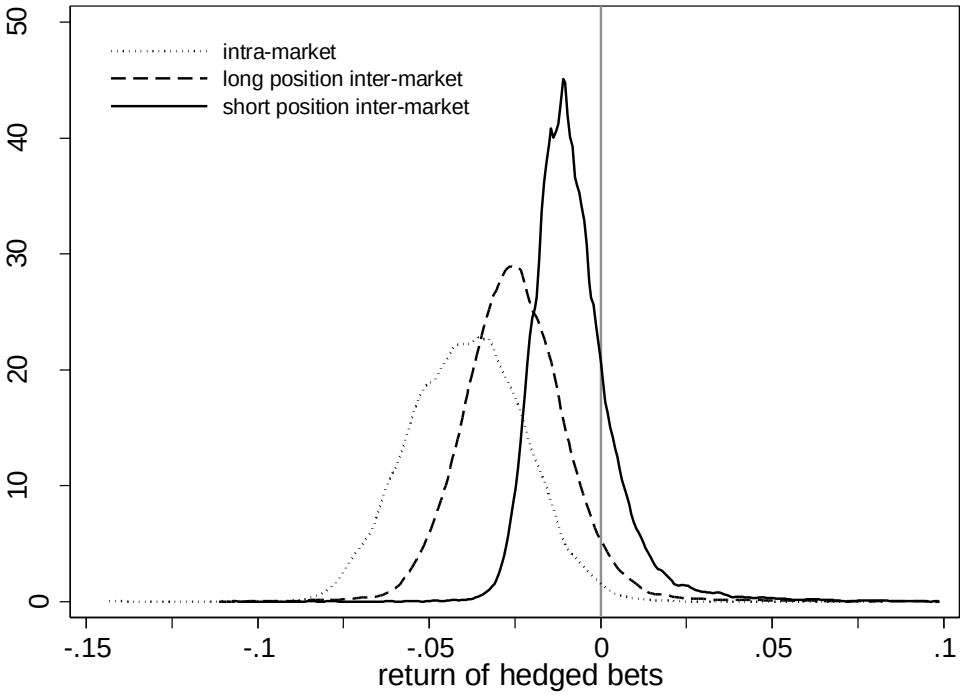

FIGURE 1. Density Functions of the Hedged Bets' Returns

Note: The density functions of the returns of the hedged bets when following the three different arbitrage strategies (inter-market arbitrage, long position inter-market arbitrage, and short position inter-market arbitrage) are depicted.

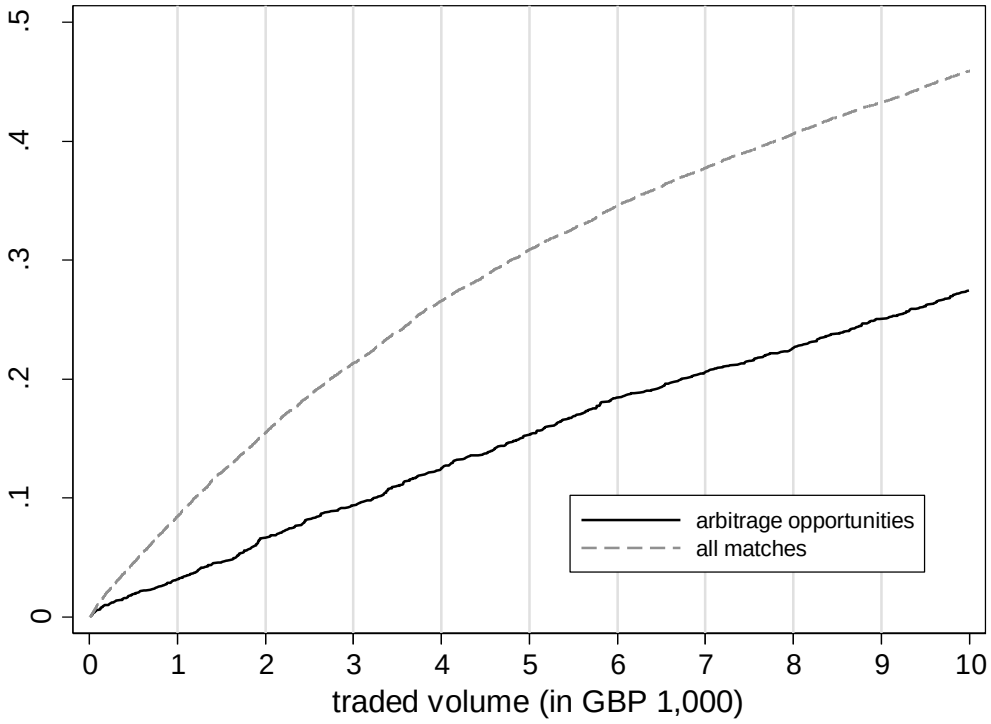

FIGURE 2. Cumulative Density Functions of Traded Volumes of Low-Liquidity Matches

Note: The cumulated density functions of the volumes traded at the given prices during the pre-play period of all matches and the matches offering an arbitrage opportunity are depicted.

APPENDIX

Table A1

Arbitrage Opportunities Using the Volume-Weighted Average of the Corresponding Betfair Odds

	All matches	Arbitrage opportunities
Long position inter-market:		
Return on the hedged bets	-0.024 (0.016)	0.017 (0.032)
Observations	11,933	417
Percentage		3.9%
Short position inter-market:		
Return on the hedged bets	-0.009 (0.013)	0.011 (0.022)
Observations	11,933	1716
Percentage		14.4%

Note: The table illustrates the frequency of arbitrage bets in the European soccer betting market using an alternative specification of the corresponding *Betfair* odds. In the baseline specification (see Table 1) we select the *Betfair* odds with the highest betting volume from the pool of potential *Betfair* odds. In this table we use the volume-weighted average of *Betfair* odds that were potentially available at the time the bookmaker odds were recorded.

Table A2

The Markets' Comparative Efficiency Using the Volume-Weighted Average of the Corresponding Betfair Odds

Dependent variable: outcome of a bet (0/1)	Bets on a home win	Bets on a tie game	Bets on an away win
Random bookmaker			
Implicit probability	1.213 ***	1.357 ***	1.103 ***
	(0.033)	(0.105)	(0.032)
Return of the hedged bet	1.381 ***	1.238 **	1.159 ***
	(0.216)	(0.305)	(0.198)
Observations	11,933	11,933	11,933
Pseudo-R^2	0.086	0.013	0.094
Betfair			
Implicit probability	1.113 ***	1.184 ***	1.006 ***
	(0.031)	(0.091)	(0.029)
Return of the hedged bet	0.274	0.017	0.141
	(0.216)	(0.313)	(0.196)
Observations	11,933	11,933	11,933
Pseudo-R^2	0.086	0.013	0.095

Note: The table illustrates the comparative efficiency of the two markets using an alternative specification of the corresponding *Betfair* odds. Whereas we select the *Betfair* odds with the highest betting volume from the pool of potential *Betfair* odds in the baseline specification (see Table 5), this table uses the volume-weighted average of *Betfair* odds that were potentially available at the time the bookmaker odds were recorded. The table presents the marginal effects of the multivariate probit regressions that explain the observed outcome (win or loss) of bets on a home win (first column), bets on a draw game (second column) and bets on an away win (third column). The robust standard errors are given in parentheses. ***, **, * denotes significance at the 0.1% , 1%, 5% level respectively.

Table A3

Arbitrage Opportunities Using the Least Favourable of the Corresponding Betfair Odds

	All matches	Arbitrage opportunities
Long position inter-market:		
Return on the hedged bets	-0.024 (0.016)	0.018 (0.038)
Observations	11,933	69
Percentage		0.6%
Short position inter-market:		
Return on the hedged bets	-0.009 (0.013)	0.012 (0.027)
Observations	11,933	156
Percentage		1.3%

Note: The table illustrates the frequency of arbitrage bets in the European soccer betting market using an alternative specification of the corresponding *Betfair* odds. In the baseline specification (see Table 1) we select the *Betfair* odds with the highest betting volume from the pool of potential *Betfair* odds. In this table we use the least favourable of *Betfair* odds that were potentially available at the time the bookmaker odds were recorded, i.e. the lowest odds if calculating the returns of the *long position inter-market hedged bets* (see Equation 9) and the highest odds if calculating the returns of the *short position inter-market hedged bets* (see Equation 14).