Impact of Swiss Betting Regulations on Cross-Country Arbitrage Opportunities: An Empirical Analysis

Bachelor Thesis
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Abstract

This study analyzes the association between regulatory regimes and the persistence of arbitrage opportunities in sports betting markets. Using a cross-country dataset that includes monopolistic markets (Switzerland, Finland, Norway) and liberalized markets (e.g., United Kingdom, Germany), survival analysis techniques such as Kaplan-Meier estimators, log-rank tests, and Cox proportional hazards models, are employed to examine arbitrage durations. Findings indicate that arbitrage opportunities tend to last longer in monopolistic markets, with Finland and the pooled group of Switzerland, Finland, and Norway showing significantly lower hazard rates of closure. Switzerland shows a similar but statistically non-significant pattern, possibly due to limited sample size. Adjusting for arbitrage margin does not notably change results. These observations suggest that market structure correlates with differences in arbitrage persistence, highlighting variations in market dynamics across regulatory environments.

1 Introduction

The global sports betting industry has grown rapidly in recent years, fueled by advances in mobile internet technology and changes in legal and regulatory frameworks. Across jurisdictions, these structural shifts have created diverse betting environments, from highly regulated, monopolistic markets to liberalized, competitive ones. This variety provides a unique opportunity to study how market design influences betting behavior and market efficiency.

Central to understanding efficiency in sports betting is the concept of arbitrage opportunities (situations where bettors can guarantee profit by placing simultaneous bets on all possible outcomes with different bookmakers). The persistence (or duration) of these arbitrage opportunities signals frictions or inefficiencies in how quickly mispricings are corrected. This thesis investigates the following question:

> *Does a monopolistic or tightly regulated betting market facilitate the persistence of arbitrage opportunities compared to more liberalized markets?*

This study focuses on Switzerland, Finland, and Norway as key cases of monopolistic or tightly regulated betting markets. Switzerland's restrictive regime,

established under the Swiss Federal Act on Gambling in 2019 (Geldspielgesetz, BGS, 2018), permits only two state-licensed operators to offer sports betting, creating a segmented market structure. Similarly, Finland and Norway maintain monopolistic frameworks where state-controlled operators dominate the market. These settings contrast sharply with more liberalized and competitive jurisdictions such as the United Kingdom and France. Regulatory differences create friction, affecting arbitrage. Thus, examining how these regimes impact arbitrage duration provides insights into broader questions of market efficiency and competition.

Using a large cross-country dataset of arbitrage opportunities, this study finds that monopolistic or tightly regulated markets, specifically Finland, and to a lesser robust extent Switzerland, exhibit longer-lasting arbitrage opportunities compared to more liberalized markets. The mean duration of arbitrage opportunities in Switzerland is 10.0 minutes, and in Finland, 8.0 minutes, compared with averages around 6-7 minutes in more liberalized countries. Kaplan-Meier survival analysis shows that arbitrage opportunities remain open longer in Finland and Switzerland relative to other countries, though the effect size for Switzerland does not reach statistical significance, likely due to a smaller number of observations. Norway's arbitrage opportunities are rare and short-lived, with a mean duration of 0 minutes and none exceeding 15 minutes, limiting its impact on overall results.

Log-rank tests confirm statistically significant differences in survival curves for Finland alone (test statistic = 6.955, $p = 0.008$) and for the pooled group of Switzerland, Finland, and Norway (test statistic = 8.174, $p = 0.004$) relative to other countries. Cox proportional hazards models quantify these differences, revealing that belonging to Finland reduces the hazard of arbitrage closure by 15.7% (HR = 0.843; 95% CI: 0.742-0.957; $p = 0.009$), while the pooled group shows a 16.7% reduction (HR = 0.833; 95% CI: 0.736-0.944; $p = 0.004$). Switzerland's hazard ratio suggests a 22.5% reduction (HR = 0.775; 95% CI: 0.529-1.136), but this is not statistically significant ($p = 0.192$). These effects remain robust after adjusting for arbitrage margin, which itself exhibits no significant effect (HR ≈ 1.05, $p > 0.2$). Together, these findings indicate that less competitive market environments in monopolistic regimes are associated with slower resolution of arbitrage opportunities compared to liberalized markets.

To reach these conclusions, each arbitrage opportunity is treated as a single

observation, characterized by its duration and key features such as the bookmakers and their countries involved. Bookmakers' country assignments rely on geographic web traffic data from SimilarWeb, providing a proxy for their principal markets. The analysis employs survival analysis methods, including Kaplan-Meier estimators to describe survival functions of arbitrage events. This non-parametric approach is well suited given the heavily skewed, non-normal distribution of arbitrage durations, where mean-based tests would be inappropriate. Complementary log-rank tests assess statistical differences in survival curves between groups defined by country and regulation type. Finally, Cox proportional hazards regression models estimate hazard ratios of arbitrage closure associated with membership in monopolistic regulatory regimes, controlling in some models for the arbitrage margin.

This research contributes new evidence on how regulatory regimes shape market efficiency in sports betting. The findings suggest that monopolistic settings, often justified on grounds of public health or consumer protection, may inadvertently slow the correction of arbitrage mispricings by reducing competitive pressures and cross-border betting activity. Meanwhile, liberalized markets appear more dynamically efficient, resolving pricing anomalies more quickly through greater bookmaker competition and bettor responsiveness. These results inform policy debates by highlighting a potential trade-off between regulation and market informational efficiency in the sports betting industry.

This work relates to an extensive body of literature on market efficiency, a concept central to financial markets since the seminal work by Fama, 1970, which posits that prices reflect all available public information. This principle extends to betting markets, which are often viewed as "real-world laboratories" for testing efficiency due to their defined termination points and readily available information. Thaler and Ziemba, 1988, introduced the concept of "strong-form betting market efficiency," implying that all bets in a contest should yield equal expected returns, while "weak-form efficiency" suggests no bets should have a positive expected value. However, a "stronger form" requiring equal returns across different events is known not to hold due to varying bookmaker margins for different event profiles (Hegarty and Whelan, 2024).

Prior research has explored various forms of inefficiencies and anomalies in betting markets. One prominent anomaly is the "favorite-longshot bias" (Griffith, 1949), where high-probability outcomes (favorites) provide better

expected returns than low-probability outcomes (longshots). This bias has been consistently documented in racetrack betting and also found in European football markets.

A key area of inefficiency research involves arbitrage opportunities, defined as simultaneously buying and selling an asset in different markets to exploit price discrepancies for a risk-free profit. In betting, this translates to placing bets across different bookmakers to guarantee a return. While arbitrage opportunities exist, they are often rare, particularly in online betting markets, with some studies finding them in less than 1 in 1000 matches (Vlastakis et al., 2009). Deville and Riva, 2007, investigated the persistence of such deviations in financial options markets, linking it to the challenges traders face in exploiting mispricing, highlighting the role of market liquidity and volatility. Their work on options found that the introduction of ETFs, by facilitating spot trades in the index, lessened the arbitrage closure times.

The existing literature has extensively examined market efficiency and arbitrage in various betting contexts, including factors driving inefficiencies such as behavioral biases, insider information, transaction costs, and capital constraints. This thesis builds on that foundation by specifically investigating how different regulatory regimes affect the persistence (duration) of arbitrage opportunities. Rather than simply identifying arbitrage presence or magnitude in individual markets, this research systematically compares arbitrage survival times across countries with contrasting regulatory frameworks (monopolistic versus liberalized). By adopting a comparative, cross-country perspective that emphasizes national betting regulations, it offers a novel contribution to understanding market efficiency dynamics in the sports betting industry.

2 Institutional Context

2.1 Swiss Regulatory Environment

Switzerland operates under one of the most restrictive betting regimes in Europe, governed by the Swiss Federal Act on Gambling Geldspielgesetz, BGS, 2018, which came into force on January 1, 2019, with the following characteristics:

- *Licensing and Market Entry*: Only companies licensed by Swiss authorities may operate legally. Sports betting by unlicensed foreign providers is

banned (Geldspielgesetz, BGS, 2018, Art. 16, 21, 24).

- *Access Blocking*: A public list of unauthorized betting sites is maintained by regulatory bodies (ESBK, Gespa). ISPs in Switzerland are obliged to block these domains (Geldspielgesetz, BGS, 2018, Art. 86 Abs. 4).

- *Geographical Restrictions*: Swiss operators serve only domestic customers, while Swiss residents are not permitted to access foreign betting sites, segmenting the market nationally.

2.2 Other European State Monopolies: Finland, Norway, and Iceland

Switzerland is not unique in maintaining a state monopoly on sports betting. Other significant examples are Veikkaus (Finland), Norsk Tipping (Norway), and Íslensk Getspá (Iceland), all operating as the sole legal provider of sports betting services in their respective countries. The characteristics of these regimes are very similar to those of Switzerland's regulatory framework.

While this thesis includes empirical data for Switzerland, Finland, and Norway, no data could be collected for the Icelandic market due to the absence of the bookmaker in public odds aggregators.

2.3 Implications for Arbitrage and Market Efficiency

These monopolistic systems generate similar frictions affecting market efficiency and arbitrage:

- *Limited Cross-Market Arbitrage*: In contrast to liberalized markets where bettors can exploit pricing discrepancies across national borders, monopolistic and segmented regimes make simultaneous betting in multiple jurisdictions difficult, which could potentially increase both the size and duration of arbitrage opportunities.

- *Reduced Competition*: The lack of alternative legal providers could reduce alignment with international odds, and make price discrepancies more likely to emerge and to persist.

- *Slower Odds Adjustment*: The isolation of national monopolies could potentially obstruct the flow of capital between bookmakers, which would slow down the elimination of arbitrage opportunities and lead to inefficiencies compared to open markets.

For the aformentioned reasons, and in order to provide more robust empirical results, in this thesis I not only include Switzerland as a monopolistic case, but also Finland and Norway.

3 Theoretical Framework

Bets are placed on the outcomes of an event. I assume a probability space of n mutually exclusive and exhaustive outcomes, $O = \{1, 2, \ldots, n\}$.

Odds. Odds can be defined on the outcomes of an event, and represent the probability of the corresponding outcome occurring. They are used instead of percentages, as the return on the wager is easier to interpret. In this study, I will use European-style odds, also called decimal odds. The European odds on outcome $o \in O$ would be calculated as $\frac{1}{\pi_o}$, where π_o is the implied probability of outcome o. The actual probability of outcome o occurring is defined as p_o. When staking a wager of W on outcome o, the return is $W \cdot \frac{1}{\pi_o}$, (the odds multiplied by the stake).

Bookmaker margin. By definition, the actual decimal probabilities of mutually exclusive outcomes in a probability space add up to 1. However, the implied probabilities bookmakers use add up to more than 1 (Archontakis and Osborne, 2007, Cortis et al., 2013, Štrumbelj, 2014). This difference is usually called "bookmaker margin" (Cain et al., 2003, Štrumbelj, 2014).

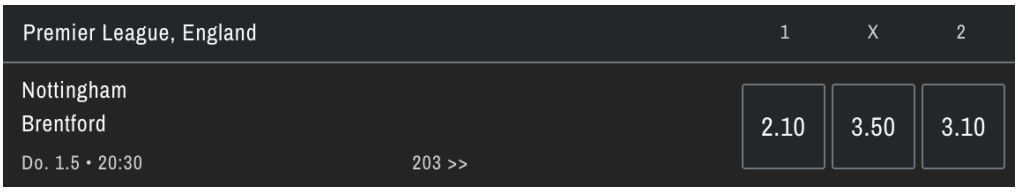


Fig. 1 – Caption for the image

To provide an example, consider the Premier League match between Nottingham and Brentford in Figure 1. The implied probabilities are: $2.10^{-1} \approx 0.48$,

$3.50^{-1} \approx 0.29$, and $3.10^{-1} \approx 0.32$. This means the most likely outcome, as indicated by the implied probabilities, is Nottingham winning, with an implied probability of approximately 48%, followed by Brentford winning, and then the teams drawing. The sum of these inverse implied probabilities is $2.10^{-1} + 3.50^{-1} + 3.10^{-1} = 1.084495$, implying a bookmaker margin of 8.4%. The margin of a bookmaker can be formally defined as:

$$k = \sum_{o \in O} \pi_0 - 1. \tag{1}$$

The margin of a bookmaker does not directly correspond to the profit of the bookmaker, and the expected profit of a bookmaker can be proven to be (Cortis, 2016):

$$\frac{k}{1+k}.$$

For the analysis in this thesis, I will use the bookmaker margin, not the expected profit of the bookmaker.

3.1 Arbitrage Opportunities Across Multiple Bookmakers

Let $B = \{1, 2, \ldots, m\}$ be the set of m different bookmakers. Each bookmaker $b \in B$ quotes an implied probability $\pi_{o,b} > 0$ for outcome o, with an overround (bookmaker margin), such that:

$$\sum_{o \in O} \pi_{o,b} > 1.$$

Since a bettor may back each outcome at only one bookmaker, I select an injective assignment, $\Phi = \{\phi : O \to B \mid \phi \text{ is injective}\}$, where $\phi(o)$ is the bookmaker assigned to outcome o.

For any $\phi \in \Phi$ define the total implied probability:

$$C(\phi) = \sum_{o \in O} \pi_{o,\phi(o)}.$$

We can then solve the assignment problem:

$$\phi^* = \arg\min_{\phi \in \Phi} C(\phi).$$

Arbitrage Opportunity. Set $\Sigma^* := C(\phi^*)$, then if $\Sigma^* < 1$, there is an arbitrage opportunity.

To prove this, assume $\Sigma^* < 1$. Let $W > 0$ be the total stake you are willing to distribute. Define, for each $o \in O$,

$$s_o = \frac{W\,\pi_{o,\phi^*(o)}}{\Sigma^*}. \tag{2}$$

Where s_o is the stake placed on outcome o at bookmaker $\phi^*(o)$. Then:

1. The total amount staked is:

$$\sum_{o \in O} s_o = \frac{W}{\Sigma^*} \sum_{o \in O} \pi_{o,\phi^*(o)} = W.$$

2. If outcome o occurs, the bookmaker $b = \phi^*(o)$ pays out $\frac{s_o}{\pi_{o,b}}$. Hence the return is:

$$\frac{s_o}{\pi_{o,\phi^*(o)}} = \frac{W}{\Sigma^*}, \quad \text{from the definiton of } s_o\text{, Equation 2,}$$

   independently of o.

3. The net profit is:

$$\frac{W}{\Sigma^*} - W = W\,\frac{1-\Sigma^*}{\Sigma^*} > 0.$$

Arbitrage Margin. The margin of the arbitrage opportunity is defined as the difference between the sum of the actual probabilities of the outcomes and the sum of the implied probabilities of the outcomes of the bookmakers chosen by ϕ^*:

$$1 - \Sigma^* \tag{3}$$

Expressed as a fraction of total stake W, the profit is:

$$\frac{\frac{W}{\Sigma^*} - W}{W} = \frac{1-\Sigma^*}{\Sigma^*}.$$

For the analysis in this thesis, I will use arbitrage margins, not the profits of arbitrage opportunities.

3.2 Arbitrage Detection

Programmatically finding arbitrage opportunities for n bookmakers on three different outcomes (1X2 market), being sure the highest paying opportunity is chosen, can be broken down into a fundamental combinatorial optimization problem, specifically, the assignment problem. Kuhn, 1955, first introduced and proposed a solution method to the problem.

I solve the assignment problem by using an implementation of a modified Jonker-Volgenant algorithm (Crouse, 2016) from the Python library SciPy.

4 Data

4.1 Data Sources and Scope

The dataset for this study comprises data on European-style odds for the 1X2 market (match-result) in the English Premier League, starting from the 11th of April 2025, to the 24th of March 2025 (the season ended on the 25th), at 15-minute intervals. I collected odds quotes for three outcomes, home win (1), draw (X), and away win (2), from 89 different bookmakers. The raw dataset contains 3'361'705 odds rows for 71 matches, where every odds row is a tuple of the form (odd for home wins, odd for a draw, off for away wins).

4.2 Scraping Approach

Odds data was collected from:

- Public APIs: ParionsSport (France) and SNAI (Italy), with rate limits not being a problem because of the low request frequency.
- Residential Proxies: For Swisslos (Switzerland's monopoly bookmaker) and BetMonitor (aggregating 80–90 bookmakers). Proxies were rotated per request to avoid IP bans.

All requests were dispatched asynchronously at the start of each 15-minute window to ensure temporal alignment. This ensured a delay between the requests in the order of milliseconds.

4.3 Sample Construction

Only bookmakers with more than 70% of their estimated traffic coming from a single country were included in the dataset. The allocation was done by checking the geographic traffic information of the bookmakers, and allocating them to the country where most of their traffic comes from. The traffic information was obtained from SimilarWeb, as it is widely recognised as the most reliable source of estimated traffic information. It is not possible to obtain the exact traffic information for most websites, as they do not share it publicly. A table with the traffic information of the included bookmakers can be found in Table 5 in the Appendix B.

Another reason why I decided to not include some bookmakers were discrepancies between the odds scraped from Betmonitor (the aggregator) and the odds I manually checked on the bookmakers' websites. Only bookmakers with no discrepancies found in multiple checks were included in the dataset.

Additional cleaning was also necessary. Proxy requests would sometimes fail, or be sent from the wrong geographical region, which would result in the events data having discrepancies in the starting time of the events.

This brought the number of bookmakers down from 89 to 21, the number of odds rows down to 783'316, while the number of events remained the same at 71. Visual representation of the odds per date and the events over time can be found in the Appendix C, Figure 23 and 24 respectively.

4.4 Descriptive Statistics

Bookmaker margin. By looking at bookmaker margins, as defined in Equation 1, we can better understand how the margin set by a bookmaker on their odds affects the number of arbitrage opportunities they appear in. Arbitrage happens when the combined odds from different bookmakers result in a negative total margin, which means a positive arbitrage margin (see Equation 3). Therefore, we expect that bookmakers with higher margins to be mathematically less likely to be part of arbitrage opportunities.

Fig. 2 – Bookmaker margins

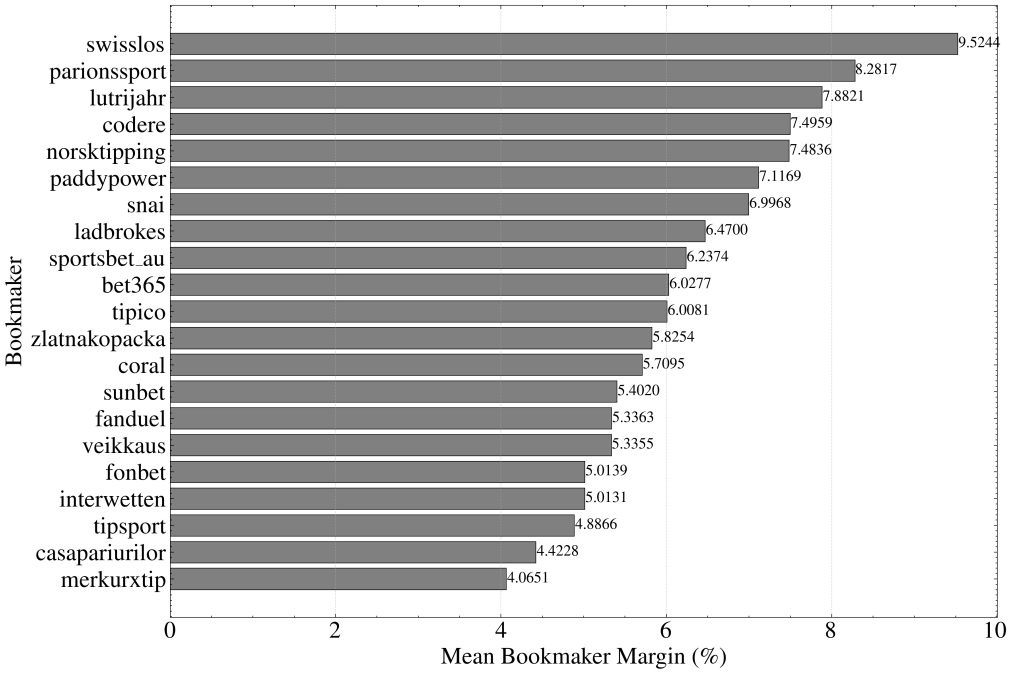


Figure 2 shows the bookmaker margins. Notably, Swisslos is the bookmaker enforcing the highest margin (9.52%). Norsktipping also has a high margin (7.48%), while Veikkaus is on the lower end of the spectrum (5.34%).

Number of arbitrage opportunities. Over the considered time span, 1'526 arbitrage opportunities were found.

Fig. 3 – Arbitrage Opportunities by Country

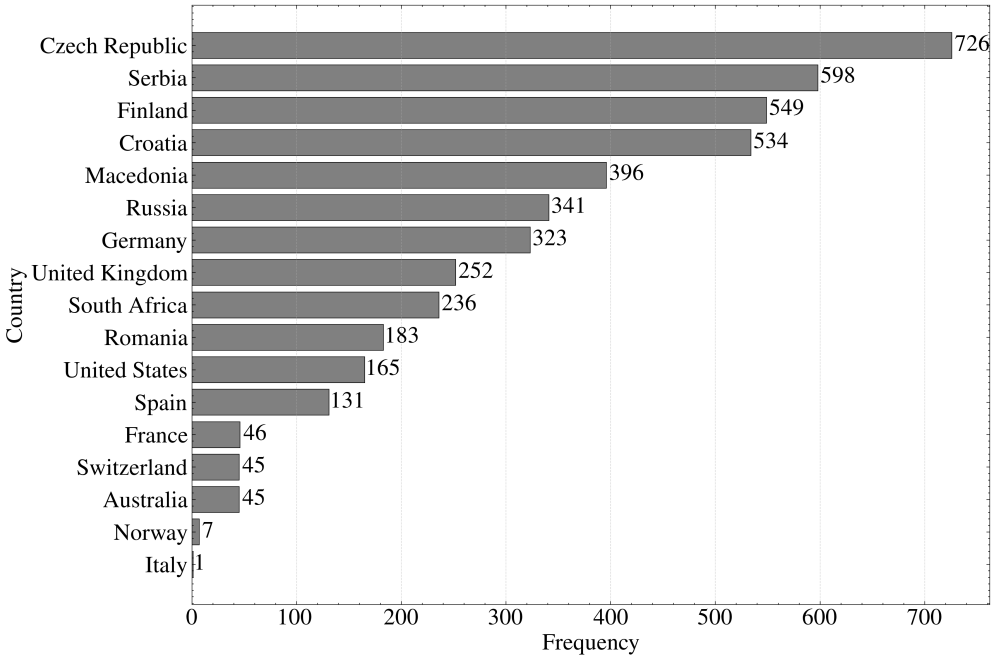
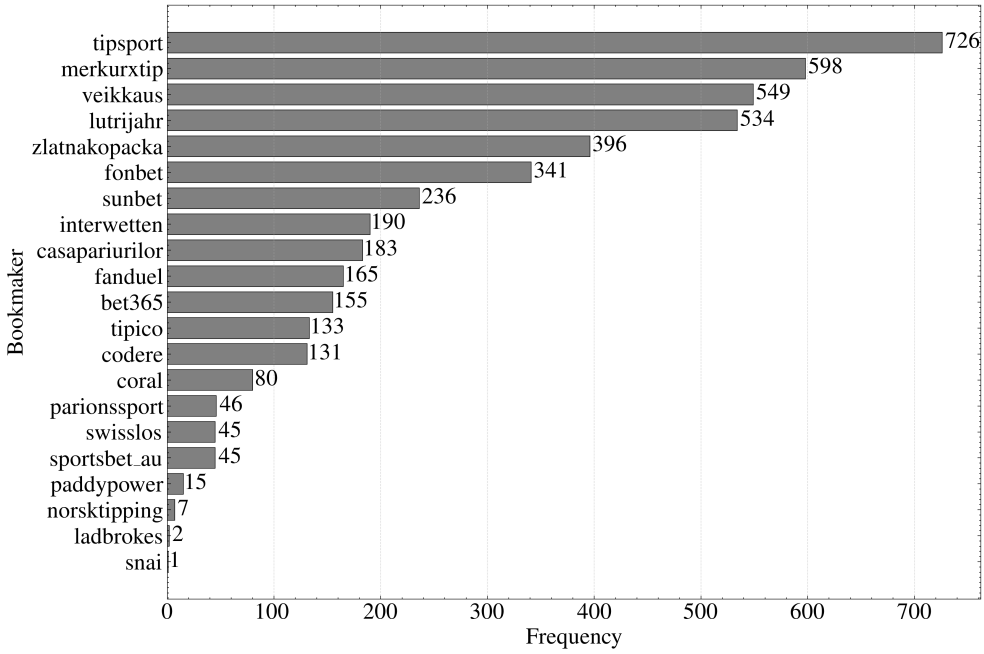


Fig. 4 – Arbitrage Opportunities by Bookmaker

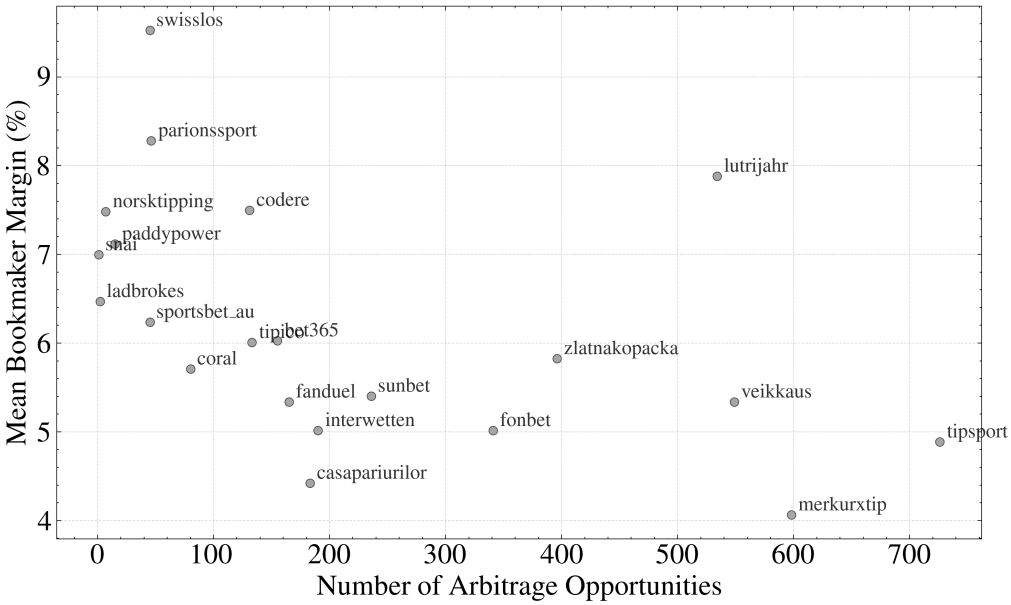


Notes: These columns do not add up to 1'526, because every arbitrage opportunity is counted for every country involved in it, and involves three different bookmakers.

Figure 3 shows the distribution of arbitrage opportunities by country. Switzerland, Finland and Norway show great heterogeneity, with Finland having the most (549), Norway the least (7) and Switzerland being in the middle (45). This could be attributed to the fact that Finland is one of the bookmakers with lowest margins.

Other notable countries are Serbia and the Czech Republic, both with more than 550 opportunities, and Italy with just 1 opportunity. Figure 4 only adds information about the distribution of arbitrage opportunities between Germany's and the United Kingdom's bookmakers.

Fig. 5 – Bookmaker margin vs. Number of arbitrage opportunities



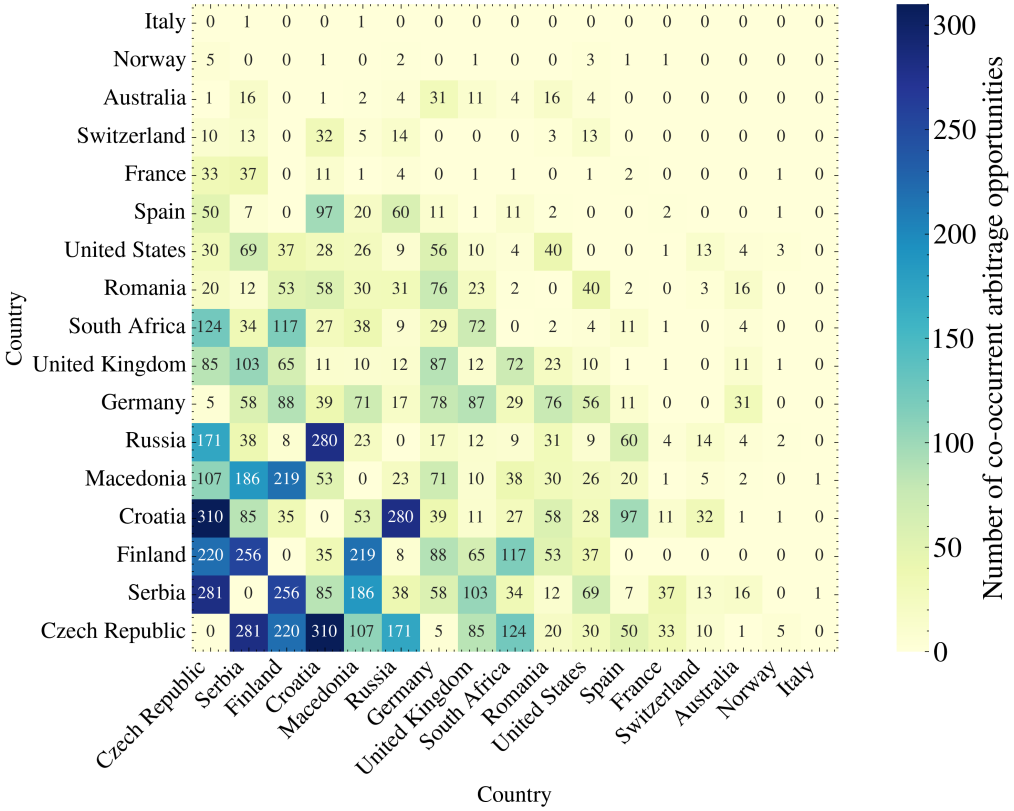
As seen in the beginning of this section, as one would expect, Figure 5 shows a negative correlation between bookmaker margin and the number of arbitrage opportunities a bookmaker is involved in.

Finland, with one of the lowest bookmaker margins, also is one of the countries appearing the most in arbitrage opportunities. Switzerland and Norway have high bookmaker margins, and are involved in a much lower number of arbitrage opportunities.

Lutrijahr seems to be an outlier, but additional variation could for example be attributed to how quickly bookmakers react to outside information. As arbitrage

opportunities rely on a handful of bookmakers offering exceptionally good odds compared to the rest of the market, bookmakers that react slower than others to outside information, will be more likely to be involved in arbitrage opportunities. The opposite argument could also be made for providers such as Ladbrokes, Snai and Norsktipping, which could be reacting very quickly to outside information, and thus be underrepresented in the arbitrage opportunities. These arguments could explain the heterogeneity of the number of arbitrage opportunities between bookmakers.

Fig. 6 – Co-occurrence heatmap by Country



Notes: This graph was generated by iterating over all arbitrage opportunites, and counting how many times a country was involved in an arbitrage opportunity with another country. For example, and arbitrage opportunity involving Switzerland, Finland and Norway, would count as one co-occurrence for Switzerland-Finland, one for Switzerland-Norway, and one for Finland-Norway. The diagonal is different from zero only for Germany and the United Kingdom, as they are the only countries with more than one bookmaker in the dataset.

Figure 6 shows the co-occurrence of arbitrage opportunities between different countries. Notably, no country is strongly dependent on another country (50% or more arbitrage opportunities involving the same country).

Arbitrage margins. The arbitrage margins of arbitrage opportunities, as defined in Equation 3, are important in the context of this study, as they determine the attractiveness of an arbitrage opportunity, and one would be justified in assuming that higher arbitrage margins could lead to shorter lasting arbitrage opportunities.

Fig. 7 – Distribution of Arbitrage Margins

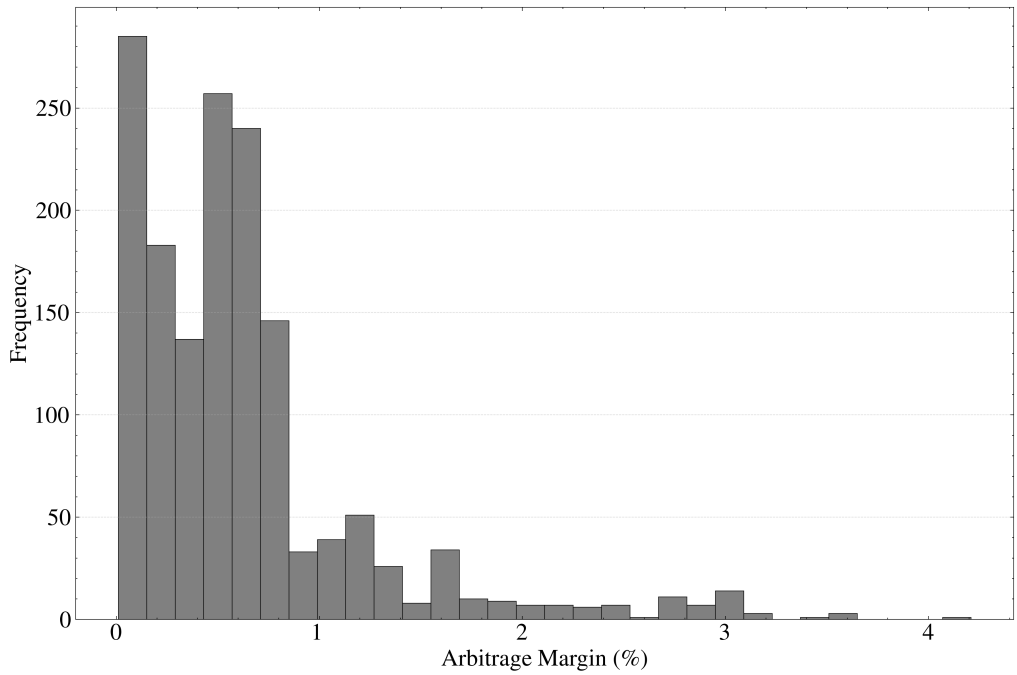
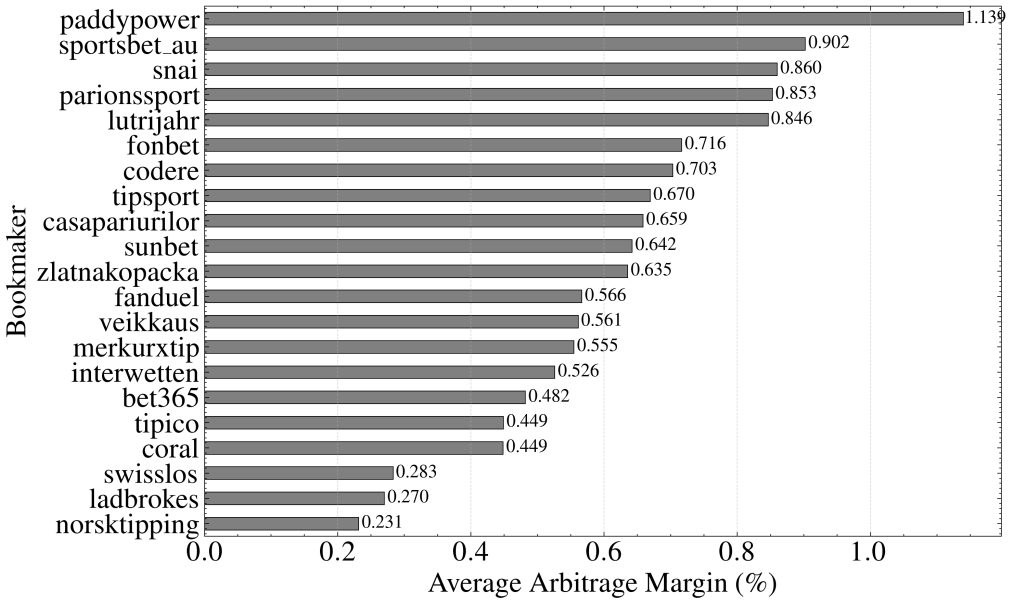


Figure 7 shows the distribution of arbitrage margins of arbitrage opportunities. Most arbitrage margins are below 1%.

Fig. 8 – Average Arbitrage Margin per Bookmaker



Notes: This graph was generated by iterating over all arbitrage opportunities, and every time a bookmaker was involved in an opportunity, the arbitrage margin of that opportunity was added to the bookmaker's arbitrage margins. The average arbitrage margin was then calculated by dividing the total arbitrage margin by the number of opportunities the bookmaker was involved in.

Figure 8 shows the average arbitrage margin by bookmaker. Both Swisslos and Norsktipping have low average arbitrage margins. Paddypower only has 15 observations, which could explain the high average arbitrage margin as just randomly occurring profitable arbitrage opportunities.

Fig. 9 – Average Arbitrage Margin per Country Pair

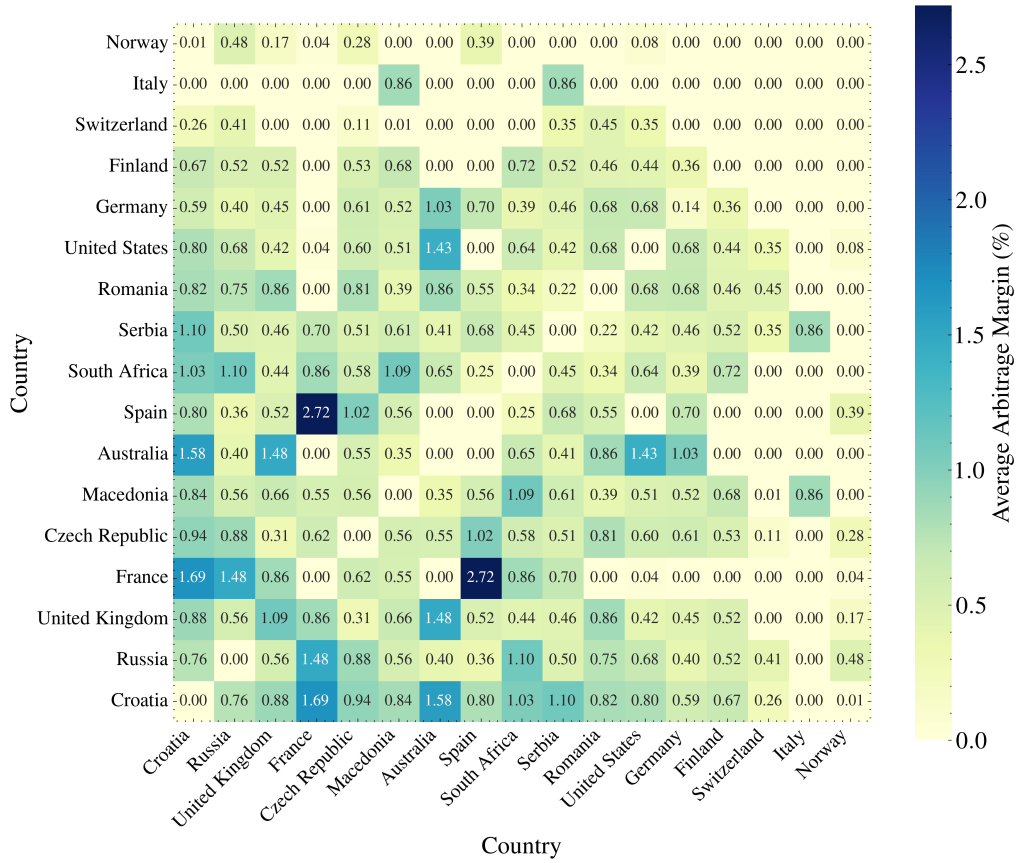


Figure 9 shows the average arbitrage calculated across country pairs. Notably, high average arbitrage margins are present in country pairs with a low number of co-occurrent arbitrage opportunities, such as France and Spain (2 co-occurrences, average arbitrage margin of 2.72%), or Australia and Croatia (1 co-occurrence, average arbitrage margin of 1.58%). This can then be attributed to profitable arbitrage opportunities randomly appearing in pairs of countries with low co-occurrence, and strongly influencing the average.

5 Methodology

5.1 Research Design

This study focuses on the impact of regulatory regimes on the persistence of arbitrage opportunities in the sports betting context. As I need to analyze the

persistence (survival) of an observation, I will use common aproaches from survival analysis, and some descriptive statistics in order to try and explain the patterns we can observe in the data.

5.2 Variables and Measures

This study is based on the analysis of arbitrage opportunities. Every arbitrage opportunity found in the data is recorded as a single observation, with the following characteristics:

- *Duration*: The outcome variable is the time until an arbitrage opportunity closes. As the observation frequency is 15 minutes, the survival times can be between 0 and 15 minutes, which I indicated as 0 minutes, between 15 and 30 minutes, which I indicated as 15 minutes, and so on.
- *Date and time*: The exact date and time when the arbitrage opportunity was first identified. It is always at 15 minutes lags.
- *Event scheduled date*: The date and time when the event for which the arbitrage opportunity was identified is scheduled to take place.
- *Odds*: Three odds, one for the event "home wins" (1), one for "draw" (X), one for "away wins" (2).
- *Arbitrage margin*: The arbitrage margin of the arbitrage opportunity, as defined in Equation 3.
- *Providers involved*: The three bookmakers involved in the arbitrage opportunity. The bookmakers are never repeated in the same observation, as most bookmakers do not allow multiple bets on the same event.
- *Countries involved*: There are always a maximum of three countries involved in an arbitrage opportunity, corresponding to the countries where the bookmakers receive most of their web traffic. Germany and the United Kingdom are sometimes repeated in the same observation, as they have more than one bookmaker.

Other variables I use to explain the patterns observed in the data are:

- *Regulatory regime*: Monopolistic for Switzerland, Finland and Norway and non-monopolistic for the other countries.
- *Number of bookmakers per country*: Which would be 3 for the United Kingdom, 2 for Germany, and 1 for every other country.
- *Number of arbitrage opportunities per country*: As seen in Figure 3.
- *Bookmaker specific margin*: as defined in Equation 1, and as seen in Figure 2.

5.3 Statistical Methods

In order to interpret the survival times of arbitrage opportunities, conduct hypothesis tests, and estimate the impact size of the regulatory regimes on the persistence of arbitrage opportunities, I use the following statistical methods:

Kaplan-Meier Survival Curves. The Kaplan-Meier method (Kaplan & Meyer, 1958) is used to estimate the survival function $S(t)$ of arbitrage opportunities, representing the probability that an arbitrage opportunity remains open beyond time t. It is defined as:

$$\hat{S}(t) = \prod_{t_i \leq t} \left(1 - \frac{d_i}{n_i}\right) \tag{4}$$

where:

- $t_1 < t_2 < \cdots < t_m$ are the ordered distinct times at which arbitrage opportunities close,
- d_i is the number of arbitrage closures (events) occurring at time t_i,
- n_i is the number of arbitrage opportunities still open (at risk) just before time t_i.

Although the underlying Kaplan-Meier estimator calculates the survival probabilities at each time point accounting for censoring, the main output of interest here is the visualization of these estimates as survival curves. These plots illustrate the probability that an arbitrage opportunity remains open beyond a given time, and allow for comparison between countries, or between regulatory regimes.

Log-Rank Test. The log-rank test (Mantel, 1966) is a non-parametric test used to assess the null hypothesis that survival functions are equal across two or more groups (in my case, I will use it for countries and regulatory regimes). For comparison between two groups, the test statistic is:

$$\chi^2 = \frac{\left(\sum_{i=1}^{m} (O_{1i} - E_{1i})\right)^2}{\sum_{i=1}^{m} V_{1i}} \tag{5}$$

where, at each event time t_i:

- O_{1i} is the observed number of arbitrage closures in group 1,
- $E_{1i} = \frac{n_{1i}}{n_i} d_i$ is the expected number of arbitrage closures in group 1 under the null hypothesis,
- $V_{1i} = \frac{n_{1i} n_{2i} d_i (n_i - d_i)}{n_i^2 (n_i - 1)}$ is the variance of O_{1i},
- n_{1i} and n_{2i} are the numbers of arbitrage opportunities at risk in group 1 and group 2 just prior to t_i,
- $n_i = n_{1i} + n_{2i}$ is the total number at risk at time t_i,
- d_i is the total number of arbitrage closures across both groups at time t_i.

Under the null hypothesis, the test statistic χ^2 asymptotically follows a chi-squared distribution with 1 degree of freedom.

Cox Proportional Hazards Model. To estimate the effect size of regulatory regimes on the hazard rate of arbitrage closure, I apply the Cox Proportional Hazards regression (Cox, 1972). This approach complements the log-rank test by providing an effect size estimate and enabling adjustment for other covariates. The model relates the hazard function $h(t \mid \mathbf{X})$–the instantaneous risk of arbitrage closure at time t given covariates $\mathbf{X}$–to a baseline hazard $h_0(t)$ and covariates through the equation:

$$h(t \mid \mathbf{X}) = h_0(t) \exp\left(\beta^\top \mathbf{X}\right) \tag{6}$$

where:

- $h_0(t)$ is the unspecified baseline hazard function,

- $\mathbf{X} = (X_1, X_2, \ldots, X_p)$ is the vector of covariates, such as indicators for country groups or arbitrage margin,
- $\beta = (\beta_1, \beta_2, \ldots, \beta_p)^\top$ are regression coefficients estimated from data,
- $\exp(\beta_j)$ represents the hazard ratio (HR) associated with a one-unit increase in covariate X_j.

The model parameters are estimated by maximizing the partial likelihood function:

$$L(\beta) = \prod_{i=1}^{m} \frac{\exp\left(\beta^\top \mathbf{X}_{(i)}\right)}{\sum_{j \in R(t_i)} \exp\left(\beta^\top \mathbf{X}_j\right)} \tag{7}$$

where:

- $t_1 < t_2 < \cdots < t_m$ are the observed event times (arbitrage closures),
- $\mathbf{X}_{(i)}$ is the covariate vector of the arbitrage opportunity experiencing the closure event at time t_i,
- $R(t_i)$ is the risk set of arbitrage opportunities still open just before t_i.

Maximization of the partial likelihood provides estimates for β, which quantify the multiplicative effects of covariates on the hazard of arbitrage closure.

5.4 Identification Assumptions and Threats to Validity

The validity of causal interpretations in survival analysis depends on several assumptions:

Exogeneity of Covariates. It is assumed that the regulatory regime and other covariates (arbitrage margin etc.) are not influenced by unobserved confounders that also affect the survival time of arbitrage opportunities. A possible unobserved confounder could be the country's population attitue towards gambling. A less tolerant population could lead to more restrictive regulations, and also less betting activity, which could lead to slower reabsorption of arbitrage opportunities.

Proportional Hazards Assumption (PHA). The Cox model assumes hazards are proportional over time. Violation of this assumption can lead to biased estimates. I test the PHA using scaled Schoenfeld residuals.

Censoring. It is assumed that censored observations (i.e., arbitrage opportunities not closed within the observation window) do not significantly affect the estimation of the survival function. Since at any given time only a few arbitrage opportunities remain open, the proportion of arbitrages censored at the end of the observation period is very small relative to the total.

Measurement Error. The main source of measurement error is the frequency of the data collection. As every observation lasting less than 15 minutes is considered as lasting 0 minutes, every observation lasting between 15 and 30 minutes is considered as lasting 15 minutes, and so on, the survival times are rounded to the nearest 15 minutes.

Moreover, as seen in Section 4.3, sometimes proxy requests failed. This means some arbitrage opportunities are ended prematurely, or not identified at all. This could bias the results, by underestimating the survival times of arbitrage opportunities. As these inaccuracies are randomly distributed over the whole sample, I argue that they do not influence the comparison between countries, or between regulatory regimes.

5.5 Software and Reproducibility

The code used to scrape the data, the code used to analyze the data, and the data itself are made openly available for reproducibility purposes and can be freely accessed and downloaded here: link. The whole codebase is written in Python.

6 Results

6.1 Descriptive Statistics

Table 1: Mean, Standard Deviation and Trimmed Mean Duration of Arbitrage Opportunities by Country

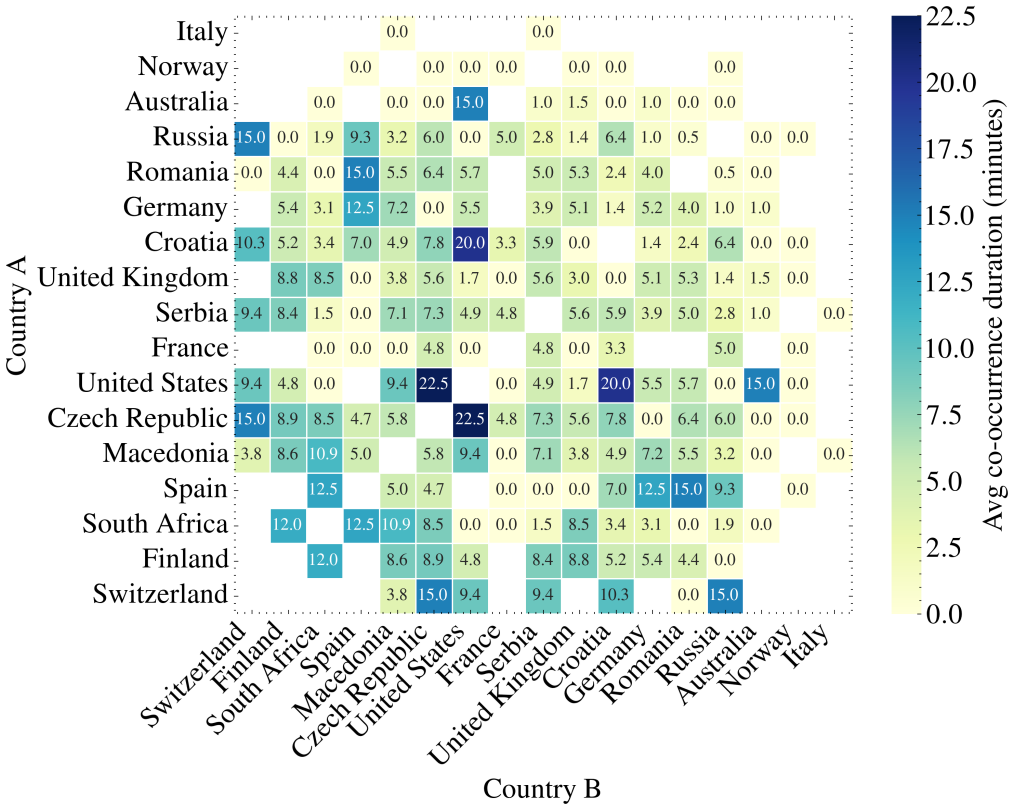
	Mean	Standard Deviation	Trimmed Mean (5 %)
Switzerland	10.00	15.00	9.00
Finland	8.00	16.94	5.32
South Africa	7.55	16.70	5.03
Spain	6.83	15.44	4.57
Macedonia	7.00	15.55	4.43
Czech Republic	7.32	17.85	4.33
United States	6.90	16.77	4.22
France	4.17	6.81	3.97
Serbia	6.26	14.49	3.91
United Kingdom	5.66	11.82	3.82
Croatia	6.25	17.01	3.34
Germany	4.46	9.81	3.00
Romania	3.67	7.77	2.71
Russia	5.30	16.22	2.50
Australia	1.07	3.91	0.39
Norway	0.00	0.00	0.00
Italy	0.00	0.00	0.00

As seen in Table 1, Switzerland's mean duration is the highest, at 10 minutes. Finland follows with a mean duration of 8 minutes, while Norway, the last monopolistic country, has a mean duration of 0 minutes, possibly also because of the low number of arbitrage opportunities found in the data. I will consider Norway in my analysis of monopolistic regulatory regimes, but because of the low number of arbitrage opportunities, and absence of arbitrage opportunities lasting 15 minutes or more, it will not significantly affect the results.

Switzerland not only has the highest mean duration, but also the highest trimmed mean, being one of the countries least affected by outliers.

Nonetheless, the standard deviations of the durations are very high, implying that any mean duration is not representative of the distribution of durations.

Fig. 10 – Co-occurrence Duration of Arbitrage Opportunities by Country



Notes: Every empty cell is due to the absence of arbitrage opportunities between the two countries. Every cell containing a 0 is due to the arbitrage opportunities between these countries never lasting more than 15 minutes. Germany and the United Kingdom have co-occurrence durations on the diagonal because they have more than one provider registered in the country.

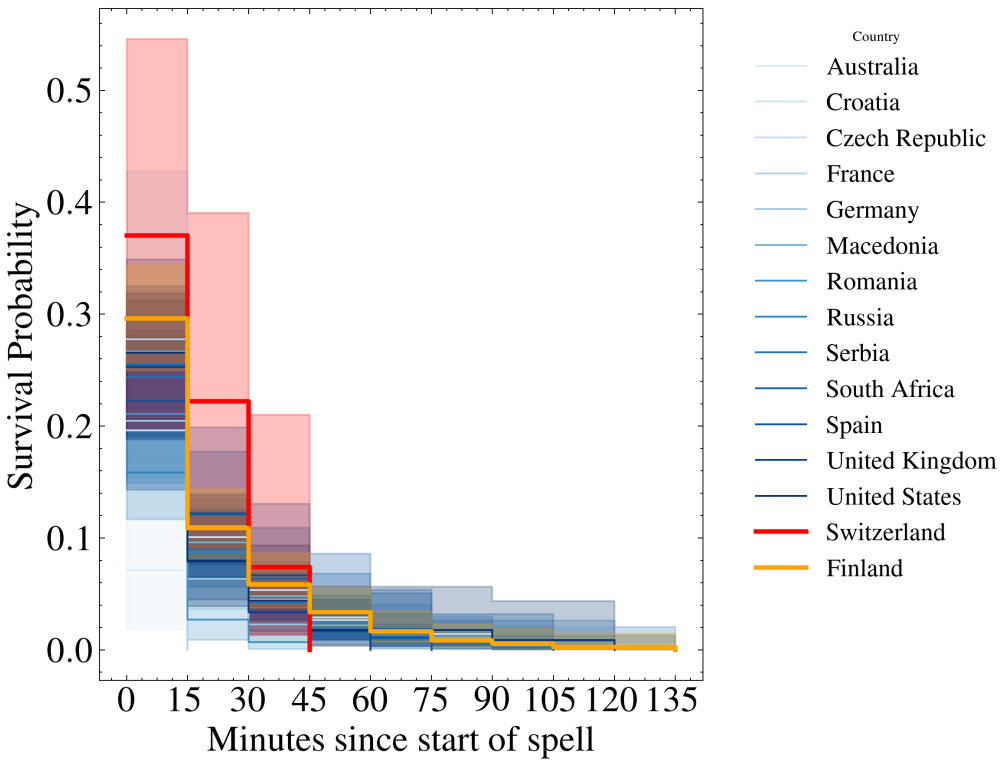
Figure 10 shows the co-occurrence duration of arbitrage opportunities by pair of countries. Both Switzerland and Finland do not strongly depend on any country, as also seen in Figure 6.

Nonetheless, as seen in Figure 4, Switzerland only has 45 arbitrage opportunities, so statistical power is limited and any conclusion should be drawn with caution.

6.2 Kaplan-Meier Survival Curves

In survival analysis, a simple hypothesis test comparing the mean duration to 0 is not sufficient. Extreme values can skew the results, and the distribution of survival times is not normal. I use the Kaplan-Meier estimator to estimate the survival function.

Fig. 11 – Kaplan-Meier Survival Curves by Country



In Figure 11, I plot the Kaplan-Meier survival curves of the arbitrage opportunities by country. The survival curves show the survival probability of an overall arbitrage opportunity, and the time until it is no longer present. Switzerland has the highest survival probability up to 30 minutes, and its survival probability is statistically significantly different from 0 up to 45 minutes. Switzerland has no observations lasting more than 45 minutes, which is also the reason why it is not strongly affected by outliers. Finland also has higher than average survival probabilities, which are statistically significantly different from 0 up to 75 minutes. Norway does not appear, as all its arbitrage opportunities have a duration of 0 minutes.

No country shows unexpected patterns, and no observation lasts more than 135 minutes.

Fig. 12 – Kaplan-Meier Survival Curve - Switzerland vs Other Countries

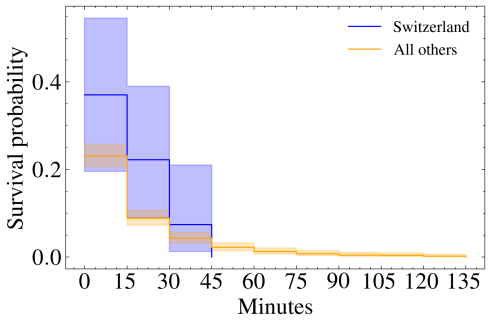
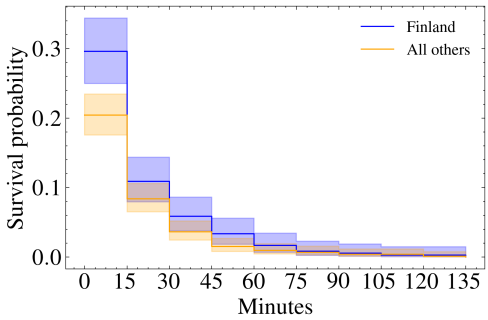
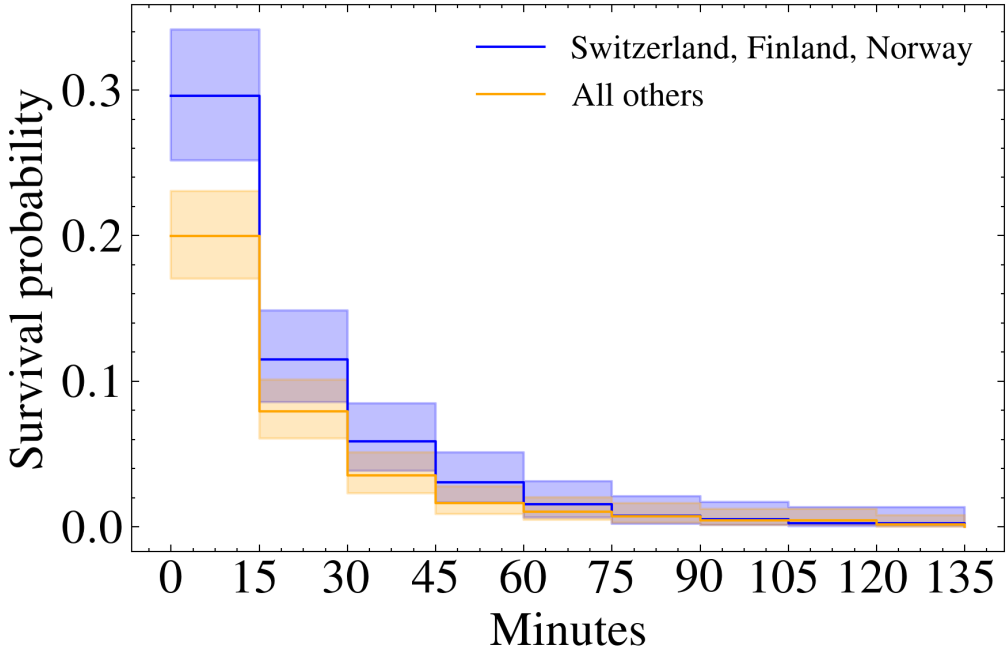


Fig. 13 – Kaplan-Meier Survival Curve - Finland vs Other Countries



Figures 12 and 13 show, respectively, the Kaplan-Meier survival curves of Switzerland and Finland against all other countries pooled together. The survival curves of both countries showcase higher than average survival probabilities. Switzerland is never statistically significantly different from the other countries pooled, while Finland is statistically significantly different from the other countries pooled up to 15 minutes. Even if Switzerland seems to have a higher effect size, the low number of observations compared to Finland makes it impossible to conclude that it is statistically significantly different from the other countries pooled.

Fig. 14 – Switzerland, Finland, and Norway Kaplan-Meier Survival Curves vs Other Countries



As seen in Figure 14, pooling together Switzerland, Finland and Norway further increases the offset between the survival curves of the two groups, but almost unnoticeably. The survival curve of the three countries pooled together is very strongly influenced by Finland.

6.3 Log Rank Tests

In order to test whether the survival curves of the countries are statistically significantly different altogether, I use the log-rank test.

Table 2: Survival Analysis Results: Log-rank Tests by Country Group

Groups	Test Statistic	P-value
Switzerland	1.704	0.192
Finland	6.955	0.008
Switzerland, Finland	9.363	0.002
Switzerland, Finland, Norway	8.174	0.004

Table 2 shows the results of the log-rank tests. Switzerland's survival curve is not statistically significantly different from the other countries pooled together, while Finland's survival curve is, with a p-value of 0.008. When pooling together Switzerland and Finland, the survival curve is statistically significantly different from the other countries pooled together, with a p-value of 0.002. As expected, adding Norway to the pool of Switzerland and Finland lowers the test statistic, as Norway only has arbitrage opportunities with a duration of less than 15 minutes. Nonetheless, the influence is very limited, as Norway only has seven arbitrage opportunities, and the log-rank test remains statistically significant, with a p-value of 0.004.

As we know that the effect of adding Norway to the pool of Switzerland and Finland is limited, and as it leads to a more conservative estimate, from now on I will consider the group where Switzerland, Finland and Norway are pooled together. Any result I get for this group will also hold, and be more conservative, than the Switzerland and Finland group.

6.4 Cox Proportional Hazards Model

To further quantify the differences in survival times between the selected country groups and the other countries, I employ Cox proportional hazards regression models. In particular, I model the hazard of event occurrence (arbitrage opportunity ending) as a function of group membership.

Table 3: Cox Proportional Hazards Model Without Controlling for Arbitrage Margin

Group	HR	95% CI	p-value
Switzerland	0.775	(0.529–1.136)	0.192
Finland	0.843	(0.742–0.957)	0.009
Switzerland, Finland, Norway	0.833	(0.736–0.944)	0.004

Table 3 shows results from Cox proportional hazards models without controlling for arbitrage margin. For Switzerland (CH), the hazard ratio is 0.775 (95% CI: 0.529–1.136) with a p-value of 0.192, which suggests a non-significant tendency toward longer arbitrage durations. For Finland (FI), hazard ratio is 0.843 (95% CI: 0.742–0.957, p = 0.009), confirming significant longer durations.

Similarly, the pooled group CH, FI, NO shows a hazard ratio of 0.833 (95% CI: 0.736–0.944, p = 0.004), again confirming the significant association between group membership and longer arbitrage durations.

Fig. 15 – Average Arbitrage Margin vs. Average Duration, at Bookmaker Level

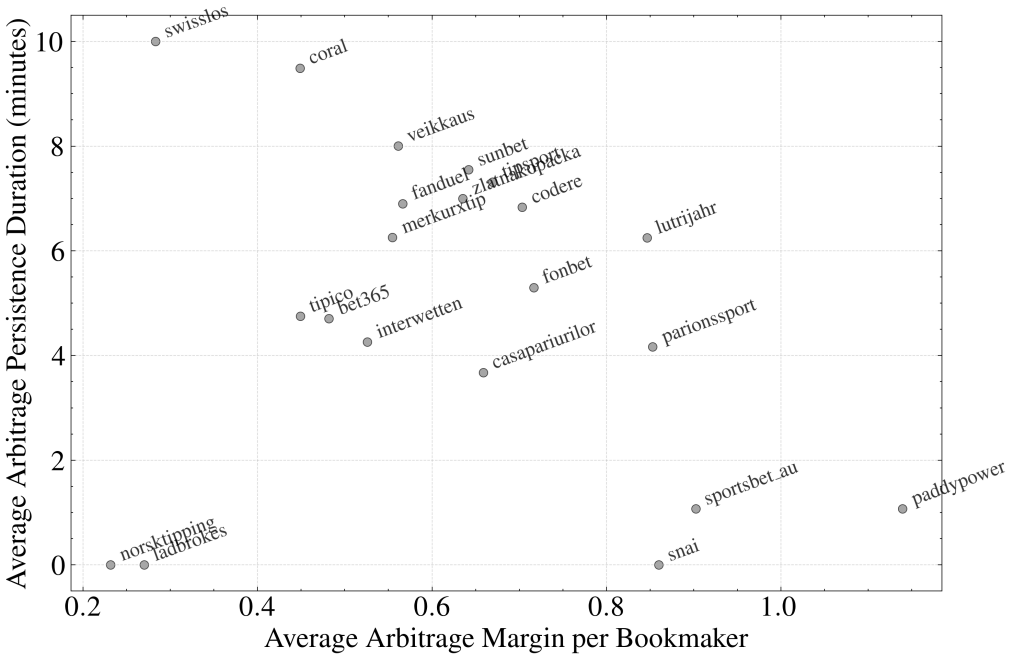
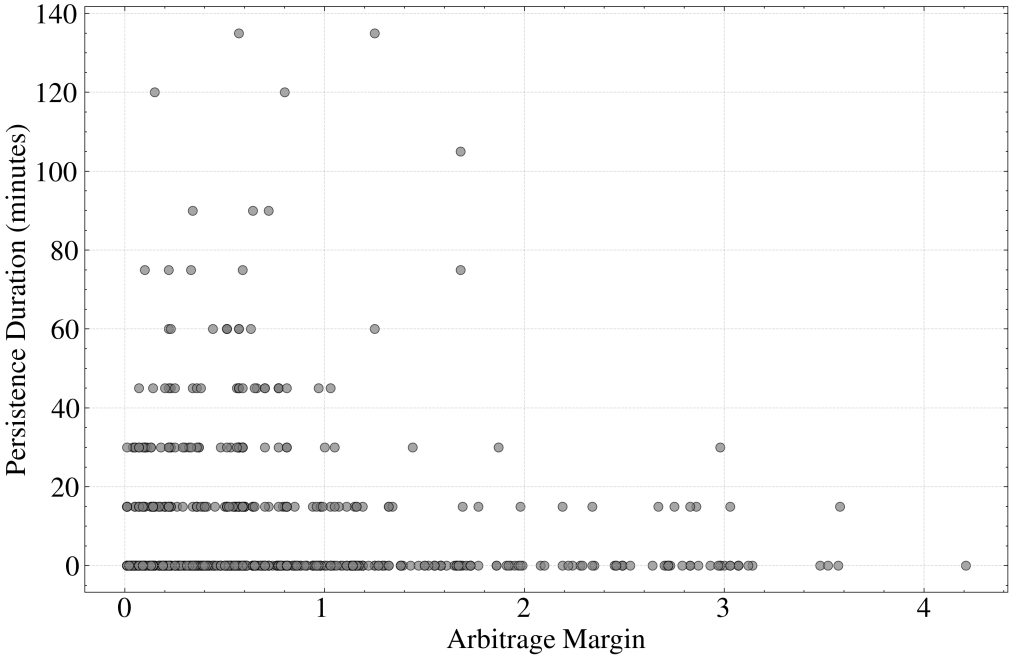


Fig. 16 – Arbitrage Duration vs. Arbitrage Margin, at Observation Level



Additionally, I decided to adjust for arbitrage margin because, as seen in Figure 15, and Figure 16, a negative correlation can be observed between the average duration of arbitrage opportunities and the average arbitrage margin, both at the provider and observation level. This can be interpreted as arbitrage opportunities with higher arbitrage margins being more likely to end sooner, possibly because they are more attractive to bettors.

Table 4: Cox Proportional Hazards Model Controlling for Arbitrage Margin

Group	Group belonging			Arbitrage Margin		
	HR	95% CI	p-value	HR	95% CI	p-value
CH	0.792	(0.540–1.164)	0.235	1.063	(0.964–1.173)	0.222
FI	0.848	(0.746–0.963)	0.011	1.059	(0.961–1.167)	0.248
CH, FI, NO	0.840	(0.741–0.952)	0.006	1.052	(0.954–1.160)	0.307

Notes: For formatting reasons, Switzerland, Finland and Norway are abbreviated to CH, FI and NO, respectively.

Table 4 presents the results of the Cox proportional hazards regression models estimating hazard ratios for the end of arbitrage opportunities, controlling for the arbitrage margin as a covariate.

For Switzerland (CH), the hazard ratio is 0.792 with a 95% confidence interval (0.540–1.164) and a p-value of 0.235. This indicates a 20.8% lower hazard of arbitrage opportunities ending compared to other countries, implying longer durations, but the effect is not statistically significant. For Finland (FI), a hazard ratio of 0.848 (95% CI: 0.746–0.963) and a p-value of 0.011 indicate a statistically significant 15.2% reduction in the hazard, suggesting significantly longer arbitrage durations. The pooled group CH, FI, NO yields a hazard ratio of 0.840 (95% CI: 0.741–0.952) with a p-value of 0.006, confirming a significant association between group membership and longer arbitrage durations.

The arbitrage margin covariate itself has hazard ratios slightly above 1 (1.052 to 1.063) but none are statistically significant ($p > 0.2$), suggesting no strong influence of margin size on arbitrage duration in this model.

Overall, these results reinforce earlier findings based on Kaplan-Meier survival curves and log-rank tests.

6.5 Cox Proportional Hazards Model Diagnostics

To verify the validity of the Cox proportional hazards models presented in Table 3 and Table 4, I examine diagnostic plots assessing the proportional hazards assumption for both the country group variable and the arbitrage margin covariate. The diagnostics include graphical checks of Schoenfeld residuals over transformed time and statistical tests for independence between residuals and time.

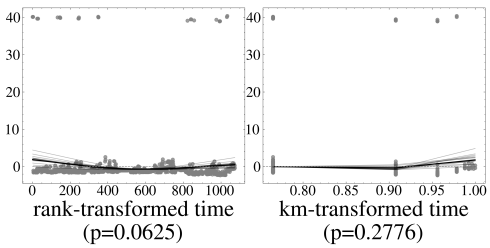


Fig. 17 – (a) Switzerland: Schoenfeld Residuals for Country Group

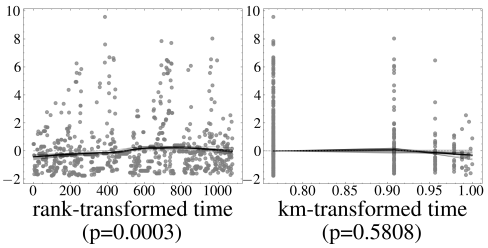


Fig. 18 – (b) Switzerland: Schoenfeld Residuals for Arbitrage Margin

For Switzerland, the residual plots for the country group (Figure 17) show

slight deviations from zero, but neither in rank-transformed time or km-transformed time is the p-value significant at conventional levels (0.0625 and 0.2776 respectively). However, for the arbitrage margins (Figure 18), the residual plot for the rank-transformed time shows a significant deviation, with a p-value of 0.0003, indicating a violation of the model assumptions for this transformation. In contrast, the km-transformed time residuals do not show significant deviation, with a p-value of 0.5808.

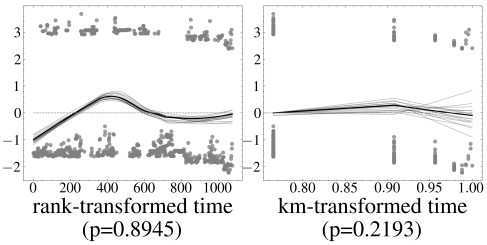


Fig. 19 – (a) Finland: Schoenfeld Residuals for Country Group

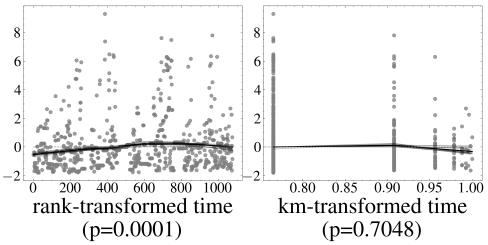


Fig. 20 – (b) Finland: Schoenfeld Residuals for Arbitrage Margin

For Finland, the residual plots for the country group (Figure 19) do not show significant deviations from zero, with p-values of 0.8945 for the rank-transformed time and 0.2193 for the km-transformed time. Again, the residual plots for arbitrage margins (Figure 20) reveal a significant deviation for the rank-transformed time (p = 0.0001), suggesting a violation of the proportional hazards assumption. However, the km-transformed time residuals do not indicate a significant deviation (p = 0.7048).

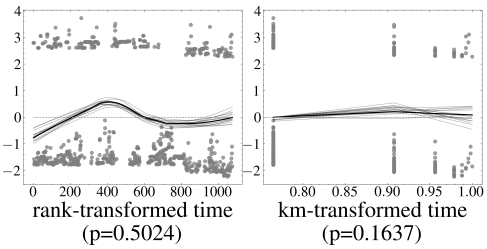


Fig. 21 – (a) Pooled Group (CH, FI, NO): Schoenfeld Residuals for Country Group

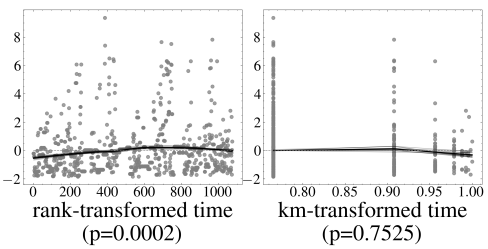


Fig. 22 – (b) Pooled Group (CH, FI, NO): Schoenfeld Residuals for Arbitrage Margin

For the pooled group comprising Switzerland, Finland, and Norway, the residual plots for the country group (Figure 21) do not exhibit significant deviations, with p-values of 0.5024 for the rank-transformed time and 0.1637 for the

km-transformed time, indicating that the proportional hazards assumption holds for this covariate under both transformations. Again, the residual plots for the arbitrage margin (Figure 22) show a significant deviation for the rank-transformed time ($p = 0.0002$), suggesting violation of the proportional hazards assumption. However, for the km-transformed time, the residuals do not indicate a significant deviation ($p = 0.7525$).

Overall, the Cox model diagnostics indicate that the proportional hazards assumption holds well for the country group covariate across both rank-transformed and Kaplan-Meier (KM)-transformed time scales, supporting the reliability of the estimated effects on arbitrage duration. However, the arbitrage margin covariate shows a significant violation of this assumption when evaluated against rank-transformed time, while no violation is detected with KM-transformed time. Since rank-transformed time orders arbitrage opportunities by the sequence in which they end (regardless of their actual duration), this suggests that the effect of arbitrage margin on the hazard rate varies depending on the order of arbitrage events rather than their elapsed survival time. In other words, arbitrage margin may influence the likelihood of ending differently for arbitrage opportunities that close earlier in the overall sequence of events compared to those that close later, possibly reflecting evolving market conditions or shifts in arbitrage dynamics during the data collection period.

7 Findings and Interpretation

7.1 Main Findings

The results consistently indicate that regulatory environments are correlated with differences in the duration of arbitrage opportunities.

Descriptive statistics. Table 1 shows that Switzerland exhibits the highest mean and trimmed mean duration, while Finland also shows above-average values.

Kaplan-Meier survival curves. Figure 11, 12, 13, and 14 confirm that arbitrage opportunities in Switzerland and Finland persist significantly longer than those in other countries. The effect for Switzerland is sizable but does not reach statistical significance, possibly due to the low number of observations.

Log-rank tests. Table 2 shows statistically significant differences in survival functions for Finland and the pooled group (Switzerland, Finland, Norway) versus other countries, with p-values below conventional significance thresholds.

Cox proportional hazards models. Table 3 and 4 show that group membership in the selected monopolistic regimes is associated with a lower hazard of arbitrage opportunity expiring (i.e., longer duration). For Finland and the pooled group (CH, FI, NO), hazard ratios are significantly below 1. Switzerland's effect is not statistically significant, likely reflecting limited sample size. Inclusion of the arbitrage margin as a covariate does not meaningfully alter these findings, and its own effect is not significant.

Proportional hazards assumption. Figure 17, 18, 19, 20, 21 and 22 suggest that the proportional hazards assumption holds for country groups but presents some violation for arbitrage margin with respect to rank-transformed time, though not with KM-transformed time, implying any such effect is not pronounced over actual survival times.

7.2 Interpretation and Implications

Several interpretations emerge from these results. The longer duration of arbitrage opportunities in countries with monopolistic regimes (especially Finland, and to some extent Switzerland) suggests that factors such as reduced cross-border capital flows, and less competitive market structures may lead to slower adjustments by operators and slower reactions by bettors to exploit inefficiencies.

The graphical negative correlation between duration and arbitrage margin suggests that arbitrage opportunities with higher margins are more rapidly exploited or closed by bookmakers. However, this relationship is not statistically significant in the Cox models, and the proportional hazards assumption for this variable depends on time transformation.

8 Limitations and Future Research

8.1 Limitations

Several limitations must be acknowledged. The time-span covered by the dataset is relatively short (42 days), and the observational frequency (every 15 minutes),

although high compared to other studies, is still probably not sufficient to capture the exact duration of most arbitrage opportunities, as most last less than 15 minutes. This may also lead to an underestimation of the true average duration of arbitrage opportunities.

The small sample size means that some countries have very few arbitrage opportunities, which lowers the statistical power of the analysis. This limitation is not due to missing data during the period, but because arbitrage opportunities are generally rare. Also, it is anecdotally known that bigger and more frequent arbitrage chances often happen in more specialized markets, while this thesis only looks at the most popular one, the 1X2 market.

Moreover, the analysis primarily controls for country and arbitrage margin, but other factors, such as the specific national interest in the event type, or the number of bettors in each country, could also affect arbitrage duration but are not included in the analysis.

As I only included English Premier League odds for the 1X2 market, the results may not generalize to other sports, leagues, or market types. The short time-span also implies that the results may not generalize to other time periods.

The analysis also involves multiple country groupings and statistical tests, potentially raising concerns about inflated type I error rates. However, the results are consistent across methods, and even when not statistically significant, no result contradicts the main findings.

Finally, as I used an aggregator, I cannot guarantee that the odds are always the same on the bookmaker's website. Nonetheless, I manually checked multiple times all of the bookmakers I am using, and removed every bookmaker that happened to ever have discrepancies between the aggregator and the website.

8.2 Directions for Future Research

Future research could build on this study in several ways to deepen understanding of the impact of betting regulations on arbitrage opportunities and market efficiency.

Higher observational frequency, possibly down to the minute, would be attainable if the study were to be well funded, as residential proxies are relatively expensive when used frequently. Otherwise, collaborating directly with bookmakers or aggregators could also be a viable option, if the request came from a

reputable institution.

A larger dataset covering multiple seasons and a wider range of leagues, sports and betting markets would enhance the robustness and generalizability of the findings, and would allow for more nuanced analyses of how different countries and betting markets respond to regulatory changes.

For example, Finland is planning to dismantle its long-standing state monopoly, moving towards a licensing model projected for 2027. An interrupted time series analysis could be conducted over the transition period to assess how this change affects arbitrage opportunities and their duration in Finland.

Furthermore, future analyses may explore Cox models with time-dependent coefficients or stratified analyses to capture dynamic effects of arbitrage margin or other covariates over time, which would help address the violations of the proportional hazards assumption observed in this study.

9 Conclusion

This thesis employed survival analysis methods, including Kaplan-Meier estimators, log-rank tests, and Cox proportional hazards models, to examine how regulatory regimes affect the persistence of arbitrage opportunities in sports betting markets. Drawing on a comprehensive cross-country dataset, individual arbitrage events were analyzed in terms of their duration and key covariates such as market structure and arbitrage margin.

The evidence suggests that betting market structure, particularly monopoly regimes, is positively correlated to longer-lived arbitrage opportunities, most visibly in Finland and, to a lesser-robust extent, Switzerland. While large arbitrage margins may attract faster closures, regulatory environment appears a stronger predictor of duration in these data. Caution remains warranted due to sample size limitations and unmeasured confounding. Nevertheless, these findings underscore the potential for regulatory policy to shape market efficiency, as reflected in arbitrage persistence.

References

Archontakis, F., & Osborne, E. (2007). Playing it safe? a fibonacci strategy for soccer betting. *Journal of Sports Economics*, *8*(3), 295–308. https://doi.org/10.1177/1527002506286775

Bundesgesetz über Geldspiele (Geldspielgesetz, BGS), June 22, 2018, retrieved June 1, 2024, from https://fedlex.data.admin.ch/eli/fga/2017/1777/de

Cain, M., Law, D., & Peel, D. (2003). The favourite-longshot bias, bookmaker margins and insider trading in a variety of betting markets. *Bulletin of Economic Research*, *55*(3), 263–273. https://doi.org/https://doi.org/10.1111/1467-8586.00174

Cortis, D. (2016). Betting Markets: Defining odds restrictions, exploring market inefficiencies and measuring bookmaker solvency. https://figshare.le.ac.uk/articles/thesis/Betting_Markets_Defining_odds_restrictions_exploring_market_inefficiencies_and_measuring_bookmaker_solvency/10156445

Cortis, D., Bezzina, F., & Hales, S. (2013). Profiting on inefficiencies in betting derivative markets: The case of uefa euro 2012. *The Journal of Gambling Business and Economics 1751-8008*, *7*, 39. https://doi.org/10.5750/jgbe.v7i1.597

Cox, D. R. (1972). Regression models and life-tables. *Journal of the Royal Statistical Society. Series B (Methodological)*, *34*(2), 187–220. Retrieved June 20, 2025, from http://www.jstor.org/stable/2985181

Crouse, D. F. (2016). On implementing 2d rectangular assignment algorithms. *IEEE Transactions on Aerospace and Electronic Systems*, *52*(4), 1679–1696. https://doi.org/10.1109/TAES.2016.140952

Deville, L., & Riva, F. (2007). Liquidity and arbitrage in options markets: A survival analysis approach. *Review of Finance*, *11*(3), 497–525.

Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. *The Journal of Finance*, *25*(2), 383–417. Retrieved June 28, 2025, from http://www.jstor.org/stable/2325486

Griffith, R. M. (1949). Odds adjustments by american horse-race bettors. *The American Journal of Psychology*, *62*(2), 290–294. Retrieved June 28, 2025, from http://www.jstor.org/stable/1418469

Hegarty, T., & Whelan, K. (2024). Comparing two methods for testing the efficiency of sports betting markets. *Sports Economics Review*, *8*, 100042. https://doi.org/https://doi.org/10.1016/j.serev.2024.100042

Kaplan, E. L., & Meyer, P. (1958). Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association*, *53*(282), 457–481. https://doi.org/10.1080/01621459.1958.10501452

Kuhn, H. W. (1955). The hungarian method for the assignment problem. *Naval Research Logistics Quarterly*, *2*(1-2), 83–97.

Mantel, N. (1966). Evaluation of survival data and two new rank order statistics arising in its consideration [PMID: 5910392]. *Cancer Chemotherapy Reports*, *50*(3), 163–170.

Štrumbelj, E. (2014). On determining probability forecasts from betting odds. *International Journal of Forecasting*, *30*(4), 934–943. https://doi.org/https://doi.org/10.1016/j.ijforecast.2014.02.008

Thaler, R. H., & Ziemba, W. T. (1988). Anomalies: Parimutuel betting markets: Racetracks and lotteries. *Journal of Economic Perspectives*, *2*(2), 161–174. https://doi.org/10.1257/jep.2.2.161

Vlastakis, N., Dotsis, G., & Markellos, R. N. (2009). How efficient is the european football betting market? evidence from arbitrage and trading strategies. *Journal of Forecasting*, *28*(5), 426–444.

A AI Declaration and Statement of Authorship

GENERATIVE AI DECLARATION

To what extent have you used ChatGPT or other generative AI writing tools in developing this work? Please explain the extent to which you have used these tools:

I used ChatGPT (OpenAI) to refine wording, enhance clarity, and develop Python code for data analysis and scraping. This improved readability and efficiency but did not replace my own critical thinking.

Statutory Declaration / Affidavit

I hereby declare that the thesis with the title:

Impact of Swiss Betting Regulations on Cross-Country Arbitrage Opportunities: An Empirical Analysis

has been composed independently and without aids other than those declared. I am aware that I take full responsibility for the scientific character of the submitted text myself.

Name: Daniele Ambrogio Cambria
Matriculation Number: 22-737-928
Date: 29 June 2025

Daniele Cambria

Signature

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Statement of Authorship for a written thesis at the Department for Economics at the University of Zurich

I declare that this work titled

Impact of Swiss Betting Regulations on Cross-Country Arbitrage Opportunities: An Empirical Analysis

has been composed by myself, and describes my own work, unless otherwise acknowledged in the text.

This work has not been and will not be submitted for any other degree or the obtaining of ECTS points at the University of Zurich or any other institution of higher education.

All sentences or passages quoted in this paper from other people's work have been specifically acknowledged by clear cross-referencing to author, work and page(s). Any illustrations which are not the work of the author have been used with the explicit permission of the originator and are specifically acknowledged.

I understand that failure to specifically acknowledge all used work amounts to plagiarism and will be considered grounds for failure and will have judicial and disciplinary consequences according §7ff of the 'Disziplinarordnung der Universität Zürich' as well as §27 of the 'Rahmenverordnung für das Studium in den Bachelor- und Master-Studiengängen der Wirtschaftswissenschaftlichen Fakultät der Universität Zürich'.

With my signature I declare the accuracy of these specifications.

Name: Cambria

First Name: Daniele Ambrogio

Matriculation number: 22-737-928

Date: 29.06.2025

Signature: Daniele Cambria

B Traffic Provenience by Provider

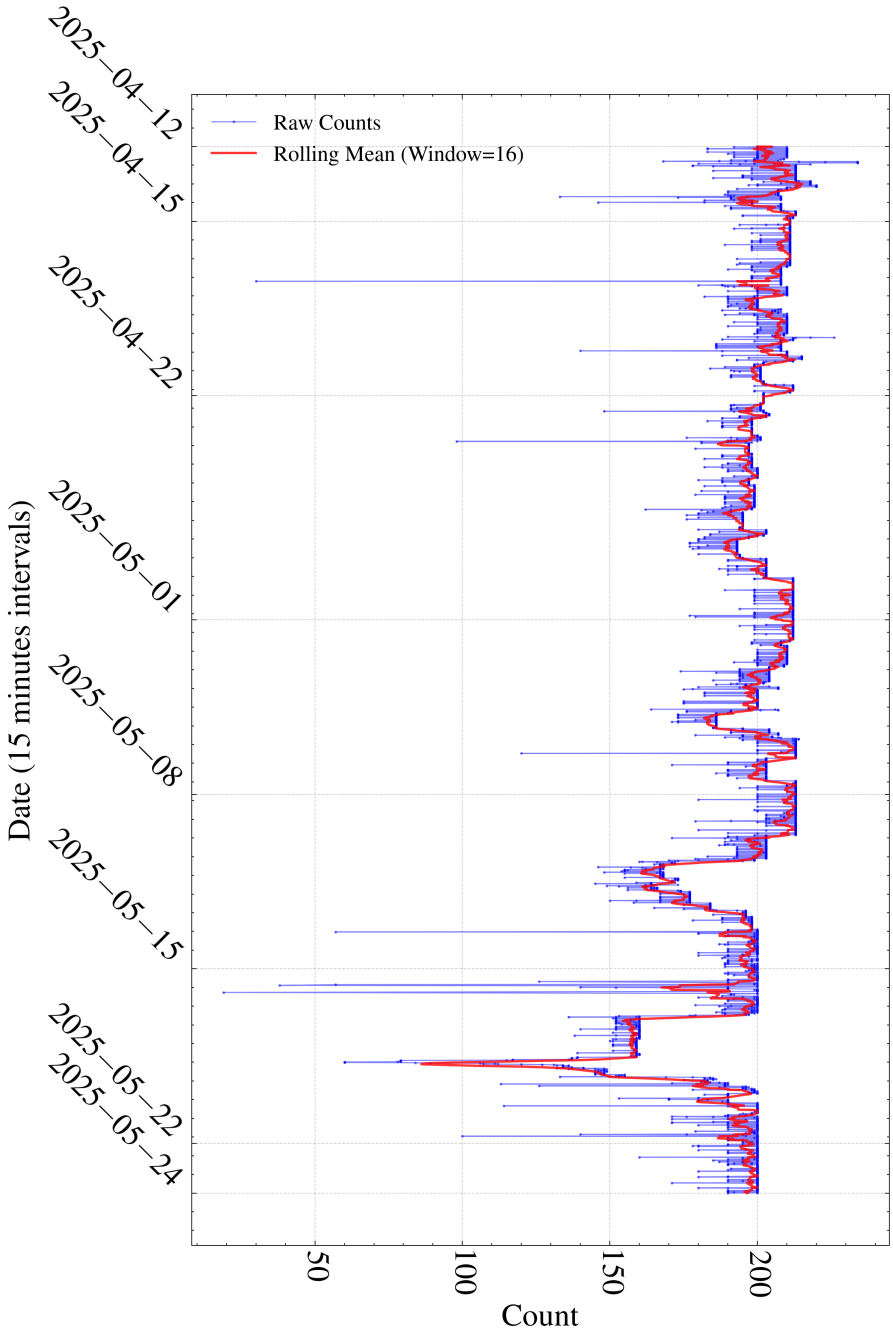
Table 5: Traffic Provenience by Provider

Provider Name	Country	Monthly Traffic	Percentage of Traffic
swisslos.ch	Switzerland	5'300'000	96%
norsk-tipping.no	Norway	5'800'000	98%
snai.it	Italy	6'300'000	98%
parionssport.fdj.fr	France	2'400'000	98%
veikkaus.fi	Finland	9'400'000	98%
lutrija.hr	Croatia	2'200'000	98%
interwetten.de	Germany	846'900	72%
sports.tipico.de	Germany	2'900'000	97%
sports.ladbrokes.com	United Kingdom	5'500'000	95%
zlatnakopacka.mk	Macedonia	11'000	98%
casapariurilor.ro	Romania	2'700'000	97%
fanduel.com	United States	11'900'000	90%
merkurxtip.rs	Serbia	912'000	96%
tipsport.cz	Czech Republic	14'600'000	98%
sunbet.co.za	South Africa	3'100'000	95%
fon.bet	Russia	31'800'000	95%
codere.es	Spain	1'600'000	90%
bet365.com	United Kingdom	29'300'000	73%
sportsbet.com.au	Australia	8'200'000	95%
coral.co.uk	United Kingdom	5'500'000	96%
paddypower.com	United Kingdom	11'200'000	85%

Notes: This traffic estimates are based on the service provided by SimilarWeb. Monthly traffic estimates tend to be overestimated, but I decided to include them as a way to provide information on relative provider size. The percentage of traffic from each country tends to be more accurate.

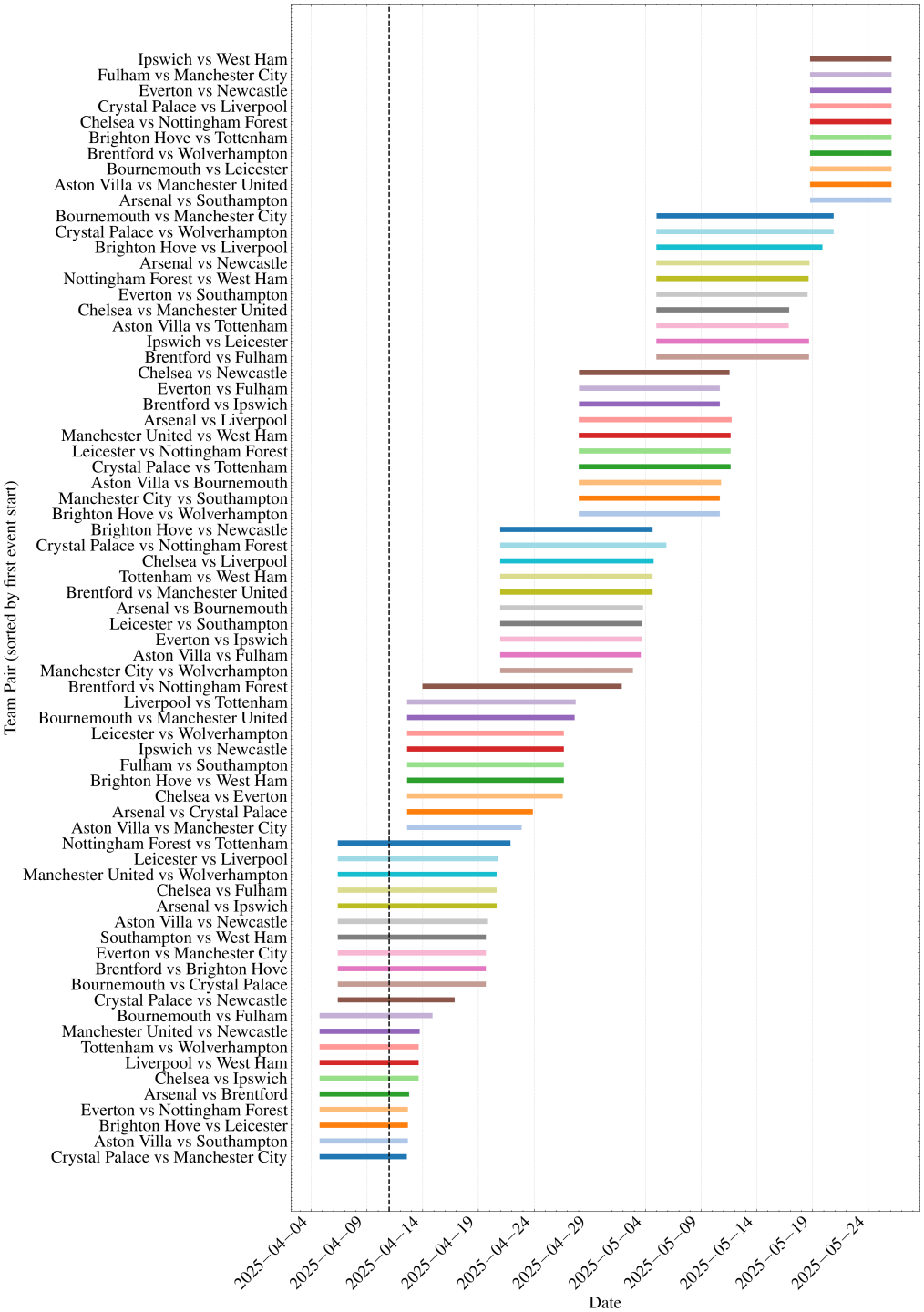
C Additional Figures

Fig. 23 – Odds Rows every 15 Minutes Interval



Notes: This graphic is provided vertically, as horizontally it would be too tight. I generated it so that it can be read normally, but I made it most readable when rotated 90 degrees anticlockwise.

Fig. 24 – Events Over Time by Team Pairs



Notes: Some events start before the 11th of April, but they were included in this graph because they were active up until after the 11th of April (black dashed line), so odds were available for them.