New Entry, Strategic Diversity and Efficiency in Soccer Betting Markets: The Creation and Suppression of Arbitrage Opportunities

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Abstract

We find that prices offered by competing bookmakers within the same quote-driven soccer (football) betting market provide arbitrage opportunities. However, the management practices of bookmakers prevent informed bettors exploiting these in practice. We identify two groups of bookmakers, 'position-takers' and 'book-balancers.' Position-takers alter their odds infrequently, while actively restricting informed traders. Book-balancers actively manage inventory by adjusting odds, and place few restrictions on their customers. We identify 545 arbitrage portfolios, and find that around 50% would require a bet on the favourite at the position-taking bookmaker. The management practices of position-takers generally prevent these opportunities being exploited in practice.

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1. INTRODUCTION

This paper examines the impact of new entrants into the European market for soccer betting, which until recently has been dominated by European (and generally UK) based operators. Specifically, we evaluate how the recent entry of several large and (predominantly, though not exclusively) Asian bookmaking organisations has affected the range of odds available to consumers, with potential consequences for the efficiency of the market. As such, this paper contributes to a significant empirical interest in, and literature on, the operation of betting markets.

A principal motivation for this study is the fact that there are clear, material differences between the recent entrants and the more established operators, both in product portfolios and aspects of operating behaviour. These differences raise the possibility of profitable arbitrage opportunities for bettors, with attendant implications for market efficiency.

The paper is structured as follows. This section explains briefly why betting markets in general constitute a fertile territory for studies of market behaviour and efficiency. This leads into a discussion of the recent structural changes in the European soccer betting market. Section 2 outlines relevant theoretical material in relation to arbitrage and bookmaker behaviour. Section 3 develops hypotheses, and the data and methods employed to test these are outlined in Section 4. Section 5 presents results and Section 6 offers a discussion and conclusion.

1.1 Betting Markets as an Investigative Medium

A number of characteristics of bookmaker-driven betting markets make them both interesting in their own right, as well as an ideal setting for field experiments to explore aspects of broader financial market efficiency (see, for example, Sauer, 1998; Vaughan Williams, 1999, 2005; Oikonomidis and Johnson, 2011). As explained by Thaler and Ziemba (1988) a key advantage of betting markets is the fact that the objective values of assets are determined with certainty at the close of the market, as the outcome of the betting event is revealed. Decisions made in betting markets (i.e. bets placed) are clearly and individually recorded and this, together with the

very large number of individual markets, ensures a rich documentary resource for empirical investigation. Additionally, betting markets resemble other financial markets in terms of the varying sophistication levels of traders, who risk their own assets on the uncertain outcome of future events. Betting markets may therefore provide more generalizable results than those from laboratory experiments, in which subjects may be inexperienced traders and hold limited motivation (Levitt and List, 2007).

Our focus in this paper is on structural change in the betting markets for European soccer associated with the entry of large, generally Asian-based bookmakers, such as SBOBet and Pinnacle, alongside traditional European bookmakers, such as the U.K.-based William Hill and Ladbrokes. An interesting aspect of this change is that there are distinct and observable differences in operating practice between the established bookmakers and the new entrants, in relation to trading restrictions, volatility of the odds menu and the range of event outcomes offered. These are now explained.

With regard to trading policy, the new entrants adopt a conspicuously more liberal approach to clients in that they make no attempt to restrict bets from potentially `informed' or more sophisticated bettors. Pinnacle, for example, explicitly state:

> `Our Winners Welcome policy is very straight-forward. We do not limit, discriminate or close accounts of successful players, and here is why:
>
> - Our business model is focused solely on maximising volume irrespective of whether this is generated from profitable players
> - We need sharp players to help tighten our odds as we do not take positions
> - We have the confidence in our traders to focus on managing odds, not players'

By contrast, traditional European operators actively manage their client portfolios to deter trade from these groups. Where an individual's betting activity generates what these bookmakers regard as an unprofitable line of business over a sustained period, this frequently

results either in staking limits being imposed on that individual, delays in settling debts, or at the limit, termination of the ability to trade. The following actual, but anonymised, example of an e-mail communication (one of a number of similar examples held by the authors) illustrates this practice.

> `Following a review of your account by our trading department, moving forward you are no longer going to be able to place bets to the stake size that you have been accustomed to. Although your account will remain open and active, the bets you are likely to be able to place will be significantly less than what you have been able place in the past. ‘

In addition, this practice of turning away or deterring potentially unprofitable business has been widely reported in the general and specialist media. The Guardian (28 June, 2016) describes one such instance:

> `Bet365, one of the internet’s biggest bookmakers, is facing legal action from a customer over its failure to transfer a £54,000 balance to her bank account despite repeated requests over a period of months. While refusing to release the backer’s winnings on a series of horse racing bets, Bet365 also told her that she would be restricted to a maximum stake of £1 if she wished to bet with the balance but was welcome to gamble as much as she wished on gaming products, which have a guaranteed margin for the operator. The punter, whose identity is known to the Guardian, opened an account with Bet365 on 16 April and deposited £30,000 with the firm the following day, when she placed a series of bets on horse racing and lost £23,000. She received an email from Bet365 the same day, which stated that the size of the maximum bet she was allowed to place had been increased. The following day she placed further bets with the remaining £7,000, winning a total of £47,000, which raised her balance to about £54,000. The same day she was informed via email that in future her account would be restricted to a maximum stake of £1 on racing bets as the result of a “trading decision”.’

The UK Horseracing Bettors’ Forum (UKHBF) conducted a survey in April 2016 of betting account closure, which demonstrated the widespread nature of the practice among UK bookmakers. On the basis of the survey, it was estimated that around 20,000 accounts had been closed in the previous six months (The Guardian, 13 June 2016, UKHBF (2016)).

These sharply distinct approaches to clients are further reflected in differences in the evolution of betting markets relating to individual events. European operators vary the initial menu of odds only occasionally. In contrast, the new entrant operators engage in much more frequent odds adjustments as information is brought, unfettered, to market by a wider clientele.

A comparison between leading representatives of each group of bookmakers (SBOBet and Ladbrokes), employing the main dataset used in this study (see Section 3, below, for details), charts changes in odds collected at nine points in time in the 24 hours leading to the kickoff of 2,132 matches. This reveals that the odds of the book-balancing bookmaker SBOBet are different at point t (compared to its odds at point t-1) on 77% of occasions. However, the odds of the PTB, Ladbrokes, only differ from the preceding time period on 12.4% of occasions. SBOBet odds changed, on average, on 5.4 occasions per match in the 24 hours prior to kick off whilst the equivalent figure for Ladbrokes is 0.8. A t-test confirms that the difference in the frequency of changes is very unlikely to be random (p-value= 0.000).

The active client management adopted by established European-based operators restricts turnover, relative to their new entrant counterparts. However, the former can expect to secure higher margins by avoiding exposure to informed behaviour. These relatively high margins will also be required to offset risks of holding inventory in the form of unbalanced liabilities across match outcomes.

We refer to traditional European operators as 'position-taking bookmakers' (PTBs), reflecting the inflexibility of their odds. The dynamic odds of the new entrant bookmakers, by contrast, whilst minimising the risk of holding outcome-dependant inventory, result in lower margins associated with the higher processing costs of frequently changing odds. We refer to these bookmakers as 'book-balancing bookmakers' (BBBs). The theoretical underpinnings of the distinctions between PTBs and BBBs are explained more fully in Section 2.2.

A further significant distinction between the groups, in product terms, relates to the prominent use of the Asian Handicap (AH) product by the BBBs. This effectively eliminates the need for the bookmaker to set odds against the 'draw' outcome by setting a point spread involving a fraction of a goal, or refunding bets in the case of a draw. Effectively, this simplifies inventory rebalancing

as the market consists of two, rather than three outcomes, compared with the threefold 'Home-Draw-Away' or 1X2 menu offered by PTBs.

Table 1 offers a summary comparison of differing characteristics of the distinct bookmaker groups.

Table 1: Summary of distinctions between established and new-entrant bookmaker groups in the European soccer betting market

Feature of bookmaker group	***Established Group***	***New Entrant Group***
Geographic origin/HQ	Europe	(generally) Asia
Trading medium	Betting offices + On-line	On-line
Principle of operation	Position-taking	Book-balancing
Trading volume	Relatively low	Relatively high
Margins	Relatively high	Relatively low
Match outcome portfolio	Win/Draw/Lose (1X2)	Asian Handicap
Frequency of odds changes	Low	High
Exposure to result-specific risk	Relatively high	Low
Client management	High, restrictive	Low, non-restrictive

The contrast in operating strategies across the two types of bookmaker operating in parallel offers a unique opportunity to analyse parallel dealer-driven markets. A clear focus for investigation is the potential for exploitation of profitable arbitrage opportunities associated with the heterogeneous pricing behaviour of the two types of bookmaker.

2. THEORETICAL BACKGROUND

This section offers some theoretical context for the issues explored in this paper. Two strands of theory are considered. The first relates to arbitrage as a mechanism of market adjustment where temporary but consistent opportunities for profitable trading occur. The second relates to different conceptual approaches to our understanding of bookmaker behaviour. Together they underpin the classification of bookmakers suggested in the previous section and provide

the basis for interpretation and understanding of the results generated by the empirical analysis.

2.1. Arbitrage and Efficiency in Financial and Betting Markets

Central to the Efficient Market Hypothesis (EMH) (Fama, 1970) is the idea that rational arbitrageurs drive temporary deviations in prices towards efficient benchmarks. Prices will therefore reflect fundamental values, providing that arbitrageurs are willing to trade sufficiently to impact market values (Friedman, 1953) and in the absence of limitations to arbitrage (see Gromb and Vayanos, 2010). There is evidence to suggest that theoretical arbitrage opportunities may be illusory in the face of institutional frictions (McLean and Pontiff, 2016).

Theoretical models of dealer market microstructure emphasise the role of institutional factors such as order processing (e.g. Roll, 1984), inventory (e.g. Stoll, 1978; Amihud and Mendelson, 1980) and pre-trade transparency on market efficiency (see, for example reviews of market microstructure by Madhavan, 2000 and Biais, Glosten and Spatt, 2005) as well as more general factors such as asymmetric information (e.g. Glosten and Milgrom, 1985; Easley and O'Hara, 1987).

Sauer (1998) indicates that a betting market is considered efficient if it is not possible to generate abnormal returns (strong test), or if differential returns are unavailable to the bettor simply by placing stakes at different odds, such as on favourites (weak test). In general, the main determinant of betting market efficiency is the degree to which market odds reflect the true probabilities of event outcomes over a large sample. This is analogous to the degree to which market prices reflect fundamental values in other financial markets. The possibility of 'zero' risk arbitrage has been explored in the soccer betting market, examining the extent to which differences in quoted odds across bookmakers are sufficient to guarantee profitable, fully hedged positions through the construction of a synthetic Dutch Book. Pope and Peel (1989) showed that arbitrage opportunities were *occasionally* available across U.K. bookmakers. However, later research suggested that the degree of coordination between bookmakers has increased (Dixon and Pope, 2004; Deschamps and Gergaud, 2007; Luckner and Weinhardt, 2008; Deschamps, 2008; Vlastakis, Dotsis and Markellos, 2009; Spann and Skiera, 2009; Franck, Verbeek and Nüesch,

2010). This may have arisen due to the emergence of professional arbitrageurs (Dixon and Pope, 2004).

Recently, Franck *et al.* (2013) analysed bookmakers' odds and parallel betting exchange odds for a sample of 12,782 European soccer matches over a seven-year period, 2004-05 to 2010-11. They found that cross-bookmaker arbitrage opportunities existed in 0.8% of matches in their sample, which included only PTBs. However, when considering bookmaker odds in parallel to the betting exchange *Betfair*, the proportion of matches offering arbitrage opportunities increased to 19.2%. These opportunities involved taking a long position at the bookmaker and 'laying' the same position at the betting exchange.[1] Profits from the arbitrage portfolios were almost exclusively against the bookmakers (7% in portfolios against the bookmaker, and close to zero in portfolios against the betting exchange).

Conclusions regarding the existence of arbitrage opportunities vary with the market under investigation. Arbitrage opportunities arise more frequently *between* market structures than *within* market structures (Edelman and O'Brian, 2004; Franck, Verbeek, and Nüesch, 2013). To date, studies analysing arbitrage in betting markets have considered only bookmakers operating as PTBs. Levitt (2004), for example, notes that PTBs set odds strategically in order to profit from the biases of uninformed bettors. This study seeks to uncover the extent to which this price setting mechanism affects market efficiency when BBBs, who do not seek to exploit trader biases, operate in parallel.

2.2. The Behaviour of Bookmakers

Levitt (2004) argues that betting markets are, in one important respect, organized differently from other financial markets. As the main providers of liquidity, bookmakers essentially take large positions against their customers (or against particular event outcomes favoured by customers) rather than necessarily matching sellers with buyers and simply earning the commission from the spread (overround). Franck *et al*. (2013) suggest that bookmakers also, effectively, choose the bettors against whom they take such positions. They achieve this by monitoring client trades and

[1] Long only arbitrage portfolios employing the betting exchange and bookmakers in the creation of a synthetic Dutch book were also considered in the study by Franck, Verbeek, and Nüesch (2013), but arose in only 5.0% of matches.

restricting service to those profiled as potentially skilled. In this context, bookmakers may occasionally publish inefficient match odds that are likely to attract customers in general, safe in the knowledge that they can eliminate (by restricting or preventing their bets) those who seek to place the majority of their bets at these inefficient prices. Any cost to the bookmaker from the setting of theoretically inefficient odds is therefore potentially lower than the gain from the increase in the size of the customer base. Newall (2015) notes that in the U.K., PTBs tended to advertise exotic bets (such as first goalscorer) to further attract uninformed clients.

An alternative view is that the objective of bookmakers is to balance their books, and as a result, secure profit independent of the event's outcome (Magee, 1990; Woodland and Woodland 1991, Hodges, Lin, and Liu, 2013). Such bookmakers will change their odds frequently in order to account for inventory imbalance. They act as uninformed market makers and essentially set up an over-the-counter market. Holding 'zero-book', these market-making bookmakers act as though they are infinitely risk-averse (Fingleton and Waldron, 1999) and could plausibly charge lower transaction commissions, due to the absence of adverse selection costs. Discriminating against skilled bettors is less of an issue with BBBs, since their model is based on the maximization of volume rather on successful positions (see Forrest, 2012 for more details of the BBBs model).

In soccer betting, despite the coexistence of PTBs and BBBs, the literature has focused almost exclusively on analysing odds offered by the former. This is surprising, as the economic significance of the latter is probably greater, at least in terms of volumes wagered (Forrest, 2012). Given the significant differences in the structure of the bookmakers' models, potential arbitrage between the two types of bookmakers may be regarded as inter-market opportunities.

Franck *et al*.'s (2013) proposition that bookmakers set odds to maximise long-term profit from an increased customer base, rather than to maximise profit per game, is novel in linking odds-setting with the bookmaker's option to withhold service from those clients it believes to be

informed.[2] This presents a distinction between betting and other financial markets, which should be acknowledged when the efficiency of bookmakers' odds is investigated.[3]

Whilst the current study represents a development of Franck *et al*.'s (2013) line of enquiry, it differs from the earlier approach in a number of respects that are important in terms of the robustness of the results generated. The first difference relates to the fact that arbitrage requires that different prices must be *simultaneously* available. The bookmakers' odds utilized by Franck *et al.* (2013) bear no time-stamp; rather, they are *assumed* to be constant and available for a given time interval, which is often not the case, certainly for BBBs and even on occasion for PTBs. Second, Franck *et al.*'s focus on the matched offers between a *betting exchange* and bookmakers were observed up to 2 days prior to kick-off, when the amount of money that can be staked in a betting exchange is very low, suggesting that even if arbitrage opportunities exist, they may not be economically meaningful. Third, Franck *et al.* (2013) only examined one particular exchange, *Betfair*, which levies a commission on winning customers (referred to as 'premium charges').[4] Fourth, even though the volume that one can stake in a betting exchange increases as kick-off approaches, it is shown below that there is significant variation in the size of the stakes that can be placed across games. This compromises the homogeneity of the sample, as several apparent arbitrage opportunities are economically insignificant, because only small wagers are possible. Consequently, it is important to test the proposition suggested by Franck *et al*. (2013), in the particular context of arbitrage between exchange and bookmaker markets, employing a dataset that avoids the above limitations, in order properly to test empirically the theoretical proposition. Certainly, the widening of the set, and the greater diversity, of bookmaker activity under consideration here might reasonably be expected to generate a significant increase in arbitrage opportunities. This observation applies equally when comparing our results with those of

[2] An example of the restriction notices from *Bet365* and *William Hill*, among others can be found at http://www.the-secret-system.com/bookmakers-shutdown-messages.html. PTBs refer to the use of restrictions as a 'commercial decision'.

[3] Proprietary dark pools (equity trading services that do not publicly display orders) offered by firms such as Getco and Knight Capital trade on principal accounts, and may exclude sophisticated, or informed counterparties. Because they are relatively opaque in their execution services, and do not guarantee execution (especially for informed investors), they present an interesting analogue to position-taking bookmakers. See Zhu (2014) for further details on proprietary dark pools.

[4] *Betfair* may withhold up to 60% out of winning bettors profits (see the website http://www.betfair.com/www/GBR/en/aboutUs/Betfair.Charges/)

Vlastakis *et al.* (2009) who investigated arbitrage opportunities among a population of five PTBs and one BBB. Their results revealed sixty three arbitrage opportunities across the aggregate group of six, which reduced to just ten within the group of five PTBs, though they caution that these results may underestimate actual arbitrage opportunities as their analysis considered only closing odds, which would deny identification of opportunities associated with earlier available price menus.

In addition, we argue that any investigation of the EMH using odds provided by PTBs may lead to biased conclusions. Specifically, as suggested by Franck *et al*. (2013), such market operators may intentionally set "inefficient" prices as a marketing strategy to attract customers. Such complications in the assessment of market efficiency should not exist when employing the odds of BBBs, since their prices should not be influenced by client identity. Consequently, odds in this market constitute more appropriate data for testing the EMH.

3. HYPOTHESIS DEVELOPMENT

The preceding discussion suggests that arbitrage opportunities between bookmakers from the same group (i.e. PTBs or BBBs) will be rare, but prices of PTBs and BBBs, operating in the same market, may be sufficiently disparate to incentivise arbitrage. However, because PTBs effectively prevent skilled traders from exploiting these opportunities, such arbitrage will be illusory. In exploring the validity of this proposition, we test the following five related hypotheses:

H1: There exist instances where price dispersion in the betting market is adequate to generate apparently risk-free opportunities for bettors to profit by simultaneously betting with different bookmakers on alternative outcomes related to the same event.

Levitt (2004) studied trading volume from a major PTB, showing that bettors tend disproportionately to prefer staking on favourites, rather than longshots, relative to their odds implied probabilities. Profit-maximizing bookmakers hence face net exposure to favourites. Relatedly, Forrest and Simmons (2008) and Franck *et al.* (2011) show that PTBs offer better prices for bets on popular teams, in order to sustain competition and to build/maintain their customer base. Consequently, we expect that in most cases where apparent arbitrage opportunities exist,

the PTB will post the best offer for the favourite and the BBB will post the best offer for the longshot, suggesting the following hypothesis:

H2: Apparent arbitrage opportunities most commonly arise between BBBs and PTBs, by PTBs offering the longer odds for favourites and BBBs offering the longer odds for longshots.

Based on Franck *et al*.'s (2013) finding that arbitrage profits between the betting exchange and PTBs were typically earned at the expense of bookmakers, we expect that in exploring trade across PTBs and BBBs, apparent arbitrage profits are also earned at the expense of the PTBs, not the BBBs (given PTBs' failure to adjust odds quickly enough to incorporate price-informative trends signalled by informed money traded with BBBs). We, therefore, test the following hypothesis:

H3a: When an apparent arbitrage opportunity arises, a greater proportion of the risk-free profit will be earned in trade with the PTB, rather than the BBB.

We also expect that the odds offered by BBBs (cf. PTBs) are better calibrated, i.e. we expect that BBBs' odds-implied probabilities are more reflective of match outcomes. If PTBs were solely interested in efficient estimation of event probabilities, they could simply adjust their odds to those of the BBBs. If we show that the PTBs do not adjust their odds in this way then this is supportive of Franck *et al*.'s (2013) proposition that promotional considerations form part of their odds-setting strategy. We, therefore, test the following hypothesis:

H3b: BBBs' odds constitute more accurate predictors (cf. those of PTBs) of event outcomes.

4. DATA AND METHODOLOGY

4.1. Bookmaker Classification and Data

We employ data from major bookmakers representing both BBBs and PTBs. We classify *Ladbrokes*, *William Hill*, *Bet365*, and *Stan James* as PTBs, and *IBCBet*, *Pinnacle*, *SBOBet* and *188Bet* as BBBs, based on extensive consultation with bettors and interpretation of the information presented below.

PTBs: *Ladbrokes* and *William Hill* operate retail businesses with thousands of betting shops, mainly in the U.K. They also operate online, and their combined aggregate gross revenue exceeds £1 Billion.[5] *Bet365* is a major UK-based betting company founded in 2001, which achieved turnover of £8.5 Billion and gross profit of £422 Million in 2011.[6] *Stan James* is a private company operating mainly online, while owning 65 betting shops in the U.K.[7] One of the defining characteristics of PTBs is their physical-world presence, which is important to each of these bookmakers. Annual reports for these bookmakers note that their profitability depends on match results.[8]

BBBs: *SBOBet*, *IBCbet*, *188Bet* are leading BBB operators, handling trading volumes far in excess of more traditional European bookmakers (Forrest, 2012). *Pinnacle* is a major online operator, trading billions of dollars, which describes itself explicitly on its website[9] as attempting to maximize trading volume while minimizing exposure, using information arising from informed traders as a tool to set efficient odds. In particular, *Pinnacle* emphasizes that it is friendly to arbitrageurs, as the expected value of a trade to the operator should not depend on the motives of the counterparty placing the stake. The model described by *Pinnacle* also fits the operations of the three bookmakers listed above and is aligned with the model of BBBs. Importantly, each of these operators lacks physical-world presence (betting shops) and has an empirically demonstrable tendency to change odds frequently.

In order to ensure that potential arbitrage trades could have realistically been executed, we designed a data collection program to obtain odds information systematically from bookmakers' websites. This involved surveying different bookmakers' websites *simultaneously*, so differential odds from our panel of bookmakers reflect genuine, real-time price dispersion, rather than information-driven outcomes. The program included a time-out coefficient to ensure a maximum discrepancy in odds collection of 30 seconds. In other words, where odds were/were not

[5] See William Hill (2013) "Preliminary Results 2012" and Ladbrokes (2013) "Preliminary Results for the Year Ended December 2012."

[6] Source: http://www.publications.parliament.uk/pa/cm201213/cmselect/cmcumeds/writev/ 1554/ga104.htm.

[7] Source: http://howtobet.net/sportsbook-review/stan-james.

[8] For example, *Ladbrokes*' 2013 annual report (p.23) notes "Ladbrokes may experience significant losses as a result of a failure to determine accurately the odds in relation to any particular event."

[9] See, inter alia, http://www.pinnaclesports.com/about-us.aspx, http://www.pinnaclesports. com/betting-promotions/arbitrage-friendly, and http://www.pinnaclesports.com/ betting-promotions/winners-welcome.

forthcoming from the bookmaker within 30 seconds, it was assumed that these odds were/were not available as a basis for arbitrage.[10] All odds were collected in a period within 2 hours of kick-off, when the staking levels reach their peak. We focused on the major European soccer leagues in order to ensure that the findings of the study carry economic significance, as the volumes traded in leagues of lower status are significantly smaller. We collected data, for the whole of the 2012-13 season for the 6 major leagues; the English Premier League, the German Bundesliga, the Italian Serie A, the Spanish La Liga, the French Ligue 1, and the Dutch Eredivisie. Overall, this resulted in a sample of 2,132 games, which we refer to as the `main sample'.

For each match, odds were collected for several bookmaker products: the AH, and home win, draw, and away win (also known as 1X2) markets. In AH betting, one of the teams (usually the favourite) is given a goal-deficit (handicap) to overcome, the size of which is indicated by a negative number. A bet is successful if the handicapped team wins the match by a greater margin than the handicap. A bet on the opposing team is successful providing it does not lose by a margin greater than the handicap. Fractional AHs include the draw outcome. For example, a team with a handicap of −0.5, starts with a half goal deficit, meaning that the team must win outright (that is, not draw) for the bet to pay off[11]. A team which is handicapped +0.5 starts with a half goal advantage, so a bet on that team wins even if the outcome is a draw. A bet on a team with a 0 handicap is refunded in the event of the draw, whereas a bet on team with a -0.25 (+0.25)

[10] The cost of this was that several bookmakers occasionally failed to respond within the maximum allowed period. In these cases, we repeated the full request (i.e. for all bookmakers) three times in order to obtain a complete sample. In some cases, due to heavy load on bookmakers' websites, some would remain unresponsive. In those cases, the odds of those who failed to respond were not considered, which may lead to a slight underestimation of the frequency of arbitrage opportunities overall. The timeout could be increased in future studies, however, this would risk the integrity of the results overall, as a higher time interval would increase the chance of odds of the quickest responding bookmaker changing until the response of the slowest bookmaker came back. The collection of data from bookmakers remains a difficult practice at best.

[11] To illustrate, assume that the following Asian Handicap odds are offered on a match between Chelsea and Arsenal::

Chelsea (-0.5 goals) 1.83

Arsenal 1.80

This means that a successful bet requires Chelsea to overcome the (-0.5 goals) handicap, i.e. they must win by any single goal (or above) margin. Any draw would (with the handicap) mean a win for Arsenal (e.g. a 1-1 draw would, in effect, become Chelsea 0.5 - Arsenal 1. This format reduces the match outcome to two alternatives.

handicap is considered as a half-bet on 0 handicap and a half-bet on -0.5 (+0.5).[12] The AHs that are of interest here are those in the interval of -0.5 to +0.5, because none of the bets in this range is dependent on the number of goals scored. Hence, an arbitrage portfolio can potentially be formed by betting in the home win, draw, and away win (1X2) markets.

Our supplementary set of data (we refer to this as the 'extended set') contains historical odds from six bookmakers (*Ladbrokes*, *William Hill*, *Bet365*, *SBOBet*, *188Bet*, and *Pinnacle*) for each of the six leagues in our sample; a total of 6,396 matches over the three seasons from 2010-11 to 2012-13. These data were obtained in a similar fashion to our main data, and were used to explore the relative incidence of favourite-longshot bias and the degree of calibration between the odds-implied probabilities of match outcomes and actual match outcomes. We obtained home win, draw, and away win odds for each match, at a time point within two hours of match kick-off. We could not use this entire sample (excluding 2012-13 data) to test the economic efficiency of arbitrage portfolios, as odds were not collected to ensure simultaneous execution of trades. However, the longer data period allows greater power in statistical tests of efficiency.

4.2. Methodology

4.2.1. Estimating the Frequency of Arbitrage Opportunities

In order to test H1, we formulate a linear optimization problem. This is specifically designed to provide a comprehensive identification of the existence of arbitrage opportunities between bookmaker types. Particular and advantageous features of this method are that we survey arbitrage opportunities throughout the duration of each market, we can assure, reliably, the temporal co-existence of cross-operator odds differentials which define the opportunities, and we are able to identify the optimal distribution of stakes across different products in order to maximize the return. Arbitrage opportunities are deemed to exist where such a return is positive and invariant across all match outcomes. If there is insufficient dispersion in the odds

[12] We present a detailed example of the returns to each bet in the next section.

across the market to generate an arbitrage opportunity, there will be no feasible solution. Assuming sufficient dispersion, there will be a range of solutions that offer certain positive returns and the linear program will suggest the combination that offers the highest profit.

We outline below how this problem is formulated and examined for a single game. This process is repeated for all 2,132 games in the main sample.

Let $X_{j,k}$ denote the vector of gross odds offered by bookmaker k, where for each game there are $1 \leq j \leq 13$ products offered by the bookmaker (i.e. 'home win', 'home win with a -0.5 handicap,' 'away win with a $+0.5$ handicap,' etc.). The gross return to each of the 13 bookmakers' products is presented in Table 2, with products 1, 7, and 8 indicating odds from the 1X2 market, and the rest (with suffix AH) obtained from the AH market. The odds shown in the Table 2 can be multiplied by stake size *S* (a scalar) to determine non-unit payouts.

We define the vector X_{max} element-wise as $X_{j,max} = \max_k X_{j,k}$. In cases where bookmakers are tied for the highest odds, we retain all possible combinations of maximum prices. For example, if both *Ladbrokes* and *William Hill* were offering gross odds of 1.50 on a home win ($j = 1$) for a particular match, and this price was higher than all the other bookmakers' prices for $j = 1$, we would retain two X_{max} vectors, in order to avoid losing information for *H*1 and *H*2.

Table 2: Gross return to a \$1 stake for a single bookmaker on each potential match outcome for different types of bet, with odds vector $(X_1, \ldots, X_{13})'$ indicating the gross payoff for each corresponding market. The suffix AH indicates that the product is from the Asian Handicap market.

Outcome (j)	Bookmaker Product	Return if Home Win	Return if Draw	Return if Away Win
1	Home	X_1	0	0
2	Home (-0.5) AH	X_2	0	0
3	Home (-0.25) AH	X_3	0.5	0
4	Home (0) AH	X_4	1	0
5	Home $(+0.25)$ AH	X_5	$1 + 0.5(X_5 - 1)$	0
6	Home $(+0.5)$ AH	X_6	X_6	0
7	Draw	0	X_7	0
8	Away	0	0	X_8
9	Away (-0.5) AH	0	0	X_9
10	Away (-0.25) AH	0	0.5	X_{10}
11	Away (0) AH	0	1	X_{11}
12	Away $(+0.25)$ AH	0	$1 + 0.5(X_{12} - 1)$	X_{12}
13	Away $(+0.5)$ AH	0	X_{13}	X_{13}

Second, we aim to find the set of bets that a bettor would place to best exploit potential arbitrage opportunities. Let S_j be the bettor's allocated stake for each bet type j. The profit function $Z = \{Z_{homewin}, Z_{draw}, Z_{awaywin}\}$ for each possible match outcome can be defined from the following set of equations:

$$Z_{homewin} = \sum_{j=1}^{6} S_j X_{j,max} - \sum_{j=1}^{13} S_j \tag{1}$$

$$Z_{draw} = S_7 X_{7,max} + 0.5(S_3 + S_{10}) + (S_4 + S_{11}) + 0.5\left(S_5 + S_{12} + S_5 X_{5,max} + S_{12} X_{12,max}\right) - \sum_{j=1}^{13} S_j \tag{2}$$

$$Z_{awaywin} = \sum_{j=8}^{13} S_j X_{j,max} - \sum_{j=1}^{13} S_j \tag{3}$$

Identifying the best possible arbitrage opportunity requires identifying the distribution of stakes S that maximizes the payoff for any of the three match outcomes, subject to a set of constraints. Hence, the optimization identifies the distribution of stakes S that maximizes the payoff for any of the three match outcomes. The optimization routine can be written as

Find optimal strategy S^* by varying S such that $Z_{homewin}$ is maximized (4)

Subject to constraints

$$Z_{homewin} = Z_{draw} \quad (5)$$

$$Z_{homewin} = Z_{awaywin} \quad (6)$$

$$Z_{homewin} > 0 \quad (7)$$

$$\sum_{j=1}^{13} S_j = 1 \quad (8)$$

$$S_j \geq 0 \quad \forall j \quad (9)$$

Due to the linear nature of the problem, the simplex algorithm can be used to maximize the objective function (Dantzig, 1951). Constraints (5) and (6) ensure that the selected combination of stakes leads to the same return independently of the outcome. Constraint (7) implies that for the solution to be acceptable, the net return should be positive. Constraint (8) requires that the sum of stakes should equal 1, so that each S_j will represent the fraction of the available capital that should be staked on each bet type. Finally, constraint (9) requires that all stakes are positive.

The optimization will fail to find a feasible solution in the event that arbitrage is not possible for the given set of bet types on a given game. If there is more than one feasible solution per game, we would select the bet with the highest return per outcome. In order to test H1 we run this maximization for each match in the sample.

4.2.2. Identifying Favourites and Longshots by Bookmaker in the Arbitrage Portfolio

We now explore the methodology employed to test H2, that is, whether arbitrage opportunities are more likely to occur *between* PTBs and BBBs (rather than between PTBs, or between BBBs) and whether the arbitrage portfolio is more likely to involve bets on the favourite against the PTB.

Matches where an arbitrage opportunity was identified were isolated. We then compared the frequency of instances in which the PTB offers the highest odds for the 'favourite'. We then define indicator variables D_f and D_l for each match i as $D_{fi} = 1$ if the PTB offers the highest odds for the favourite on match i, and 0 otherwise, and $D_{li} = 1$ if the PTB offers the highest odds on the longshot for match i, and 0 otherwise. Over the sample of n games in which an arbitrage opportunity arises, we calculate the proportion of cases where the best offer for the favourite was provided by PTB.

For H2 to be accepted, this proportion should be significantly higher than $1/2$.

4.2.3. The Source of Returns by Bookmaker in the Arbitrage Portfolios

Testing H3a involves exploring whether the bet responsible for the positive returns to the arbitrage portfolio will be placed with the PTB on the favourite, with the longshot being bet with negative or zero expectation at the BBB. We conduct a betting simulation, where a unit stake ($1) is placed on each bet that is selected from the linear program across the total sample of matches. For each type of bookmaker, we calculate for each match i and potential stake at offer j the bettor's profit Z_{ij}, as

$$\begin{aligned} Z_{ij} = \sum_{j=1}^{6} S_{ij}X_{ij} + S_{i7}X_{i7} + 0.5(S_{i3} + S_{i10}) + (S_{i4} + S_{i11}) \\ + 0.5(S_{i5} + S_{i12} + S_{i5}X_{i5} + S_{i12}X_{i12}) \\ + (S_{i6} + S_{i13}X_{i13}) + \sum_{j=8}^{13} S_{ij}X_{ij} - \sum_{j=1}^{13} S_j \end{aligned} \tag{10}$$

where S_{ij} is the amount staked on product j in match i. In the unit-stake simulation, $S_{ij} = 1$ if there is a bet on product j in match i, and zero otherwise. As a result, the average profit that the

bettor achieves against each type of bookmaker, across the sample of n bets can be calculated as:

$$\mu = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{13} Z_{ij} \tag{11}$$

H3a will not be rejected if μ is higher for the group of PTBs than for the group of BBBs. It could be argued that a consequence of placing a unit stake across each bet is high variance, since average profit is highly influenced by the outcome of bets on longshots. We ensure that these latter bets do not lead to biased conclusions regarding the expected profit against each bookmaker by replicating the simulation, where each stake S_{ij} is determined by a staking strategy, the Kelly Criterion (Kelly, 1956), which involves assigning stakes which are inversely proportional to odds, thereby assuring that for each type of bookmaker, all bets generate equal expected profit.

$$S_{ij} = \frac{1}{X_{ij} - 1} \tag{12}$$

As a result, the average realized profit against each bookmaker across the sample of n bets is

$$\mu = \frac{\sum_{i=1}^{n}\sum_{j=1}^{13} Z_{ij}S_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{13} S_{ij}} \tag{13}$$

We recalculate the means for each of the two types of bookmaker and compare them, in order to confirm that the conclusions drawn from the unit-stake simulations are not biased by abnormally positive or negative results on high-odds bets.

4.2.4. The Predictive Power of BBB vs PTB Odds-Implied Probabilities

In order to test whether predictions based on BBBs' odds are more efficient (H3b) and unbiased (H3c) predictors of event outcomes than predictions based on PTBs' odds, we compare the forecasting accuracy and the favourite longshot bias (FLB) observed in predictions based on the odds of the two different types of bookmakers. For each group, we employ a conditional logistic regression (with the probability of outcome *o* derived from the odds as the sole independent variable), where the outcome of each match is the dependent variable (i.e. home win, draw, or

away win). The outcome takes value 1 for the event that occurred and 0 for the events that did not occur. Hence, the probability that outcome o in match i occurs, is given by:

$$P(Y_{io} = 1) = \frac{e^{Z_{io}}}{\sum_{o=1}^{3} e^{Z_{io}}} \tag{14}$$

where Z_{io} is a function of the probability p_{io}^{s} (as p_{io}^{s} is the probability of the event outcome implied by the odds for each outcome o of match i, where the superscript s implies the subjective probability based on the bookmaker's and bettor's combined assessment of the chance of this outcome), such that

$$Z_{io} = b \times \ln(p_{io}^{s}) \tag{15}$$

where *b* is a coefficient derived from a conditional logit regression estimated on the basis of past results, and p_{io}^{s} can be calculated from the odds X_{io} of outcome o in match i as

$$p_{io}^{s} = \frac{1}{X_{io}(1 + \rho_i)} \tag{16}$$

and ρ_i is the bookmaker's over-round. This can be calculated from the odds offered for all outcomes o of match i as

$$\rho_i = \sum_{i=1}^{3} \frac{1}{X_{io}} - 1 \tag{17}$$

Hence, (14) can be written as

$$P(Y_{io} = 1) = \frac{e^{b \times \ln(p_{io}^{s})}}{\sum_{o=1}^{3} e^{b \times \ln(p_{io}^{s})}} = \frac{(p_{io}^{s})^{b}}{\sum_{o=1}^{3} (p_{io}^{s})^{b}} \tag{18}$$

Positive FLB indicates that the bookmaker odds underestimate the probability of the most likely event occurring. Therefore, if a bookmaker exhibits this bias, the actual winning probability of favourites, as implied by their observed frequency of success, will be higher than that expected by the odds; whereas for the longshots it will be lower. Thus, denoting as p_{io}^{v} the 'true' or objective probability (the 'v' denoting 'verifiable' or objective probability) of outcome o in match i, we can infer the following.

$$p_{if}^{s} > p_{il}^{s} \Rightarrow \frac{p_{if}^{v}}{p_{if}^{s}} > \frac{p_{il}^{v}}{p_{il}^{s}} \tag{19}$$

where f denotes favourite and l denotes longshot.

Subject to (18),

$$\frac{p_{if}^{v}}{p_{if}^{s}} > \frac{p_{il}^{v}}{p_{il}^{s}} \Rightarrow \frac{\left(p_{if}^{s}\right)^{b}}{\sum_{o=1}^{3}\left(p_{if}^{s}\right)^{b}} > \frac{(p_{il}^{s})^{b}}{\sum_{o=1}^{3}(p_{il}^{s})^{b}} \Rightarrow \left(p_{if}^{s}\right)^{b-1} > (p_{il}^{s})^{b-1} \quad (20)$$

where if $p_{if}^{s} > p_{il}^{s}$, (14) is only valid where $b > 1$. Consequently, the odds of a given bookmaker underestimate favourites on average, only if b in (20) is significantly greater than 1 and higher values of *b* indicate higher degree of bias. Maximum likelihood is employed to estimate b for each bookmaker. To assess the accuracy of each bookmaker's predictions, we compared the values of McFadden's (1974) pseudo-R^2 statistic that each bookmaker's odds implied probabilities achieve in the conditional logit model (a higher pseudo-R^2 implies a superior model fit and hence a greater degree of efficiency).

5. RESULTS

5.1. Arbitrage Opportunities across Bookmakers

Table 3 reports the average closing odds correlation in our main sample that demonstrates that, on average, bookmakers' offers are reasonably well-aligned. The highest level of correlation is observed amongst BBBs. Whilst these bookmakers move their odds more frequently (adjusting for individual high stakes), such adjustments seem to happen in parallel across the set of BBBs. Among PTBs, *Bet365* seems to be the bookmaker most aligned with the BBBs (possibly because it is the only bookmaker in the group for which online betting is its main focus), whereas *Ladbrokes* and especially *Stan James* show the least correlation with the BBBs.

The optimization process presented in (4) to (9) reveals the existence of 545 arbitrage opportunities across the 2,132 (that is, in 25.6% of) matches in our sample. Notably, this figure is significantly higher than the results of earlier studies (Franck *et al.* (2013), Vlastakis *et al.* (2009)) a fact which may be explained by a combination of the methodology employed to identify opportunities in this paper and the range of bookmakers under scrutiny. The method employed

here, as described above, offers a comprehensive and reliable identification of opportunities by embodying time precision regarding the co-availability of odds and by ensuring identification of opportunities throughout the duration of the market, rather than, as with both Franck *et al.* (2013) and Vlastakis *et al.* (2009), considering opportunities only at a single point in time. In terms of the range of bookmakers identified, this study examines opportunities across six operators, three BBBs and three PTBs. This gives a degree of diversity which is not matched by earlier studies, with Franck *et al.* (2013) focusing on activity across a group of PTBs and a single betting exchange, and Vlastakis *et al.* (2009) considering a different group of PTBs and a single BBB. In this context, for reasons of both methodology and the nature of samples under scrutiny, the differences are arguably unsurprising.

The distribution of arbitrage opportunities across the different leagues is shown in Table 3 and the frequency with which each bookmaker's odds feature in the optimized portfolio are shown in Table 4. The arbitrage opportunities are well dispersed across the leagues, although the relatively low frequency in Holland returns a $\chi^2(5)$ test of independence with a *p*-value of 0.048. This is probably because Holland is the least popular of the six major leagues, and there is less competition among bookmakers to supply competitive odds (and less benefit from promoting inefficient odds). Consequently, transaction costs are higher, reducing the potential for arbitrage opportunities.

Table 3: Average closing odds correlation between bookmakers in main sample. Panel A reports the correlation matrix of closing odds across all bookmakers, Panel B reports the average correlation between and within groups of book-balancing and position-taking bookmakers.

Panel A: Correlation in Odds Between Bookmakers

		Position Takers				Book Balancers		
	Bookmaker	Ladbrokes	William Hill	Bet 365	Stan James	SBOBet	188Bet	Pinnacle
Position Takers	Ladbrokes	1.0000						
	William Hill	0.9927	1.0000					
	Bet 365	0.9907	0.9950	1.0000				
	Stan James	0.9928	0.9917	0.9891	1.0000			
Book Balancers	SBOBet	0.9884	0.9925	0.9947	0.9849	1.0000		
	188Bet	0.9890	0.9942	0.9970	0.9867	0.9971	1.0000	
	Pinnacle	0.9890	0.9944	0.9971	0.9868	0.9971	0.9987	1.0000

Panel B: Average Correlation Within and Across Groups

Group 1	Group 2	Average
Position Takers	Book Balancers	0.9913
Position Takers	Position Takers	0.9920
Book Balancers	Book Balancers	0.9976

Table 4: Number of Matches with Arbitrage Opportunities by League.

League	Number of Matches with Arbitrage Opportunity	Proportion of Arbitrage Opportunities Across all Leagues	Proportion of Arbitrage Opportunities per Match	Matches in Sample
England	90	16.51%[1]	23.68%[2]	380
Spain	109	20.00%	28.68%	380
Italy	101	18.53%	26.58%	380
Germany	94	17.25%	30.72%	306
France	94	17.25%	24.74%	380
Holland	57	10.46%	18.63%	306
TOTAL	**545**	**100.00%**	**25.56%**	**2,132**

[1] 90/545 [2] 90/380

The linear program (4) to (9) can result in the odds of a diverse number of bookmakers featuring in each potential arbitrage opportunity (ranging from 2 to 6 in our sample), in order to achieve the maximum risk-free profit. In cases where multiple bookmakers post equal maximum odds for the same market, we attribute each of the bookmakers as having supplied the arbitrage opportunity. It is clear from Table 5 that some bookmakers are more likely to be involved in the generation of a theoretically risk-free portfolio.[13] The frequency of the appearance of PTBs is likely to be related to each operator's policy on promotional odds. A test of independence rejects that bookmakers appear with equal frequency in arbitrage portfolios ($\chi^2(6)$ = 615.4, *p*-value = 0.000).

[13] Removing *Stan James* from the sample causes the instances of potential arbitrage opportunities to drop to 287, which is indicative of the influence of a bookmaker which applies a policy of offering outlying odds, on the creation of arbitrage instances.

Table 5: Number of times a bookmaker's odds feature in a potential arbitrage portfolio selected by the optimization programme for the main sample. For each bookmaker we report the relative frequency with which their odds appeared in the X_{max} vector, and featured in the optimal potential arbitrage portfolio identified for a single game.

Group	Bookmaker	Times odds featured in arbitrage portfolio	Relative Frequency
Position- Takers	Ladbrokes	237	13.27%
	William Hill	59	3.30%
	Bet 365	65	3.64%
	Stan James	452	25.31%
Book-Balancers	SBOBet	248	13.89%
	188Bet	262	14.67%
	Pinnacle	463	25.92%
	TOTAL	**1786**	**100%**

Consistent with the behaviour suggested by the inter-bookmaker correlation statistics, *Bet365* and *William Hill* appear more aligned in their pricing strategy with the BBBs, and hence their odds appear less frequently in arbitrage portfolios. All BBBs appear as part of an arbitrage portfolio, with *Stan James* or *Ladbrokes* often being on the opposite side. Amongst the BBBs, *Pinnacle* is selected most frequently by the optimization program to be part of an arbitrage portfolio. This is probably because this is the only BBB which exhibits the same low over-round on 1X2 markets as on the AH products.[14] As a result, *Pinnacle* often offers the highest odds on a draw, which is frequently a useful bet in terms of equalizing payoffs across all outcomes.[15]

If a bettor could have maintained access to all 7 bookmakers, without suffering restrictions to her stake, the fully hedged strategy would have returned an impressive 7.56 times the initial bankroll

[14] BBBs maintain an over-round of about 2% in AH markets, but their over-round is nearer 5% − 6% for the 1 × 2 market. On the other hand, *Pinnacle's* over-round is about 2% in the 1 × 2 market.

[15] Mainly when a positive handicap (i.e. either +0.25 or +0.5) is not selected, the optimization indicates a stake should be placed on the draw so that there is no negative exposure on the draw outcome.

across the season (assuming no reinvestment). This corresponds to an average risk-free profit of 1.38% per match. Taken together, the results show that sufficient price dispersion exists in the market for bettors to create a seemingly risk-free portfolio of bets that would guarantee profits in 25% of games, assuming they could successfully implement this strategy. These results serve to support Hypothesis 1, namely, there exist instances where the price dispersion is adequate to generate theoretically risk-free opportunities for bettors to profit by simultaneously betting with different bookmakers on alternative outcomes related to the same event.

5.2. Arbitrage Opportunities by Type of Bookmaker

We determine for each apparent arbitrage opportunity the source of odds that make up the arbitrage portfolio of bets (i.e. from BBBs or PTBs). In particular, we look at the instances where the odds offered by BBBs or PTBs on the favourite or the longshot feature in the arbitrage opportunities. These results are displayed in Table 6. In 84% of arbitrage opportunities, one or more PTBs offered the highest odds on the favourite while one or more BBBs offered the highest odds on the longshot. Based on this frequency of arbitrage opportunities being created by bookmakers of different types (BBBs and PTBs), the chance that this phenomenon is random is very low (Z-statistic = 16.12, p-value=0.000). This finding supports Hypothesis 2, namely, that most apparent arbitrage opportunities involve bets placed with different types of bookmakers.

Table 6**: Constituent bets in arbitrage portfolios by type of bookmaker and odds**. The first (second) column shows the type of bookmaker for which the optimal arbitrage portfolios contain bets on favourites (longshots). The favourite is identified as the team with the lower odds on the 1*X*2 betting market, bets on products 1-6 in Table 2 are considered 'favourite' bets if the home team has lower odds; bets on products 8-13 in Table 2 are considered 'favourite' bets if the away team has lower odds. All other bets (excluding draw bets) are considered 'longshot' bets. The number and proportion for which arbitrage portfolios are constructed, using bets from each type of bookmaker, are presented in column 3. Columns 4 and 5 report similar results to column 3, with the strength of the favourite increasing to \$2.00 and \$1.70 per dollar bet. Column 6 repeats the results from column 3 with the exclusion of the outlying position-taking bookmaker *Stan James*.

Favourite	**Longshot**	**Num. matches**	**Num. matches**	**Num. matches**	**Num. matches**
		(full sample)	**(Fav < 2.00)**	**(Fav < 1.70)**	**(w/o Stan James)**
Best Offer by:	**Best Offer by:**	***prop***	***Prop*[1]**	***Prop*[2]**	***Prop***
Position	**Position**	41	27	6	18
Taker	**Taker**	*0.075*	*0.071*	*0.073*	*0.061*
Position	**Book**	277	183	57	152
Taker	**Balancer**	*0.508*	*0.480*	*0.695*	*0.514*
Book	**Position**	181	142	14	78
Balancer	**Taker**	*0.332*	*0.373*	*0.171*	*0.264*
Book	**Book**	46	29	5	48
Balancer	**Balancer**	*0.084*	*0.076*	*0.061*	*0.162*
Total		**545**	**381**	**82**	**296**
		1.000	*1.000*	*1.000*	*1.000*

[1, 2] In order to illustrate how the arbitrage opportunities vary as the strength of the favourite increases, we select categories where there are sufficient matches to give meaningful proportions of arbitrage opportunities and where the favourites' odds are low. To match these criteria we select favourites' odds of < 2 and < 1.7 and show, in columns 4 and 5, respectively, the proportions of arbitrage opportunities which arise with favourites with odds less than 2 and less than 1.7

The results displayed in Table 6 also show that PTBs are significantly more likely to offer an improvement over market odds for the favourite rather than for the longshot. On 58% of occasions, a PTB offered the best odds for the favourite, compared with 44.4% offering the best odds on the longshot. Such a difference is unlikely to be random (Z-statistic = 5.86, p-value = 0.000). This tendency is more pronounced on stronger favourites. Since PTBs attract higher volumes on favourites than on longshots (Levitt, 2004), our finding is consistent with the view that PTBs16 are inclined to inflate odds for popular bets in order to attract customers. As a result, arbitrage opportunities most commonly emerge where a PTB offers the best odds for the

[16] Such studies do not distinguish between diverse types of operators, but they assume a type of bookmaker consistent with our PTB definition.

favourite and a BBB offers the best odds for the longshot.[17] These results are in line with Hypothesis 2.

5.3. The Efficiency of Bookmakers Odds by Type

In exploring the broader context for the relative values of odds on favourites and longshots between groups, Table 7 presents the results of estimating separate conditional logistic regression models (as described in (14) and (18)) based on the 1X2 odds offered on soccer matches across the six leading European leagues by PTBs and BBBs, respectively, for our extended sample of 6,396 matches over the three seasons from 2010-11 to 2012-13. The forecasting accuracy of odds offered by BBBs is higher on average compared to that of PTBs' odds, as represented by the higher average McFadden's pseudo-R^2. Whilst the increase in pseudo-R^2 appears small, it is likely to be economically significant (e.g. Benter, 1994). This result is in line with Hypothesis 3b and is consistent with the evidence provided by Franck *et al*. (2013) and Smith *et al*. (2006, 2009) that demand-driven (as opposed to traditional PTB) markets are more efficient predictors of event outcomes.

The values of the coefficients in the conditional logistic regressions, and the related significance tests, indicate in general that the FLB is more pronounced for PTBs than for BBBs. The notable exception is for the odds offered by the BBB, *SBOBet*, whose over-round for the 1X2 market is the highest amongst BBBs. The conditional logistic regression based on *Pinnacle's* odds (whose over-round in the 1X2 market is as low as it is for AHs) has a coefficient very close to 1, suggesting no FLB. This variation of the bias is in line with the Vaughan Williams's (1999) proposition that the level of transaction costs affects the degree of FLB. The extent of the bias is likely to indicate that BBBs (excluding *Pinnacle*) aim to direct the demand for longshots to AH markets, in order to facilitate the balancing of their books in that market.

[17] In general, PTBs, do not offer higher odds for favourites on average than BBBs due to their higher over-round. However, their odds on favourites are closer to those offered by BBBs than the odds they offer on longshots. This finding suggests that they probably do not distribute their over-round proportionally.

Table 7: This table reports the results of conditional logit modelling (using equations (14) and (18)) based on the odds offered by six bookmakers in the extended sample for all match outcomes (Home win, Draw, Away win; 19,188 total observations of odds per bookmaker). Bookmakers are classified as either position-takers or book-balancers. The third and fourth columns of the table report the estimated coefficient of the conditional logit model and its standard error, respectively. The fifth column reports the *p*-value of a *Z*-test to determine whether the true value of the coefficient in column three is equal to 1. The sixth column reports the result of test whether the coefficient is significantly greater than 1 at the 10%, 5%, and 1% levels with the signs (*), (**), and (***), respectively. The final column reports the McFadden Pseudo-R^2 of the conditional logit model.

Group	Bookmaker	Coefficient	Std. Error	Prob. (Coeff. = 1)	Sig.	Pseudo-R^2
Position Takers	*Ladbrokes*	1.0743	0.0309	0.0081	(***)	0.1085
	William Hill	1.0605	0.0304	0.0232	(**)	0.1101
	Bet365	1.0560	0.0302	0.0318	(**)	0.1106
Book Balancers	*SBOBet*	1.0784	0.0311	0.0059	(***)	0.1106
	188Bet	1.0413	0.0299	0.0831	(*)	0.1113
	Pinnacle	1.0081	0.0289	0.3900		0.1114

5.4. "Winners" and "Losers" in Arbitrage Opportunities

In order to identify which group of bookmakers would tend to lose against potential arbitrageurs, should the identified risk-free opportunities be exploitable, we employ the simulation described in (10). Placing $1 on all 813 outcomes for which the odds posted by PTBs form part of the fully-hedged portfolio, yields an average profit of $0.16 per bet. Adopting the same strategy, of backing all outcomes where the BBBs' odds feature in the optimal fully hedged portfolio, results in a loss

of \$0.024 per bet.[18,19] The profit obtained on the bets placed at the PTBs odds in these cases is significantly higher than the profit (i.e. in fact a loss) obtained on the bets placed at the BBBs odds (*t*-statistic = 3.37, *p*-value = 0.000).

Adjusting the strategy, as described by (13), leads to an average profit per bet of \$0.04 per \$1 stake against PTBs and an average loss of −\$0.047 per \$1 stake against BBBs. These returns remain significantly different (*t*-statistic = 2.60, *p*-value = 0.005). This result supports Hypothesis 3a, namely, that PTBs would suffer losses on average when an apparent arbitrage opportunity exists.

Interestingly, the loss incurred against the BBBs on these bets is close to their over-round.[20] Put another way, that component of the arbitrage portfolio placed through BBBs generates returns for a bettor equal to their expected loss had they placed a random bet with these bookmakers. In other words, the fact that another bookmaker offers sufficiently different odds to generate an apparent arbitrage opportunity does not change the expected value they receive from their bets. Hence, this result effectively justifies *Pinnacle's* statement that the motive for a bet (e.g. intention to arbitrage) should be irrelevant to a BBB.[21] From the bettor's perspective, a higher return is expected by placing bets against outlying odds of PTBs, rather than by hedging such positions against BBBs, since in the latter case, the average profit drops to \$0.013 per \$1 bet. Consequently, there is evidence from these simulations to support Hypothesis 3a, the expected loss from an

[18] In this case, \$1 is bet on each offer that falls part of the portfolio, no matter what the fraction of capital allocated from the optimization (4). Therefore, the results of this simulation are not comparable to the results of the fully hedged strategy. By way of example, the fully hedged strategy may assign 90% of the capital to bet *A* and 10% to bet *B* and hence, we would bet \$0.90 and \$0.10 on these products, respectively. However, in the unit-stake simulation \$1 is staked on bet *A* and \$1 on bet *B*, since the objective is to identify how the profit is distributed across the two types of bookmakers, rather than to create a hedged position.

[19] 55 out of 813 \$1 bets that were placed at gross odds greater than \$5 had an extremely high profit of \$1.30. As a result, this small number of lucky bets account for \$71.60 out of the \$130 won in total by this strategy. Hence, it is important to ensure that they do not bias the conclusions. This is achieved by applying the weighting implied by equation (13).

[20] The over-round of such bookmakers is about 2% for AH products and 5% − 6% for 1X2 products, excluding *Pinnacle*, which employs an over-round of around 2% in the 1X2 market.

[21] *Pinnacle's* statement is: "[A]ll bookmakers shouldn't care about the motivation for placing a bet, but should simply look to balance the bet volume." Source: http://www.pinnaclesports.com/ betting-promotions/arbitrage-friendly.

apparent arbitrage opportunity is likely to be suffered by the PTBs. This is consistent with Franck *et al*.'s (2013) findings.

6. DISCUSSION AND CONCLUSION

This paper explores the impact of the entry of book-balancing bookmakers (BBBs) on the efficiency of the market for European soccer betting, which was previously dominated by position taking bookmakers (PTBs). We identified arbitrage opportunities across bookmakers from a unique data set of 1X2 and AH odds for soccer games played in major European leagues. Match odds were collected close to kick-off, when markets are most liquid. Employing a linear programming methodology, we identified the best combination for each of 545 games where a fully hedged profitable investment appeared to be possible.

Such a strategy could, in theory, guarantee a profit of 1.3% per game on average. To a degree, our findings confirm those of Franck *et al*. (2013); arbitrage opportunities mainly exist across, rather than within, market structures. However, importantly, our data assembly assures that the disparate odds required to form an arbitrage portfolio were concurrently available, and were sufficiently liquid to be exploited. Whilst previous studies have treated bookmakers as a homogeneous set, our study makes the explicit distinction between incumbent PTBs and new entrant BBBs as a basis for investigating distinctions in odds menus and opportunities for profitable arbitrage. The results suggest that the two groups of bookmakers are indeed distinct in terms of odds setting and that the consequent arbitrage opportunities are principally accounted for by PTBs' inefficient pricing.

This pricing policy may be intentional, in order to attract customers, and/or the result of their prices lagging behind BBBs (due to the pace at which BBBs' odds are informatively updated, driven by the flow of "smart money").[22] Given the public availability of BBB odds, it seems fair to assume that if the sole objective of the price setting strategies of PTBs were the efficient calibration of event outcomes they would fully align their odds with those of BBBs. The setting of

[22] *Pinnacle* state "This limiting of arbitrage players is a reflection of a bookmaker's short-comings, such as posting 'bad odds,' or an inability to move odds fast enough to avoid being the focus of arbitrage players."
Source: https://www.pinnaclesports.com/betting-promotions/arbitrage-friendly.

promotional odds may assist PTBs in identifying informed clients, who tend to place bets only at prices with negative expectation for the bookmaker. In addition, and as reported above, significant evidence exists that such bookmakers operate discriminating behaviour against long-term winning customers. Consequently, we argue that the majority of apparent arbitrage opportunities observed in soccer betting markets are very unlikely to be exploitable in practice. In the context of the betting market considered here, the original concept of the EMH, where market prices converge to fundamental values, subject to the activity of informed traders, may be open to challenge as efficiency in this case, in terms of an absence of exploitable arbitrage opportunities, is a function of PTBs' restriction of trade, rather than odds convergence.

The experience from other financial markets, in which exchanges with lower commissions, such as Chi-X, have gained traction in the marketplace alongside established competitors (He, Jarnecic, and Liu, 2015), suggests that the traditional PTBs risk losing market share to the BBBs. Thus, we would predict that as bettors become more sophisticated and recognize the availability of exchanges with lower execution costs and higher liquidity, PTBs will mimic the BBB model, focusing more on holding balanced books rather than setting profit-maximizing prices.

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