Illegal Sports Bookmakers

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February 2003

Abstract

This paper provides an economic analysis of illegal sports bookmaking using detailed records from six bookmakers who operated in the 1990s. These operations are structured like standard firms and utilize incentive contracts to induce appropriate employee behavior. The bookmakers offer prices which closely follow the geographically separated legal market, but larger operations price discriminate based on individual betting patterns. Despite the availability of inexpensive hedging instruments, all operations take on substantial financial risk. This implies the bookmakers cannot be risk-averse and must hold large cash reserves. The risk-adjusted profit rate is lower than in legal financial markets. These results and behaviors are consistent with standard models of economic self-interest.

JEL classification: *K4, L0*
Key words: *economics of crime, industrial organization*

1 Introduction

Gambling is ubiquitous in the United States. Due to the spread of state lotteries and casinos, legalized gambling is currently available in all but two states. In 1998 sixty-eight percent of Americans reported gambling at least once, and in total they lost over $50 billion to legal gambling operations (National Gambling Impact Study Commission, 1999). A popular form of gambling is wagering on sporting events. Because legal sports gambling is available only in a highly regulated Nevada market, it contributes less than one percent to legal gambling losses. However, the top panel of Table 1 shows the tremendous growth rate over the last thirty years: legal bet volume has increased five thousand times since 1970 while legal bettor losses have increased one hundred fold over the same period.[1]

Even more dramatic is the magnitude and growth of widely available illegal sports gambling. While the size of the illegal market can only be approximated, the second panel of Table 1 shows that it has also grown rapidly. It currently generates over $100 billion in wagers or roughly $10 billion in bettor losses per year. The illegal market dwarfs the legal one, with only one to three percent of all sports wagers being placed in the legal Nevada market (American Gaming Association, 2000).

While much attention has been given to a recent form of sports gambling, wagers placed over the internet, the bottom panel of Table 1 shows that this probably constitutes no more than ten percent of the illegal market. The vast majority of sports gambling involves an illegal bookmaking organization which (like a legal bookmaker) pools large volumes of individual bets. Despite the long time prominence of such "bookies," to date there has been no systematic empirical evaluation of their structure, day-to-day operations, balance sheets, and relationship to the legal market. This paper begins to fill the gap based on records from six New York city bookmakers arrested by the Kings County (Brooklyn) District Attorney office between 1995 and 2000.

Economic self-interest plays a central role in shaping the industrial organization of illegal

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[1]This growth was partly aided by a reduction in the federal excise tax on wagering from ten percent to two percent in 1974 and a further reduction to a quarter percent in 1983. More recently, revenue growth has tapered off due to changes in IRS reporting rules and the rise of internet gambling.

bookmakers. Bookmaking operations have adopted a standard firm structure with executives supervising layers of specialized employees. While legally binding contracts are not possible, I argue that this organization and related institutions economize on transaction costs by enhancing trust between the bookmaker and the bettors. Small bookmakers have close contact with their clientele, who turnover infrequently and live in the same small spatial neighborhood. Large bookmakers develop trust indirectly. They do not interact with bettors and have employees called sheetholders who recruit and service their accounts. Sheetholders are paid using a system which induces them to sign up high quality customers (those likely to generate revenues and not to expose the organization to legal authorities). The resulting trust allows all bookmakers to offer financial credit, which minimizes cash exchange and so reduces the probability of arrest.

Illegal bookmaking operations have some limited market power. Because bettors tend to gamble locally, neighborhoods serve as the relevant market. Only a few bookmakers serve a given neighborhood, though even the largest bookmaker has a citywide share below five percent. One explanation for this limited scale is the difficulty in establishing trust with new and unfamiliar bettors. Consistent with this view is the far larger size of internet bookmaking firms which require cash deposits rather than rely on bettors to honor their debts.

Economic reasoning also highlights shortcomings in conventional wisdom and provides a framework for formal empirical analysis. I first consider financial risk management and profitability. Bookmakers are thought to be perfectly diversified and to profit only from commissions. This would require implausibly risk averse preferences and is inconsistent with actual practices. I find that bookmakers gamble and take positions on games. The resulting variation in net revenues is substantial, with one large bookmaker often winning or losing one hundred thousand dollars per day on a daily bet volume of a half million dollars. The large revenue volatility and the choice not to utilize a relatively inexpensive hedging instrument implies that the bookmaker cannot be risk-averse. Smaller bookmakers partially hedge their positions but still take on financial risk and behave in a manner consistent with risk-neutrality. The revenue variation means the bookmakers must maintain a large cash cushion to ensure solvency. The large bookmaker described above has a capital requirement

of three quarters of a million dollars. Expected profits are positive, with annual profits for the large bookmaker centered at about one million dollars. But because of the large revenue variation, the risk-adjusted return on capital is less than in financial markets and non-positive profits are quite likely. I argue that the large bookmaker's returns are unfavorable, despite his limited outside labor opportunities, since he must front the large capital reserve. My findings of relatively risk-seeking preferences and low rates of absolute return are consistent with equilibrium entry models of crime (Becker, 1968).

Unique features of sports gambling shape price-setting behavior. Illegal bookmakers set gambling odds in almost perfect lock-step with the legal market. This is due to bettors' favored position rather than competitive forces. Bettors may arbitrage, and they are free to wager on either side of an event (unfavorable odds for one side implies favorable odds for the other). Bookmakers deviate from legal prices in two cases. First, there are adverse odds for home-town teams, the sentimental favorites. Second, larger bookmakers use their knowledge of previous betting patterns to price discriminate. This practice is profitable only if the bettor selects the unfavorably priced side, so price discrimination is limited to bettors with strong team loyalties. For example New York Yankees loyalists are willing to pay an extra 4.2 cents for each dollar bet. But price discrimination has a modest effect on profits, since it involves a small portion of bet volume. In total these results are consistent with a bookmaker objective of profit maximization.

The main theme of the analysis is that simple models of self-interest have surprising power in explaining behavior in a non-standard environment. This work thus contributes to the literature on the economics of crime, which began with Becker (1968). Empirical crime research has been limited due to the difficulty of obtaining data. Glaeser et al. (1996) argue that social interactions play an important role in criminal decisions. This paper extends their empirical results by providing micro-level evidence of the important role for trust and personal interaction. The closest paper in spirit and approach is the Levitt and Venkatesh (2000) study of drug-selling gangs. Both papers study the empirical structure, profitability and wages of illegal enterprises. A key difference is the origin of the data used in the analysis, with Levitt and Venkatesh's coming directly from the gang while mine come from arrests.

The strengths and limitations of these sources are discussed below. Another difference is in the activities studied, with drug-selling having no close legal substitute and involving a far greater chance of violent death or injury. Nonetheless, bookmaking employees and owners enjoy a higher expected financial return.

This work also relates to the economic theory of the firm. Transaction costs and agency issues influence the organization of illegal bookmakers, an argument first developed in Coase (1937) and Williamson (1975). Various aspects of employee incentive contracts are investigated including estimates of their effect on worker turnover and productivity. This approach is in the tradition of the organizational incentives literature which has often drawn conclusions based on internal firm records (see the review in Prendergast, 1999).

Finally, the paper connects to the gambling literature. There is a large body of work on legal sports bookmaking. Sauer (1998) provides a very comprehensive overview of previous academic research on this topic.[2] There have not been formal statistical analyses of illegal bookmaking though there are a variety of detailed discussions from former bookmakers or their associates. Some recent accounts include Daniels (1993), Grossman (1998), Jeffries (2000), and Moore (1996). There is a surprising consistency in their descriptions despite differences in time and location. Largely qualitative studies of the structure and practice of illegal gambling enterprises in New York city date back at least to the 1960s. Some representative work include D'Angelo (1985), Lasswell and McKenna (1972), Reuter (1983), Reuter and Rubinstein (1982), and Rosencrance (1987). Sasuly (1982) discusses the historical evolution of illegal sports bookmaking. The practices of the bookmakers here are generally consistent with their accounts.

A potential criticism of this analysis relates to the data generation process. My results are based on the actual records of bookmaking operations. These data are preferable to those based on surveys of criminal behavior where respondents can have strong incentives to misreport their illegal behavior.[3] However, my data are collected in a non-random fashion with

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[2]Manteris (1991) and Roxborough and Rhoden (1998) provide overviews from insiders in the legal market.

[3]Another approach is to use data willingly submitted by the criminals (Levitt and Venkatesh, 2000 and Reuter, 1983). Such data generation have strengths and weaknesses relative to mine. While the participants can provide insights not contained in the written records, they may also impart their own biases on the researchers and selectively withhold information which puts them in a bad light. In principle, the informants

all observations coming from arrested bookmakers. This sample selection implies that some caveats should be applied to the results. Among bookmakers, those who are arrested could be less astute, and this could influence their bookmaking practices. Arrested bookmakers might also be more risk-loving, utilizing practices that increase their chance of apprehension. The data also cover a limited observation period and geographic area. While these points limit my ability to make sweeping generalizations, the uniformity of practices in my data suggest that the results are likely to apply to typical illegal bookmaking operations. There are also arguments against the specific channels of sample selection discussed here.[4]

The outline of the remainder of the paper is as follows. Section 2 provides basic background on the illegal bookmaking organizations (the Appendix contains an introduction to sports wagering). Sections 3-5 present empirical results on employee incentive contracts, price-setting, financial risk management, and profitability. Readers primarily interested in quantitative results can proceed immediately to Section 4. The final section discusses implications of the analysis and outstanding questions for future research.

2 Background

2.1 Descriptive Statistics and Market Conditions

This paper analyzes six illegal sports bookmakers who operated at various points over the period 1995 to 2000.[5] The available data are records seized in arrests conducted by the Kings County (Brooklyn) District Attorney office as well as court documents associated with each case. The one exception is a Newark bookmaker whose records come from a Freedom of

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need not be subject to the sample selection discussed in the text though it seems reasonable to posit that individuals willing to discuss their actions with academic researchers are not representative of those engaging in illegal activities.

[4]First, arrested bookmakers might be *more* successful because police tips often come from bettors who have accumulated significant losses. Second, the geographic concentration need not be a problem. Reuter and Rubinstein (1982) found that illegal sports bookmaking practices in New York city were similar to those in eight other cities from various regions of the country, and a disproportionate share of illegal sports betting is reputed to take place in the Northeast. Third, my results are consistent with the accounts of non-arrested bookmakers (Grossman, 1998 and Jeffries, 2000).

[5]There are only limited data for bookmaker 2 which is omitted from several tables. There are also sporadic details available for another bookmaker, bookmaker 6, located in Philadelphia.

Information Act request from the FBI. The records became available after the cases were fully resolved. All bookmakers were located in or nearby New York city, which provides close access to legal gambling alternatives (horse racing, lotteries, casinos, and jai alai) as well other forms of illegal gambling. Each operation dealt exclusively in sports gambling and did not partake in other businesses.

Table 2 gives an overview of the period of observation, size, and available records for these bookmakers. In terms of size there are two large operations with at least 250 bettors and $100 million in annualized bet volume (bookmakers 0 and 2), two moderate sized operations with at least 100 bettors and $20 million in annualized bets (bookmakers 3 and 5), and two smaller operations with at least $5 million in annualized bets (bookmakers 1 and 4).[6] It is useful to have a sense of these magnitudes. The Kings County District Attorney office estimated that illegal gambling in New York city totaled $12-$15 billion in 1995, and a majority of this was from sports betting. This means bookmaker 0, which has the largest annual volume of nearly $200 million, handles less than five percent of the city-wide market. This operation is also two orders of magnitude smaller than the largest internet bookmakers in terms of bet volume and client base (circa 2001-02).[7] Still, the bookmaker handles roughly the same volume as the largest Las Vegas bookmakers and is ten percent of the total legal market.[8]

These data can be used to approximate market power among illegal bookmakers. A standard measure of market power is the Lerner index which captures the markup of prices to marginal costs. Under Cournot competition, the Lerner index can also be interpreted as the inverse of the number of firms in the market. The Lerner index is 0.35 which indicates

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[6]This classification is consistent with a review of a dozen additional cases which were prosecuted in Kings County over the period 1995-2000. The largest bookmaker arrested in New York city over this period was roughly twice as large as bookmaker 0.

[7]The comparisons with internet bookmakers are based on values in Table 3. In 2002 the World Sports Exchange http://www.wsex.com had a client base of 30,000 and handled up to 200 bets per minute. In 2001 Intertops http://www.intertops.com received 5 million bets and SportingBet http://sportingbet.com, the first publicly traded internet bookmaker, had 15 million bets and £1 billion in bet volume. Both Intertops and SportingBet had a half million registered customers in 2001.

[8]In July 1995 bookmaker 0 handled $9.9 million in bets. During this month, the 18 large Las Vegas Strip bookmakers had about $74 million in bets or $4.1 million per bookmaker (Nevada State Gaming Control Board, 1995). Caesars Palace Race and Sports Book handled about $13 million in sports bets during the previous July (author's calculation based on Caesars World Inc. Form 10-K, 1994 fiscal year).

moderate market power, three firms under Cournot competition (see Appendix B for details). This seems puzzling because city-level concentrations point to perfect competition. The figures in the last paragraph indicate even large bookmakers have a small share of city revenues, and Reuter (1983) says the four firm concentration ratio is no higher than thirty-five percent. These results can be reconciled by the small size of bookmaking markets. Most bookmakers specialize in serving only a few neighborhoods, the typical market, but enjoy high shares in each of these markets. Later sections provide more evidence of imperfect competition and support for this notion of localized markets.[9] I also discuss below various barriers to entry which are needed to sustain market power. These barriers include raising substantial capital reserves, establishing a trusting relationship with bettors, and gaining access to financial diversification services.[10]

Additional descriptive statistics are presented in Table 3. The wagers involve high stakes with each bet averaging over one thousand dollars for bookmakers 0 and 4. The wagers for bookmakers 1 and 3 tend to about a fifth as large. Bettors wager on average at least once a day with more intense bettors placing ten or more wagers daily. A majority of bettors lose money, except for bookmaker 4 where only a week of data are available.[11] About a fifth of the bets are made as exotic (multi-part) wagers again excluding bookmaker 4. Most bets are placed on the highest profile sport at that time. The daily net revenues are quite volatile, particularly for the large bookmaker 0. Negative outcomes are common, suggesting the bookmakers are gambling on outcomes. I will return to this last topic in Section 5.

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[9]In my sample, only the two large bookmakers 0 and 2 simultaneously serve multiple neighborhoods. The smaller bookmakers are largely confined to small areas and perceive themselves as having few direct competitors. For example, bookmaker 1 is overhead in an audio tape mentioning that his bettors only have access to one other operation.

[10]In addition protection from police purportedly occurs in a highly centralized illegal market (Anderson, 1979).

[11]Bettors do not appear to have differential skills in selecting winners. More formally, a bettor's past performance does not have a statistically significant effect in explaining future performance (see also Levitt, 2002). An exploration of why bettors engage in gambling is considered in a related paper, Strumpf (2003).

2.2 Firm Organization and Operation

This section presents institutional details for illegal bookmaking organizations.[12] Operations have a textbook firm structure. The bookmaker heads the firm and is typically a single person. Multiple individuals occasionally occupy this position, such as bookmaker 0 which is a two person partnership. The bookmaker is both the owner and executive. As the owner he is the residual claimant on profits or losses, and so he must have access to capital reserves. As the executive he sets prices and wages, and he also approves or denies potential new bettors and employees. Bookmakers occasionally communicate with one another regarding prices, at least when smaller ones make layoff bets with other bookmakers (see Section 5).

The bookmakers have several common characteristics.[13] Each ran his current organization for at least two years and most for much longer. Bookmaker 0, for example, operated for at least ten years. The bookmakers are white, Italian or Irish males in their forties and fifties who have been involved in the business for most of their adult lives as bettors, employees, and later bookmakers. All but one had been arrested at least once, with the mode at three prior arrests. However, none had served a bookmaking-related prison sentence. In the cases resolved here only bookmaker 2, who was charged in federal court, received a prison sentence. This reflects the difficulty in prosecuting bookmakers.[14] Still, each of the bookmakers had to forfeit substantial assets with bookmaker 0 paying $1.5 million.

The operation is run out of a wireroom, a location containing the phones which bettors call to place wagers.[15] The wireroom keeps regular hours, usually from 11am to 8pm with a break in the afternoon, and except for small operations is open almost every day of the year. Up to 150 bettors may call into a wireroom. An office manager oversees the employees and activities of the wireroom as well as updates and checks all records. In my data the

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[12]The description is based on the bookmakers' own audio tapes, court records and my conversations with undercover detectives from the Kings County District Attorney office. The basic structure is consistent with the accounts referenced in the introduction and can be traced back until at least the 1930s (Sasuly, 1982).

[13]Bookmakers 0, 1, 2, and 5 were all purported to have some association with organized crime, though I have no detailed information about their connection.

[14]In New York state bookmaking (charging commissions on, or keeping records of, gambles) is illegal. While prison sentences are possible for certain offenses, few bookmakers or employees end up serving time except those prosecuted in federal court. There is no law in New York against placing bets.

[15]Larger operations have multiple wirerooms. For example, bookmaker 2 has four wirerooms and bookmaker 0 has two wirerooms.

bookmaker assumes the office manager position. The wireroom workers are called writers or clerks, and their responsibilities include taking bets over the phone and doing some basic figure tallying. They are paid a flat salary. In my data their weekly wage ranges from $200 to $500, and annual wages are roughly double a minimum wage job. A single writer is responsible for at least 50 bettors. Another employee– referred to as a collector, bagman, or runner– is in charge of transferring payments between bettors and the bookmaker. Runners receive wages comparable to writers despite the greater danger associated with transporting large sums of money. The final employee class, the sheetholder, refers bettors to the bookmaker. A sheetholder is also responsible for monitoring his bettors and assuming the money transfer duties of the runner. In the data there are 3 to 19 bettors associated with each sheetholder. Sheetholders are paid according to a unique system which is described in detail in the next section. Their income is typically quite high, with an average weekly salary of $1500 for bookmaker 0. A small operation, such as bookmaker 4, may not have any employees, and the bookmaker handles all of these responsibilities. In the rest of my data the bookmaker and these high level employees are mainly close relatives and/or long-time business associates. For example, bookmaker 0's employees include three sons, a brother-in-law, and an ex-wife of one of the bookmakers. Such a close knit group helps reduce the chance of theft or arrest.

The bookmaking operations share some common business practices. First, there is little use of technology. Only bookmaker 0 keeps electronic records, and the others use paper betting slips and spreadsheets. Second, all bookmakers offer the same menu of bet types and commission levels as those prevailing in the legal Nevada market (see Appendix A). Third, bettors are allowed to wager on credit. This is in contrast with legal bookmakers which require bets to be paid up-front. The office manager, in conjunction with the sheetholder, assigns each bettor a credit limit and sets a debt extension policy. Bettors typically must resolve their net positions on a weekly settle-up day. While some operations extend long-term credit and allow bettors to repay debt over weeks or even several months, others do not and deny betting privileges to delinquent customers.[16] In all cases the amount of credit

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[16]Bookmaker 0 does not give long-term credit while a fifth of bookie 5's bettors get extensions, though

is substantial, with the average bettor exchanging $3400 a week with bookmaker 0. Table 4 shows that debt default is rare, since delinquent bettors can work off their debt as writers or runners. The use of credit provides several benefits to the bookmaker.[17] More importantly, this institution is only possible if the bookmaker trusts bettors not to renege.[18] Since these debt contracts are not legally enforceable, the bookmaker must believe that bettors have the financial capacity and credibility to make the necessary payments. The next section shows how such trust develops.

Internet bookmakers are a useful comparison as they provide the same service (accepting wagers but providing no other amenities), are lightly regulated, and are currently considered illegal in the U.S. An important difference is that internet bookmakers only have an impersonal relationship with their bettors, and in many cases contact is limited to emails and cash wires. As a result, bettors must make cash deposits to open an account and do not enjoy financial credit. This arrangement allows internet bookmakers to hire many fewer employees, since they do not need sheetholders to recruit and monitor bettors.[19] As mentioned earlier, internet operations are much larger and have a worldwide client base. Yet even the largest firms have a small share of the international market. Internet bettors are not as intense as those with bookmaker 0, which may reflect the lack of screening.[20] Other aspects of the operation are similar. Most internet bookmakers, both public and private, are closely held with a small group of owners supervising all operations. And most derive almost all their revenues from sports betting. I present additional, more quantitative, comparisons with internet bookmakers throughout the remainder of the paper.

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in most cases only for a few weeks. There does not appear to be any interest charged even for the debt extensions. Despite popular legend, violence does not seem to be used in debt collection (see Reuter, 1983).

[17]Credit minimizes the number of cash exchanges, and thus the chance of arrest. Extending credit also may increase gambling among financially constrained and time inconsistent individuals.

[18]Bettors also may be concerned about getting paid, but this is less likely to be a problem given that long-lived and large organizations like bookmakers are likely to develop reputations (see Rosencrance, 1987).

[19]In 1999 World Sports Exchange handled a comparable bet volume as bookmaker 0 and yet had only about a fifth as many employees. In 2001 SportingBet's volume was ten times larger than bookmaker 0, and they employed less than five times as many workers.

[20]SportingBet had over 25,000 bettors in each of Europe, the Americas and Asia in 2001. Despite their large size described in notes 7 and 19, they claimed to have less than one percent of the world market in 2001. Their mean individual wager was £50, and their active customers gambled £25,000 on average in 2001. Extrapolating from Table 3, bookmaker 0's bettors wager ten times as much.

2.3 Revenues, Costs and Profits

Table 4 provides an accounting statement for the bookmakers. The top panel shows bet volume, net revenue (volume minus payments to bettors) and the resulting hold percentage (net revenue divided by volume). There is substantial variation across the bookmakers in the hold, with a range of -4% to 15%. These holds do not seem to be systematically related to bookmaker size, and vary above and below the contemporaneous rates for legal bookmakers listed in the top panel of Table 1.[21] Part of this variation stems from the observation period, since the last column of Table 10 shows the commission rates differ across sports. But as I show later, the vast majority of returns variation is due to bookmaker gambling on game outcomes.

The second panel of Table 4 shows costs. Sheetholder commissions are by far the largest component, contributing almost nine-tenths to the total except for the small bookmakers 1 and 4. The remainder of costs are due to delinquent debt repayment, salaries and various expenses related to operating the wireroom.

The bottom panel of Table 4 shows calculated profits, though more refined values are presented in Section 5. Excluding bookmakers 3 and 4 for whom only a week of data is available, annualized profits range from roughly one quarter to one million dollars. This likely spans the true upper and lower bounds, as the data include the least lucrative period (the baseball season, bookmaker 0) and the most lucrative period (the pro football and basketball seasons, bookmaker 5). These values are comparable to previous accounts and also those for internet bookmakers.[22] More importantly profits are the bookmakers' compensation, which seems high given their limited outside labor opportunities. But this is not exceptional pay, since I show later that bookmakers must invest substantial capital and their returns are quite variable.

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[21]A priori, it is not obvious whether holds should be higher or lower with illegal bookmakers. They purportedly receive greater volume from insiders and skilled handicappers which would reduce net revenues. However, the illegal bookmakers can utilize their knowledge of individual betting patterns to price discriminate and charge some bettors higher prices (see Section 4).

[22]The net revenues, costs and profits for bookmaker 5 are close to those given in Jeffries (2000) who ran a similar sized bookmaking organization in Atlanta during 1995-96. The profit rate is also comparable for the the internet bookmaker Sportingbet, despite differences in staff size and technology. SportingBet's 2001-2 annual report states pre-tax profits as £5 million on bet volume of £1 billion.

3 Sheetholding Arrangement

The previous discussion pointed out the important role of trust in running an illegal book-making operation. The bookmaker has to be sure that bettors will repay their debts, and that they will not turn him in to the police. Such trust develops quite naturally in small operations, since the bookmaker has frequent personal contact and familiarity with his bettors (see Appendix C). The same cannot be said for bigger operations, which have many bettors spread out over a large area. In this section I argue that the use of sheetholders facilitates trust. The payment system for these employees induces them to recruit trustworthy bettors.

3.1 Description and Analysis

An important element of the illegal bookmaking organization is the use of sheetholders to recruit and service bettors. In my data only the smallest bookmaker, bookmaker 4, does not employ sheetholders. The largest bookmaker, bookmaker 0, has two layers of sheetholders: 53 sheetholders and 22 sub-sheetholders who report to them. Figure 1 illustrates the rich array of permutations: 5 sheetholders have sub-sheets, 4 of whom also have individual bettors, and 34 bettors have no sheetholder of any kind but deal directly with the bookmaker. On average sheetholders with bettors and sub-sheets have 8.5 bettors. A sheetholder tends to draw bettors from the same neighborhood and is typically their acquaintance. Bettors with the same sheetholder have relatively similar betting patterns.[23] Audio tape conversations indicate bettors have an exclusive relationship with their sheetholder.

Most sheetholders get paid according to the red figure system. Their weekly commission is the product of their sheetholder rate and their net weekly position. The sheetholder's rate is some value between zero and one. The sheetholder's net weekly position is his bettor's losses for the week *minus* their cumulative wins. A sheetholder is only paid after his bettors' prior winnings, his red figure, is exceeded (and the bettors pay their debts). For example,

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[23]For bookmaker 0 the intraclass correlation among bettors with the same sheetholder is 0.43 for daily bet results. This is a high value given the largely random nature of outcomes and stems from the similar betting patterns within each sheet (e.g. one sheet has bettors who wager almost exclusively on the New York Yankees). An explanation for this pattern is the common background/neighborhood of bettors on the same sheet.

suppose a sheetholder with a 0.50 rate starts the week with a $1000 red figure. If his bettors lose $2000 and pay their debts, he receives a commission of ($2000−$1000)×0.50 = $500 and starts the next week with no red figure. The key feature is that sheetholders are not charged for their bettors' winnings, and so they are like a franchisee that is shielded from losses.

Why do bookmakers use this system? The two key factors are the sheetholders' credit constraints and their superior information about their bettors. The sheetholders do not have to front any capital, since the bookmaker makes all payments if their bettors have a net winning week. This is quite important, since a third of bookmaker 0's sheetholders have a red figure in any given week and, as participants in the illicit sector, they are unlikely to have access to most credit markets. The system allows sheetholders to share in profits while limiting their risk. At the same time, I have already argued that sheetholders are quite familiar with their bettors while the bookmakers have little information about them. Bookmaker 0, for example, neither personally knows nor has contact with many of the bettors. A sheetholder has strong incentives under the red figure system to supply bettors who he believes will generate substantial revenues (heavy gamblers who repay debt and have limited access to Las Vegas and the potential for arbitraging) and will not inform legal authorities. This aligns his preferences with the less well-informed bookmaker.

The main danger for bookmakers is that a sheetholder with a large red figure may steer his clients to a new bookmaker where he has no prior losses to make up. This problem can be mitigated if sheetholders are rewarded for longer tenure or for a reputation of not reneging on debt. The next sub-section presents formal empirical evidence on these points.

Even presuming there is no debt flight, the red figure system is costly for bookmakers. Because sheetholders are only paid when the bettors lose, the system reduces the bookmaker's expected income far more than it reduces their income dispersion.[24] Another disadvantage is

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[24]Consider a stylized example where a single 0.50 rate sheetholder handles a stream of $1 straight spread bets, which are discussed in Appendix A. In the long run, half of the bets win (yielding revenue to the bookmaker of −$1 per bet) and half lose (yielding revenue $1 + vig$). Assuming for simplicity that losing and winning bets alternate, the following sequences occur,

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\begin{aligned}
Net\ Revs &= -1, (1 + vig), -1, (1 + vig), \ldots \\
Sheet\ Pay &= 0, vig/2, 0, vig/2, \ldots \\
Net\ Revs - Sheet\ Pay &= -1, (1 + vig/2), -1, (1 + vig/2), \ldots
\end{aligned}
$$

that the red figure can reduce or delay the bookmaker's revenues. While in aggregate all bettors may have losses in a given week, some sheetholders will have groups with net winnings. These sheetholders do not front any capital (their red figure increases), and the sheetholders with losing bettors receive commissions. The red figure system front-loads commissions and delays the implicit payment of sheetholder debt.[25] This is an important issue for bookmaker 0 because of the high correlation of within-sheet betting patterns documented in note 23. Since wins and losses are concentrated within sheets, Table 4 shows this bookmaker pays commissions which are quite high relative to net revenues.

Despite these drawbacks, it would be difficult for any given bookmaker to profitably deviate to another compensation system which respects the sheetholders' capital constraints and information advantage. Consider what happens if a bookmaker unilaterally starts paying sheetholders a flat salary or a proportion of betting volume. He will suffer an adverse selection problem: this arrangement will be disproportionately attractive for sheetholders who have low quality clients. This new policy generates a less desirable pool of bettors and will typically lower the bookmaker's profits. Universal adoption of the red figure system is a nash equilibrium as no bookmaker has incentive to deviate.

This analysis suggests that the information asymmetry regarding bettor type (in conjunction with sheetholder capital constraints) is the force driving adoption of the red figure system. Consistent with this view, in my data the sheetholding arrangement is more extensive for larger operations where information asymmetry is more severe. This is also consistent with the slow growth rate of my smaller bookmakers, which rely less heavily on sheetholding,

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where the sheetholder accumulates a \$1 red figure when net revenues are negative. Hence,

$$E(Net\ Revs) = vig/2 \qquad\qquad Std\ Dev(Net\ Revs) = (1 + vig/2)$$

$$E(Net\ Revs - Sheet\ Pay) = vig/4 \qquad Std\ Dev(Net\ Revs - Sheet\ Pay) = (1 + vig/4)$$

A comparison of the rows shows that sheetholder payments are equivalent to a reduction in the vig. This decreases the mean bookmaker return more than the dispersion: the elasticity of the expected revenue with respect to the vig is 1 while the elasticity of the standard deviation with respect to the vig is $vig/(2+vig) \ll 1$. This result generalizes to any sequence with an equal number of wins and losses which has no residual red figure in the last stage (the mean is unchanged and the variance increases by a second order term).

[25]Consider a bookmaker with two 0.50 rate sheetholders whose initial net weekly receipts are \$1000 and $-\$1000$. The bookmaker pays \$500 to the sheetholder with losing bettors and nothing to the other one. While the bookmaker breaks even with the bettors, his net income is $-\$500$.

since they have a limited pool of direct acquaintances whom they could trust as clients. The larger bookmaking operations can leverage the indirect trust which sheetholders foster to more rapidly add bettors.[26]

3.2 Empirics of the Incentive System

I have argued that sheetholders with longer tenure or favorable reputation would have to be rewarded to mitigate problems with the red figure system. This also implies that the sheetholder labor market should follow standard economic theory and compensate more productive workers with higher wages. To empirically assess these claims, I consider the 11 weeks of records for the 13 sheetholders employed by bookmaker 5. This relatively long time period allows me to consider the dynamics of sheetholder behavior (entry and exit) and of wages (the commission rates).

To begin I consider variation in wages. The sheetholders receive rates between 0.25 and 0.50, and each experiences an average of 1.5 rate changes over the sample period. There are slightly more rate reductions. I try to explain this variation using the prior week's results. For sheetholder i in week t I posit the model,

$$Sheetholding\ Rate_{it} = \alpha \times X_{i,t-1} + \nu_i + \epsilon_{it} \tag{1}$$

where $X_{i,t-1}$ is a set of prior outcomes and ν_i is a sheetholder fixed effect. Table 5 column (1) shows that higher rates are given to sheetholders who generated more net revenues and bet volume the previous week (the number of previous bettors also has a small positive effect). A one standard deviation increase in these variables results in a rate increase of 0.11. That is, more productive employees are paid higher wages. Column (2) repeats this estimation omitting the fixed effects but including previous years of service, which range from 0 to 3, and the previous year's net revenue. These variables also have a positive effect on commissions,

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[26]My smallest bookmaker, bookmaker 4, does not appear to have added bettors in the year prior to his arrest. The very large bookmaker 0 had a net increase of 28 bettors, all associated with new sheetholders, over the one month observation period. This is also consistent with the even more rapid growth of internet bookmakers who have little contact with bettors (SportingBet added 100,000 registered customers in 2001).

Other accounts also support this view. Grossman (1998) allowed new bettors into his operation only if he personally knew them or they had been referred by a current customer.

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and I find a similar effect for previous employment in explaining bookmaker 0's rates. The premium for employment tenure is consistent with the reputation story. In the results below I use the variables in column (2) and period indicators to instrument for commission rates to avoid endogeneity issues.

Next I try to explain sheetholder entry and exit behavior. Over the sample period, two new sheetholders were added, two others quit, and one was on hiatus for two weeks. Using a weekly employment indicator I estimate a Cox proportional hazards model,

$$\Pr(Employed_{it}) = \lambda_0(t)\exp(X_{i,t-1}\beta) \tag{2}$$

where $\lambda_0(t)$ is the baseline hazard and $X_{i,t-1}$ are lagged sheetholder characteristics. Table 5 column (3) shows that sheetholders with higher previous bet volume or wages are significantly less likely to exit. No other covariate has a statistically significant effect. Importantly, having a large red figure does not significantly induce quits. This is consistent with a market where sheetholder reputation mitigates the desire to repudiate debt and exit, and I find a similar effect using bookmaker 0's sheetholders.

A potential criticism of this interpretation is that sheetholders with large red figures might channel only a portion of their bettors to other bookmakers where they have no debt. This will reduce bookmaker 5's revenues even in the absence of exits. To investigate this I determine whether larger red figures reduce the daily bet volume or number of bettors for a sheetholder. I estimate,

$$Sheetholder\ Intensity_{it} = \gamma \times X_{i,t-1} + \mu_i + \delta_t + u_{it} \tag{3}$$

where $Sheetholder\ Intensity_{it}$ is the measure of how much "effort" the sheetholder is exerting (the bet volume or number of bettors each day). Importantly, the specification includes day fixed effects δ_t which account for the varying attractiveness of that day's games or any secular trends in gambling. Table 5 columns (4) and (5) present the estimates. The red figure has an insignificant and economically small effect. For example a one standard deviation increase in the red figure ($1000) reduces the daily number of bettors by 0.1 while each sheetholder has on average 9 bettors. These results are consistent with bookmakers acting

in a manner which prevents sheetholders from undermining the red figure system.

4   Prices

In this section I investigate empirical price-setting behavior. The main objectives are: (i) to compare prices (odds) with those prevailing in the legal Las Vegas market, and (ii) to estimate the extent and correlates of price discrimination. Some formalities are relegated to the Appendix. Appendix D.1 defines prices for the different types of wagers, with the key property that prices on opposite sides of a game sum to a constant. Appendix D.2 presents a price-setting model for a profit maximizing bookmaker who faces heterogeneous bettors.

Before turning to the estimates, it is worth commenting on each of the aims of this section. The bookmakers can easily link their prices to those in the legal market. Each bookmaker subscribes to a service which provides real-time Las Vegas odds. Further simplifying this task, bookmakers only accept wagers on the day of an event. While the legal market provides odds on future events, they are somewhat volatile when far in advance of the game.

In contrast, price discrimination is difficult in this market.[27] Two conditions are needed to price discriminate among even a subset of bettors for a subset of games. First, the bettors cannot have access to other bookmakers. This is because bettors presumably will wager at the lowest available price. Second, the bookmaker must know the bettors' sentiment on the games.[28] This is because bettors select which side to wager on, and an unfavorable price for one side of an event implies a favorable price for the other side. For example, making a team overcome a very large spread implies that its opponent is spotted the same large spread. To profitably price discriminate, the bookmaker has to be reasonably certain which side the bettor will select. As I argue below, this may be possible given the personal and repeated nature of the interaction: the illegal bookmaker knows the betting history of his customers.

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[27]There are no technical barriers precluding customer-specific prices. Typically a bettor phones the illegal bookmaker's wireroom, announces his user-name, and then receives the prices for the day's games. Since the bettor's identity is revealed first, the bookmaker could offer him a specific menu of prices. This is distinct from legal bookmakers where transactions are anonymous, and so price discrimination is not possible.

[28]Avery and Chevalier (1999) discuss the conditions under which bettor sentiment influences equilibrium price dynamics. My results extend their empirical analysis which is based on aggregate prices.

4.1 Large Bookmaker

The first set of empirical results focus on the large bookmaker 0, who primarily offers money line baseball wagers. The legal price for baseball moves frequently, with an average of three changes per game during the typical seven hour window when the bookmaker is accepting wagers. These price changes reflect shifts in the sentiment of Las Vegas bettors (Roxborough and Rhoden, 1998). Bookmaker 0's price can be readily compared to the legal price, since this bookmaker records the exact minute a bet is placed.[29] For reference, Table 6 presents the definitions and descriptive statistics for all the variables used in the analysis below.

The objective is to determine how the illegal bookmaker sets prices. I consider the specification,

$$price_{i,t} = \alpha + \beta \times price_{vegas,t} + \gamma_1 X_{i,t} + \gamma_2 X_i + \nu_i + \nu_t + \epsilon_{i,t} \tag{4}$$

where $price_{i,t}$ is the price offered to bettor i at minute t, $price_{vegas,t}$ is the concurrent price on the same wager in the legal market, X_{it} and X_i are matrices of time-varying and time-invariant auxiliary variables discussed below, and ν_i and ν_t are bettor and time fixed effects. When only the first two terms are included, the constant α can be interpreted as the mean deviation from the legal price. $\alpha > 0$ indicates unfavorable prices for the bettors. Similarly, the bettor fixed effects ν_i measure bettor-specific prices, and $\nu_i > 0$ indicates bettor i consistently wagers at unfavorable prices. If the bookmaker seeks to offer Las Vegas prices, then $\beta \approx 1$, all other parameters are roughly zero, and the $R^2 \approx 1$.

Table 7 presents estimates of (4). Column (1) shows the regression without any auxiliary variables or fixed effects. The results are close to what would be predicted if legal prices are offered. The parameter on the Las Vegas price is close to one, the constant is close to zero, and nine-tenths of the bookmaker price variation is explained. However, I can reject a null of equality for either parameter estimate. The statistically significant positive constant means the bookmaker price is typically higher than the legal price, consistent with the raw

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[29]For legal prices I use real-time odds from the Sports Network, as archived on Lexis-Nexis. In all cases I average the two leading Las Vegas bookmakers at the time, Stardust and Hilton. None of the results in this section differ substantially if instead I use: (i) just Stardust; (ii) just Hilton; (iii) Offshore odds.

data in Table 6. This is not simply due the bookmaker shifting the legal price on each game by a constant, because the estimates do not change noticeably if game×team indicators are included. Column (2) adds bettor fixed effects. Now the Las Vegas price parameter and constant are indistinguishable from one and zero respectively, and the R^2 is near one. This means that deviations from the Las Vegas price can be attributed to bettor-specific factors. There is an interesting pattern to the estimated bettor fixed effects. While most are near zero, many more are significantly positive than negative: 26 of the 263 fixed effects are at least 0.02, corresponding to a 9 point money line premium, and only 2 are less than −0.02. This means that ten percent of bettors tend to wager at unfavorable prices while few consistently bet at low prices.

Column (3) of Table 7 omits the bettor fixed effects and adds day of the week indicators and various auxiliary variables.[30] The auxiliary variables include factors specific to the wager (the bookmaker's cumulative position on the side of the wager; time from the game; average wager size) and bettor-specific characteristics (current debt; bet frequency; betting pattern persistence). The first variable is of particular interest since conventional wisdom dictates that the bookmaker increases the price on the side of the game which is experiencing disproportionate betting volume. The R^2 is again near one, and the auxiliary variables have the expected signs.[31] However, the magnitude of most of their effects is small. For example when the bookmaker stands to lose twenty-five thousand dollars if the bet team wins (a position reached in a sixth of wagers), he increases the price by only 0.004 or less than 2 money line points.

The only auxiliary variables in column (3) with large economic effects involve betting persistence, the Herfindahl's. These variables formally capture what is intuitive to the bookmaker: $\mathtt{Herfindahl}_T$ measures whether a bettor has a tendency to bet on the same set of teams, and $\mathtt{Herfindahl}_{FA}$ measures whether he bets for or against each team.[32] For

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[30]The economic effects discussed here are robust to various modifications: including higher orders of the auxiliary variables (up to cubics) and restricting the sample to bets on favorites or home teams.

[31]The positive debt variables indicate indebted bettors wager at unfavorable prices (Sunday Debt is included since this is the last betting day before credit must be repaid). The negative Time from Game parameter means that bets placed near game time occur at an unfavorable price.

[32]The persistence measures are Herfindahl concentration indices which have been re-scaled to ensure the possible range is the unit interval. They are defined over the set of wagers for a given bettor and are time

example, `Herfindahl`$_{FA}$ is one for a bettor with perfect team loyalty– and who always bets for or against some set of teams– and is zero for a non-partisan bettor who evenly splits his wagers for or against teams. The estimates indicate that persistent betting patterns are associated with markedly higher prices. A bettor with perfect team loyalty wagers at prices which are 0.024, or 11 money line points, higher than a non-partisan bettor who evenly splits his wagers. This price difference is so large that the bookmaker can arbitrage.[33] Because of the interaction term, this effect is even larger for bettors who wager frequently. A bettor who wagers one hundred times over the sample (a level which six percent of bettors reach) and has perfect team loyalty pays a price premium of 0.036 relative to a non-partisan.[34]

Columns (4) and (5) of Table 7 repeat the analysis for a special subsample, bets on New York Yankees games. The Yankees are the sentimental favorites throughout much of New York city, and so it should be easier for the bookmaker to discern betting patterns on their games.[35] While the parameters in column (4) are close to those for the full sample in column (1), the price variation which is explained falls considerably. When the sample is restricted to just bets in favor of the Yankees in column (5), the constant is relatively large and positive indicating unfavorable prices. In the remaining bets, which are against the Yankees, the constant is indistinguishable from zero (results omitted). This indicates the bookmaker is not simply linearly shifting the legal price. If he were, the constant in the anti-Yankees sample would be negative since prices on opposite sides of a game sum to a constant by construction. Finally when bettor fixed effects or the betting persistence variables are included the R^2 is near unity (results omitted), meaning bettor-specific factors are explaining a fifth of the price variation.

The price data can be used to quantify how much loyalists are willing to pay to support their team. I define a Yankees loyalist as a bettor who bets for the team in at least ninety

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invariant. I also included a measure of each bettor's persistence using particular bet types, but this variable has an economically insignificant effect.

[33]Arbitrage means the bookmaker can lock in a profit with a simultaneous, offsetting wager in Las Vegas. This is because there is a ten point money line spread, but no commission, on baseball wagers (Appendix A).

[34]`Herfindahl`$_{FA}$ is interacted with the other bettor-level covariates in unreported specifications. These interactions have a small economic effect.

[35]Pricing patterns on New York Mets games are not noticeably different from those in the overall sample.

percent of his wagers involving Yankees games.[36] A quarter of the bettors satisfy this criterion. Under certain reasonable assumptions, Yankees loyalists are willing to pay an extra 4.2 cents for each dollar bet.[37] The willingness to pay is almost twice as large as the standard bookmaker commission rate for baseball.

At the same time, this differential pricing policy has a modest effect on profits. Only a small set of bettors tend to wager at unfavorable prices, and their wagers usually involve relatively small stakes. Further offsetting this is the small number of wagers at favorable prices. I calculate that differential prices increase the bookmaker's net revenue per bet by roughly 0.3 percentage points (details are available upon request). This is far smaller than the two to three percent commission which all bookmakers make on baseball wagers.

Despite the barriers discussed in the preliminaries of this section, price discrimination is the likely explanation for these results.[38] A large majority of bettors tend not to receive prices which are systematically favorable or unfavorable relative to Las Vegas. However some bettors have relatively clear betting patterns, strong team loyalty, and do not seem to have access to other bookmakers. The bookmaker offers such sentimental bettors unfavorable prices on the teams they favor, and the bettors take the unfavorable gamble.[39] The extent of price discrimination is increasing in wagering frequency which could reflect bookmaker learning about a bettor's preferences. This sentimentality should be more pronounced on home-town teams, and in fact a quarter of the bettors are New York Yankees loyalists who consistently wager on their team at quite unfavorable prices. Alternatively, few bettors

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[36]The results here are robust to modifying the loyalist definition: using a one hundred percent or seventy-five percent cutoff; adjusting the cutoff to account for the number of wagers on Yankees games; or using alternative criteria (the bettor wagers on seventy-five percent or more of all available Yankees games; eighty percent or more of his pro-Yankees bets have higher prices than Las Vegas).

[37]The assumptions are: (i) the Las Vegas price reflects the objective odds; (ii) loyalists bet a fixed amount on the Yankees unless the price exceeds some threshold; (iii) the bookmaker extracts all of the rents. The expected return from a \$1 money line bet is $\Pr(Y) \times \frac{1-price}{price} - (1 - \Pr(Y)) \times 1$ where $\Pr(Y)$ is the probability the Yankees win and $price$ is the implicit bookmaker price. Willingness to pay is the opposite of this return as the bookmaker commission is subsumed in assumption (i). This is a conservative estimate because bettors should be willing to wager at even higher prices if they can bargain, e.g. assumption (iii) fails.

[38]An alternative explanation is based on bettor behavior. The patterns documented here might occur if some bettors shop (and wager only at favorable prices) and others take whatever price is offered to them (say one that randomly varies around the legal price). But this theory cannot explain why persistent bettors wager at unfavorable prices, since even non-shoppers should receive both favorable and unfavorable prices.

[39]Appendix D.2 shows that even a profit maximizing bookmaker offers prices which induce sentimental bettors to wager persistently on their preferred team.

consistently wager at favorable prices, and crosstabs reveal those that do bet infrequently and do not have clear betting patterns. These bettors wager heavily and only when there is a large price differential, just as an arbitrageur who has access to Las Vegas would behave. A profit maximizing bookmaker who has strong beliefs on the game relative to Las Vegas would still prefer to accept such wagers with arbitrageurs (see Appendix D.2).

Some additional evidence, contained in an earlier version of the paper, supports the notion of price discrimination.[40] First, I compare prices for different bettors making simultaneous wagers on the same game. A majority of these bets are at different prices, and only bettors with strong team loyalty consistently wager at the higher price. This is direct evidence of bettor-specific prices. Second, I re-estimated the regressions after converting all prices into those for the favorite team (this controls for the bettor's choice of side). While the legal price parameter is similar, the persistence variables are insignificant. This is consistent with price discrimination, since a sentimental bettor's preferred team is sometimes not the favorite. Third, I try to explain the bettor fixed effects from column (2) of Table 7. The goal is to see what characteristics lead some bettors to systematically receive favorable or unfavorable prices. As with the earlier results, the key explanatory variable is team loyalty. Fourth, I focus on bets with large differences from the legal price. Eight percent of bets allow the bookmaker to arbitrage, and these unfavorable prices are highly concentrated among persistent bettors. Alternatively, less than one percent of the bets have such favorable prices that the bettor can arbitrage. The bookmaker offers prices close to Las Vegas unless he is rather sure the bettor will take the unfavorable side. All the patterns discussed here are accentuated for bets on New York Yankees games.

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[40]Qualitative evidence supports the price discrimination interpretation. There are specific references to such practices in the audio tapes from bookmaker 5,

> voice 1: Was that Norm40? Did he play the Knicks again?
>
> voice 2: Yeh. Picked them for a nickel `[a $500 bet]`.
>
> voice 1: What a *****! Don't he realize the boss is charging him four points extra? We might as well just pick his pocket...Andy50 never gets a soft line, he always gets Vegas. A real wise guy `[a well informed bettor]`. `[Re]`member when he busted us on Jack`[sonville]`? He can always get his boys in Vegas to lay off the other way.
>
> *excerpted conversation between wireroom clerks*

The accounts in the literature provide further support. Grossman (1998), Jeffries (2000), and Moore (1996) all mention that illegal bookmakers should utilize past betting patterns to price discriminate between bettors.

4.2 Smaller Bookmakers

I next consider the smaller bookmakers 1, 3 and 4. They primarily take football and basketball bets. Prices for these sports are based on the spread system and are scaled differently than baseball (see Appendix D.1). These bookmakers record only the hour a bet is placed, so I consider various robustness checks in the regressions below such as restricting the sample to events where the Las Vegas line does not move over the bookmaker wagering period. In the interest of brevity I omit these results, which are consistent with my findings.[41]

The very small bookmaker 1 moves his price in almost lockstep with the legal market. Table 8 column (1) shows that the Las Vegas price explains 99.9% of the variation in bookmaker prices. Moreover, it is not possible to reject the null that the constant is zero or that the Las Vegas price parameter is one. Richer specifications do not add explanatory power: it is not possible to reject a null that bettor fixed effects are jointly zero or that the additional covariates listed in Table 7 column (3) are jointly zero (results omitted). This means that the bookmaker does not adjust the price to suit his idiosyncratic circumstances or to successfully price discriminate.[42] The one clear deviation from the legal market involves games with New York area teams. Comparing the constants in Table 8 columns (2) and (3) shows that the price is uniformly shifted against New York teams and in favor of their opponent by roughly one point. It is not possible to reject a null that bettor fixed effects or the `Herfindahl` measures have zero parameters in these regressions (results omitted). This is further evidence against price discrimination and means that persistent pro-New York bettors receive the same price as do non-persistent bettors.

The moderately sized bookmaker 3 also tends to follow the legal prices, but he price discriminates against a small group of bettors. Table 8 column (4) shows that Las Vegas prices can explain about 95% of his price variation. And while the price parameter is quite close to one and the constant is near zero, in contrast to bookmaker 1 both of these

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[41]The coarse time data does not cause problems because Las Vegas spreads typically change in small increments (0.5 or 1 point) and only once or twice per day (and very rarely more than three times per day).

[42]It is not possible to consider arbitrage opportunities without making strong assumptions regarding the entire point distribution. Still it is clear that the price differentials are quite small, and only 16 of the 1893 bets involve at least a two point differential relative to the Las Vegas spread. Also, only 1 out of the 54 bettors has at least a third of his wagers at a one point or larger advantage relative to the Las Vegas spread.

nulls can be statistically rejected. Column (5) shows that these nulls cannot be rejected when bettor fixed effects are included, as would be expected under price discrimination. Examining the estimated fixed effect parameters, a few clearly stand out. While most are indistinguishable from zero, 7 of the 112 are significantly positive and all are greater than 1.5. These bettors wager at unfavorable prices. A much higher proportion of bookmaker 0's bettors had statistically significant price fixed effects. Column (6) shows that these fixed effects are associated with persistent betting patterns. The positive `Herfindahl` parameters indicate persistent bettors are consistently placing wagers at unfavorable prices. These patterns are not accentuated in the subset of games involving New York teams, though again prices are uniformly shifted against the home-town teams (results omitted).

Finally I consider the very small bookmaker 4. He behaves identically to bookmaker 1, setting prices which are indistinguishable from the legal market (omitted). What is of interest is that bookmakers 3 and 4 have identical observation periods, so it is possible to examine contemporaneous price dispersion between illegal bookmakers. Specifically, I compared wagers on each event made in the same hour at the two bookmakers. After removing the seven bettors from bookmaker 3 with significant fixed effects, the correlation in prices is 0.98 (N=79). The price difference has a mean indistinguishable from 0 and is never greater than 1 in absolute value. Smaller illegal bookmakers offer virtually identical prices. Interestingly, this is in contrast to the 1970s when there were large price dispersions among New York city bookmakers (Reuter, 1983). This likely reflects technology change as the cost of obtaining real time odds fell with the spread of pagers and later the internet.

In conclusion, all my illegal bookmakers offer prices which closely mirror those in Las Vegas. However, pricing behavior becomes increasingly sophisticated as bookmaker size increases. Smaller bookmakers offer identical prices to all bettors though they do mark up prices on home-town teams. Larger bookmakers utilize previous wagering patterns to overcome the bettors' power to choose sides and to price discriminate. Discrimination is further evidence of market power, since it implies that bettors have limited access to other bookmakers.

5 Risk, Capital, and Returns

5.1 Overview

An often held claim about bookmakers, both illegal and legal, is that they aim to eliminate risk and to profit entirely from their commissions (Roxborough and Rhoden, 1998). This is referred to as a "balanced book," since the bookmaker's net revenue on an event is the same no matter what the outcome is. Such an objective is difficult to understand unless the bookmaker is extremely risk-averse. In this section I investigate the extent of bookmaker risk-taking and discuss its implications for capital holding, profitability, and preferences.

The illegal bookmaker faces several forms of risk.[43] With the available data I can focus on the component related to the gambling activity itself. The bookmaker may seek to avoid financial risk by setting prices in a manner which yields a balanced book. Even with this objective, the bookmaker may find himself with a position on a side because of imperfect information about bettor preferences or information shocks. The bookmaker has two options to try to hedge his risk. First, he could layoff (place a bet against the team on which he has a position) with another bookmaker. This has the disadvantage that as a bettor he will have to pay a commission to the layoff bookmaker. Second, the bookmaker could try to induce wagers on the team with fewer bets by making its line more favorable (reducing its price). While this preserves his commission, it raises the possibility of being "middled" or having bettors lock-in guaranteed profits.[44] It also can result in excess bets on this team, since some bettors make large wagers when there are price discrepancies with the legal market. Bookmaker 0 experienced two such betting cascades. Instead of these options, the bookmaker might not attempt to offset his position. There was suggestive evidence of this in the last section, which showed that bookmaker 0 makes a very small price adjustment even when he has a substantial position on a game.

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[43]In addition to the possibility of getting arrested and having his assets seized, the bookmaker needs to be concerned with theft by employees and not getting repaid by indebted bettors.

[44]Under the baseball dime line discussed in Appendix A, a middle can occur when the line is moved at least ten points. If the line becomes more favorable for team A, a bettor who earlier bet against A is ensured a profit if he now makes an offsetting bet for A. Under spread systems, any line movement creates a middling opportunity. Here offsetting bets cancel out, except both win when the score difference falls in the wedge between the initial and final lines.

To more formally examine risk-handling, I calculate the possible distribution of net revenues for several bookmakers given the set of wagers each has accepted. The idea is that realized revenues will vary depending on the outcomes of the various games. The main complication I face is that many of the wagers have multiple parts which link the outcomes of different games. Therefore, it is not really possible to say whether a bookmaker has a balanced book on a particular game without specifying the outcome of the remaining ones. Instead I calculate the distribution for each day in its entirety using prices to infer the probability of each game's outcomes. It is computationally impractical to generate the exact distribution for longer periods like a week. Instead I rely on approximation methods, such as Monte Carlo simulations. Appendix E.1 presents the precise algorithm I use to generate the returns distributions.

A potential caveat to these results is my limited information about the role of organized crime. The calculations could be compromised if the bookmakers are not stand-alone enterprises, and some central authority pools risk from several operations. An appendix, which is available upon request, discusses several aspects of the data which are inconsistent with such a monopoly structure. This is not to say that organized crime plays a minor role in this market, but rather that bookmakers make independent decisions and are residual claimants on both profits and losses. For example, the analysis below is generally unaffected if organized crime controls entry and the bookmakers are autonomous franchises.

5.2   Large bookmaker

To begin I consider the large bookmaker 0. This bookmaker never places layoff bets. Figure 2 shows the possible distribution of net revenue for a representative day. While a balanced book has no revenue dispersion, here the standard deviation is $70,000. At the extremes for the day, the bookmaker could be down $210,000 or up $250,000. These values are comparable to the observed daily variation in Table 3. Figure 3 shows that weekly net revenue is also volatile. The standard deviation is $240,000 with extrema -$750,000 and $920,000. Over the four weeks I actually observe, weekly net revenues range between -$400,000 and $300,000.

The simulations reasonably match the observed data along other dimensions as well.[45]

Two forms of uncertainty contribute to the large standard deviations. There is systematic risk, the consistent bet imbalances for teams like the Yankees, as well as idiosyncratic risk specific to particular games. The latter does not simply wash out over time, since later imbalances do not offset earlier ones. This intuition helps explain why the standard deviation increases with the time period, but at a less than linear rate. This is because longer periods sum up more uncertainty, but extreme results are unlikely to repeat multiple times.[46]

The weekly distributions can be used to approximate the minimum capital reserve for the bookmaker. The idea is that the bookmaker must always have enough cash on hand to settle-up with his bettors in case an extremely unfavorable weekly outcome occurs.[47] Minimum capital is zero under a balanced book. I calculate the cash requirement, K_T^*, given various tolerances for bankruptcy, $T \in [0, 1]$. Only very small T values are reasonable given that this bookmaker existed for ten years, and none of my legal contacts had ever heard of an insolvent bookmaking organization. The top panel of Table 9 contains the K_T^* values. In the interest of robustness, I present calculations using three separate approaches which are discussed in Appendix E.1. The capital reserve ranges from a half million to a million dollars, with most values clustered around $750,000. This total is plausible given that the civil forfeiture action indicates the bookmaker had $638,000 in cash when he was arrested.[48] Bookmaking requires substantial up-front investment.

I next calculate annual financial returns, the net revenues and profits. While calibrated to the weekly results, several refinements detailed in Appendix E.2 make the exercise more realistic.[49] In particular I scale up the bookmaker commission rate since my data cover the

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[45]In terms of expected values, the daily data in Figure 2 have a simulated mean of $20,000 while the actual net revenue is $5,000 (on $590,000 in bets); the weekly data in Figure 3 have a simulated mean of $60,000 while the actual weekly net revenue is $120,000 (on $4.0 million in bets).

[46]This follows from the central limit theorem presuming game outcomes are independent. The model in Appendix E.2 shows that the standard deviation increases with the square root of the number of games.

[47]The bookmaker uses petty cash to settle all claims on the weekly settle-up day, while capital markets are available for longer time horizons. The calculation excludes costs, which are typically incurred on a monthly basis, though the values do not change dramatically when weekly prorated costs are included.

[48]Internet bookmaker's appear to require relatively larger reserves. SportingBet, discussed in note 22, held £21 million in cash at the end of 2001. Bookmaker 0's cash reserve is comparable to that for a similarly sized illegal numbers organization (Anderson, 1979), and also for the main layoff bookmaker in Chicago during the late 1910s, after scaling by bet volume (Landesco, 1968).

[49]When I derive the returns just from sampling the weekly distributions, annual profits have a similar (but

low margin baseball season, incorporate the beneficial effect of price discrimination discussed in the last section, more carefully capture the variation in sheetholder payments, and add some implicit costs. Annual net revenues are approximately normally distributed with mean $6.7 million and standard deviation $2.0 million. The probability of negative annual net revenues is virtually zero, but negative weekly revenues occur with a one-third chance. This reflects the relatively higher short term volatility pointed out earlier, and in the data net revenues were negative for one of four weeks. Annual profits are also normally distributed with mean $0.9 million and standard deviation $2 million. Relative to revenues, the smaller mean mainly reflects sheetholder payments as discussed in notes 24 and 25. There is a one-third chance that annual profits will be negative, and this calculation is reasonably robust.[50] The bookmaker actually had negative profits in one of the five years with available data, and the loss was a rather substantial half a million dollars.[51] As a comparison, eight percent of firms in the S&P 500 had negative earnings over 1992-2002 (author's calculation from COMPUSTAT data).

The annual rate of return on capital can be calculated from the profit distribution. I presume the investment capital is $K_0^* \approx$ \$1 million given the bookmaker's long period of operation, though this is not crucial. The expected annual rate of return is 90% and the standard deviation is 200%. A useful contrast is the return in legal financial markets as it represents the opportunity cost of investment capital. Modern portfolio theory predicts a linear relationship between the mean and standard deviation return. I estimate an OLS regression using data from Ibbotson (1996) on various bond and stock classes over 1926-95,

$$
\begin{aligned}
Mean &= \underset{(0.380)}{2.220} + \underset{(0.019)}{0.459}\ StdDev \\
R^2 &= 0.99
\end{aligned}
\tag{5}
$$

where $Mean$ is the average annual rate of return in percent, $StdDev$ is the standard deviation

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lower) mean and standard deviation as those presented below.

[50]If mean profits are actually twice as large, there is still a one fifth chance of negative annual profits. Most of the qualitative conclusions discussed below still hold under similar numerical perturbations.

[51]The historical records only include net revenues and bet totals, and I calculate profits presuming costs follow the structure in Appendix E.2. In the year with a loss the bookmaker appeared to finance his operations out of his own capital reserves.

of the annual return, and the parentheses contain robust standard errors. The bookmaker's calculated rate of return lies one standard deviation below this efficient frontier. He would receive a higher expected return at the same risk level in legal financial markets.[52]

Finally, I use revealed preference arguments to show that the bookmaker's behavior is inconsistent with risk-averse tastes. In the interest of brevity, the formal details are presented in Appendix E.3. The first argument is that if the bookmaker was risk-averse, he should instead have invested his capital in legal financial markets. This is because legal markets provide a higher risk-adjusted rate of return. A second and related argument is based on the bookmaker's choice to invest in the operation rather than a safe asset. This decision is inconsistent with risk-aversion. Intuitively, the bookmaking lottery is so uncertain that no risk-averse agent would select it despite its relatively high expected return.[53] A third approach is to calculate the cost of hedging financial risk through layoffs. Recall that the bookmaker can reduce risk by placing bets against teams on which he has a position. However, this will decrease expected returns since he must pay commissions on layoff bets. By varying the extent of layoffs, the bookmaker can generate various mean and standard deviation combinations. Every one dollar decrease in the annual standard deviation requires a 0.8 dollar reduction in the mean, which is comparable to the tradeoff for legal markets listed in equation (5). The bookmaker's actual choice to never layoff is inconsistent with risk-aversion.[54] The intuition is that the bookmaker forgoes any opportunity to hedge despite its inexpensive price, indicating he does not strongly dislike risk.[55] Notice that these calculations ignore the substantial non-financial risk of running an illegal enterprise, and so are biased towards finding evidence of risk-aversion. Still, the bookmaker is more risk tolerant than at least ninety-five percent of the population based on the results in Barsky et al. (1997).

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[52]A caveat is the bookmaker pays no taxes. But he also faces several other costs about which I have no information, such as payments to organized crime which are typically fifty percent of profits (Binder, 2002).

[53]An alternative explanation is the bookmaker believes he is a better handicapper then his bettors (Levitt, 2002). Some indirect evidence against this view is an analysis of large New York operators of numbers games during the 1970s. While such lotteries were based on objective outcomes and allowed for inexpensive hedging, Reuter (1983) and Reuter and Rubinstein (1982) show numbers banks took on substantial financial risk.

[54]There is an upper bound on the degree of risk-loving, since the bookmaker does not make *risk-increasing* layoffs (wagers for teams on which he has a position). In total the bookmaker is roughly risk-neutral.

[55]The risk inference does not hold if there are large fixed costs associated with layoff betting. However such costs are likely to be small in practice, and the bookmakers discussed in the next sub-section all make layoff bets with no fixed costs.

The results in this section are consistent with the equilibrium argument in Becker (1968). Under the Becker model, entry into crime continues until expected income is below the market rate. This occurs because criminals are risk-loving and accept low mean income in return for the high uncertainty of their profession. Such a model helps explain the bookmaker's relatively unfavorable rate of return compared to legal financial markets, and his decision to maintain maximal financial risk in running his operation.

5.3   Smaller bookmakers

I repeat the calculations for bookmakers 1 and 3. The smaller bookmaker 1 often lays offs bets (roughly every other day), while the moderately sized bookmaker 3 makes only a single layoff bet during the one week of observations. These layoff bets always hedge positions, but the bookmakers do not layoff in every situation where they have large betting imbalances. I include the layoffs in the calculations below.

Figure 4 shows weekly net revenue distributions for the bookmakers. Reflecting his layoffs, bookmaker 1 has a relatively tight distribution with a standard deviation of only $5,300. Bookmaker 3's weekly net revenue has greater dispersion with a standard deviation of $28,400. After scaling these values by daily bet volumes listed in Table 3, dispersion is increasing in size: bookmaker 0 from the last sub-section is the largest, bookmaker 3 is in the middle, and bookmaker 1 is the smallest.

The bottom panels of Table 9 present the minimum capital requirement these simulations imply. Bookmaker 1's reserve is quite small, even given his bet volume, which reflects his layoff policy. Outcomes in the worst tenth of a percentile only require about $15,000 in cash. As result, there is less than fifteen percent chance that his annual profits will be negative. Alternatively, bookmaker 3's capital requirement is about $75,000 and his chance of negative yearly profits is about twenty-five percent (these values should be viewed with caution since they are based on only a single week of data). Scaled by daily bet volume, the capital reserves are again increasing in size for bookmakers 0, 1 and 3.

It is difficult to make broad statements about the annual returns for the smaller bookmakers given the limited observation period. Still it is possible to draw inferences regarding

attitudes towards risk. Because both bookmakers lay off bets, they must be risk-averse. This is because layoff bets reduce expected return, and so reduce utility under risk-neutral or risk-loving preferences. However the extent of risk-aversion is quite limited, and these bookmakers are roughly risk-neutral. Additional calculations indicate that risk tolerance is increasing in the bet volume of the operation.[56]

In conclusion there appears to be a systematic relationship between bookmaker size and risk tolerance. The smallest bookmaker partially hedges his position to limit his risk, while the largest bookmaker is basically a gambler who takes substantial positions on each game. More generally, the conventional wisdom that illegal bookmakers perfectly balance their books is a poor approximation for actual practices. The limited use of layoff bets, which reduce expected return, is consistent with an objective of profit maximization.

6   Conclusion

This paper investigates the practices of illegal sports bookmakers. The industry is of interest because it operates under near classical laissez faire conditions. Simple models of economic self-interest have surprising power in explaining conduct and organization. For example, the structure of the bookmaking operation is shown to reduce information asymmetry and to enhance trust. Economic analysis also highlights shortcomings in conventional wisdom. The highly diversified strategy often ascribed to bookmakers would require implausibly risk averse preferences and is inconsistent with actual practices. Nonetheless, a few aspects of illegal bookmaking require further exploration. The commissions on bets are identical to those offered in the legal market despite differences in market power and consumer choices. Such uniformity minimizes bettor confusion but suggests sub-optimal rules-of-thumb might be used elsewhere. Another topic is a precise specification of the bookmaker objective function. Two practices described here, price discrimination and risk-neutral handling of

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[56]The coefficient of absolute risk aversion (CARA) can be calculated using the approach in Appendix E.3. Bookmaker 1's CARA parameter is 9.7×10^{-6} and bookmaker 3's CARA parameter is 8.1×10^{-6}. Both of these values are virtually zero indicating risk-neutrality. Using the upper bound of bookmaker 0's CARA parameter from Appendix E.3, I have $\overline{CARA_0} < CARA_3 < CARA_1$. This indicates that risk tolerance is increasing with bookmaker size.

financial uncertainty, are consistent with profit maximization but additional evidence is needed. Finally, a more general characterization of the role of the legal fringe is needed. Besides constraining prices, the availability of legal wagering may preclude the use of tactics unfavorable to bettors such as violent debt collection.

It would be interesting to know whether the results here can be extended to other organized illegal markets with legal quasi-substitutes. Two such examples are goods illicitly sold or traded on the internet, such as multimedia or software, and prostitution. In both cases, sellers must make their wares known to customers and yet avoid legal apprehension. Presumably institutions have developed to facilitate the necessary trust. Uncovering such institutions and contrasting them with practices described in this paper should be a lively topic for future research.

This work also helps inform policy debates on the future of sports gambling. First, the results cast doubt on the conventional wisdom that all bookmaking will soon be conducted over the internet. Many of the bettors observed here would be unable to place an internet wager simply because they cannot operate a computer. Another factor is the lack of financial credit with internet bookmakers. This policy is unlikely to change given internet bookmakers' impersonal relationship with bettors, and their lack of legal recourse against bettor default. One potential solution is a growing specialization and interaction between these newer bookmakers and the more traditional ones studied in this paper. In fact recently arrested New York bookmakers have formed alliances with internet bookmakers in which the on shore operations supervise credit lines and debt repayment. Second, the results suggest how the market might reorganize if bookmaking were to be legalized. Because legal contracts would markedly reduce the need for a trusting relationship, nationwide operations which take on a large number of customers could arise. The labor force would also change, with the elimination of the intermediaries to bettors, the sheetholders, and the addition of workers providing more traditional customer services. Finally, an illegal fringe might persist to avoid taxes much as the U.S. experienced following the end of Prohibition.

References

[1] Anderson, A. (1979). *The Business of Organized Crime: A Cosa Nostra Family.* Stanford: Hoover Institution Press.

[2] Avery, C. and J. Chevalier (1999). "Identifying Investor Sentiment from Price Paths: The Case of Football Betting." *Journal of Business.* 72(4): 493-521.

[3] American Gaming Association (2000). *Sports Wagering: An Issue Overview.* http://www.americangaming.org/casino_entertainment/aga_facts/facts.cfm/id/19.

[4] Barsky, R., F. Juster, M. Kimball, and M. Shapiro (1997). "Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study." *Quarterly Journal of Economics.* 112(2): 537-580.

[5] Becker, G. (1968). "Crime and Punishment: An Economic Approach." *Journal of Political Economy.* 76(2): 169-217.

[6] Binder, J. (2002). Personal correspondence.

[7] Coase, R. (1937). "The Nature of the Firm." *Economica.* 4(16): 386-405.

[8] Commission on the Review of the National Policy Toward Gambling (1976). *Gambling in America: Final Report of the Commission on the Review of the National Policy Toward Gambling.* Washington: U.S. Government Printing Office.

[9] D'Angelo, R. (1985). "The Social Organization of Sports Gambling," in *The Gambling Studies: Proceedings of the Sixth National Conference on Gambling and Risk Taking,* W. Eadington editor. Reno, NV: University of Nevada, Reno.

[10] Daniels, T. (1993). *The Wise-Guy's Bible.* Unknown location: North Shore Business Printers and Publishers.

[11] Genesove, D. and W. Mullin (1998). "Testing Static Oligopoly Models: Conduct and Cost in the Sugar Industry, 1890-1914." *RAND Journal of Economics.* 29(2): 355-77.

[12] Glaeser, E., B. Sacerdote, and J. Scheinkman (1996). "Crime and Social Interactions." *Quarterly Journal of Economics.* 111(2): 507-48.

[13] Glickman, M. and H. Stern (1998). "A State-Space Model for National Football League Scores." *Journal of American Statistical Association.* 93: 25-35.

[14] Grossman, L. (1998). *Confessions of An Illegal Sportsbookie.* Interview on *AudioVegas,* http://real.axion.net:8080/ramgen/ruonthenet/audio/s0001.rm.

[15] Ibbotson (1996). *Stocks, Bonds, Bills, and Inflation Yearbook.* Chicago: Ibbotson Associates.

[16] Jeffries, J. (2000). *The Book on Bookies: An Inside Look at A Successful Sports Gambling Operation.* Boulder, CO: Paladin Press.

[17] Landesco, J. (1968). *Organized Crime in Chicago (Part III of The Illinois Crime Survey, 1929).* Chicago: University of Chicago Press.

[18] Lasswell, H. and J. McKenna (1972). *The Impact of Organized Crime on an Inner City Community.* New York: The Policy Sciences Center, Inc.

[19] Levitt, S. (2002). "How Do Markets Function? An Empirical Analysis of Gambling on the National Football League." typescript.

[20] Levitt, S. and S. Venkatesh (2000). "An Economic Analysis of a Drug-Selling Gang's Finances." *Quarterly Journal of Economics.* 115: 755-89.

[21] Manteris, A. (1991). *SuperBookie: Inside Las Vegas Sports Gambling.* Chicago: Contemporary Books.

[22] Moore, J. (1996). *The Complete Book of Sports Betting.* New York: Carol Publishing Group.

[23] National Gambling Impact Study Commission (1999). *National Gambling Impact Study Commission Final Report.* http://www.ngisc.gov.

[24] Nevada State Gaming Control Board (various years). *Gaming Revenue Report [Annual Report].* State of Nevada Gaming Control Board: Carson City.

[25] Prendergast, C. (1999). "The Provision of Incentives in Firms." *Journal of Economic Literature.* 37: 7-63.

[26] Reuter, P. (1983). *Disorganized Crime: The Economics of the Visible Hand.* Cambridge, MA: MIT Press.

[27] Reuter, P. and J. Rubinstein (1982). *Illegal Gambling in New York: A Case Study in the Operation, Structure, and Regulation of an Illegal Market.* Washington DC: US Department of Justice.

[28] Rosencrance, J. (1987) "Bookmaking: A Case Where Honesty is the Best Policy." *Sociology and Social Research.* 72(1): 7-12.

[29] Rosner, B. (1976). "An Analysis of Professional Football Scores," in *Management Science in Sports,* R. Machol and S. Ladany editors. Amsterdam: North-Holland Publishing Company.

[30] Roxborough, R. and M. Rhoden (1998). *Sports Book Management: A Guide for the Legal Bookmaker.* Las Vegas: Las Vegas Sports Consultants.

[31] Sasuly, R. (1982). *Bookies and Bettors: Two Hundred Years of Gambling.* New York: Holt, Rinehart and Winston.

[32] Sauer, R. (1998). "The Economics of Wagering Markets." *Journal of Economic Literature.* 36(4): 2021-64.

[33] Shin, H. (1991). "Optimal Betting Odds Against Insider Traders." *The Economic Journal.* 101: 1179-85.

[34] Stern, H. (1991). "On the Probability of Winning a Football Game." *The American Statistician.* 45(3): 179-183.

[35] Strumpf, K. (2003). "Gamblers: An Analysis of a Unique Panel of Bettors." typescript.

[36] Williamson, O. (1975). *Market and Hierarchies.* New York: Free Press.

Appendix (not intended for publication)

A Sports Wagering Primer

The mechanics of sports betting are virtually identical for legal and illegal bookmakers. The basic sports bets is a binary proposition called a straight bet. One straight bet is to wager on the winner of a game. Basketball and football use a spread: the bookmaker places some point handicap on one team which is only considered the winner if it exceeds this amount. For example if the New York Giants are a five point favorite over the the Philadelphia Eagles, when the Giants win by more than (less than) five points then bets on the Giants (Eagles) win. Ties are considered a push and all bets are refunded. The bookmaker also charges a commission or a *vig* (from the Yiddish vigorish; this is sometimes also called "juice"). The vig is universally ten percent and is only applied to losing bets. Thus a one dollar wager yields the bettor one dollar on net if he wins and costs him $1.10 if he loses.[57]

Baseball has a money line system. Here the bet is literally on the winner of the game, but one team is designated a favorite and pays out at a lower rate. Prices/odds are listed in terms of the amount needed to win $100 (for the favorite) or the payoff for a $100 bet (for the underdog). While there is no vig in baseball, the bookmaker still has an advantage because of the gap in these prices. Current Las Vegas bookmakers and my bookmaker 0 use a dime line meaning there is a $10 gap. For example suppose the New York Mets are listed as -130 (the negative indicates favorite) and their opponent the Philadelphia Phillies is listed as +120; this means a $130 bet on the Mets is needed to win $100 while a $100 bet on the Phillies only pays $120.[58] At different times the twenty cent line ($20 gap in the price for the favorite and underdog) and even larger wedges were common.

Hockey has several systems which incorporate elements of spreads and money lines. The bookmakers in my sample use the puck line which has a spread (like football or basketball), but there is a half goal difference between the favorite and the underdog and there is no vig. Other sports like boxing, golf, and NASCAR have minor variants of these systems.

The other kind of straight bet is an over/under bet. Here the goal is to pick whether the total number of points/runs exceeds the total listed by the bookmaker. An over (under) bet wins if the total is greater than (less than) the listed number. Ties are considered a push and all bets are refunded. The ten percent vig is applied to losing bets. There are variants like the money line which also give differential payoffs.

Finally, the basic straight bet can be combined in a variety of ways. Bets can be conditional on the outcome of other bets, and multiple events can be bet simultaneously for the possibility of a large payoff. Table 10 summarizes the main forms of such exotic bets. Complexity increases as we move down the table, and the exotic bets at the bottom have quite intricate payoff structures. Table 10 also shows the commission rate for each bet type presuming the bookmaker does not have a position on any side of the event(s). An Appendix which is available upon request provides details for these calculations.

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[57]A variant of the straight bet allows the bettor to buy points or move the line in one direction or the other. Such a "teaser" bet requires the bettor to win multiple events and/or to face a higher vig.

[58]When the favorite advantage becomes large enough, the dime line gap increases. The typical scale is $15 when the favorite is -200, $20 when the favorite is between -200 and -250, and $30 when the favorite is less than -250.

B Estimating Market Power

This section presents details on approximating industry conduct. The key assumptions are: bookmakers perfectly balance their books, so their revenue is the product of their vig/commission rate and bet volume; bet volume is determined by the vig which is charged; costs are determined by bet volume; all bookmakers have identical revenue and cost functions; bookmakers maximize profits; the game is static and involves no uncertainty; Cournot-Nash characterizes firm interaction. The reasonability of the balanced book assumption is discussed in Section 5.

A bookmaker i selects his vig, v_i, to maximize profit given a set of N identical competitors and the above assumptions. His profits are,

$$\pi(v_i) = v_i B_i(v_1, \ldots, v_N) - C(B_i(v_1, \ldots, v_N)) \tag{6}$$

where $B_i(v_1, \ldots, v_N)$ is his total bet volume (with $\partial B_i / \partial v_i < 0$, $\partial^2 B_i / \partial v_i^2 > 0$), $v_{\sim i}$ are the other bookmakers' prices, and $C(\cdot)$ is his costs (with $\partial C / \partial B_i > 0$, $\partial^2 C / \partial B_i^2 < 0$). Solving the first order condition with respect to v_i and using the symmetry assumption shows all bookmakers charge the same vig, v, which satisfies the familiar formula,

$$\theta = -e^D \frac{v - MC}{v} \tag{7}$$

Here $e^D \equiv (\partial B / \partial v)(v / B)$ is the vig/price elasticity of industry bet revenue $B \equiv \sum_i B_i$, and $MC \equiv \partial C / \partial B_i$ is the common marginal cost with respect to bet volume. $\theta \equiv N^{-1}$ is the measure of industry concentration with $\theta = 1$ indicating a monopoly and $\theta = 0$ indicating perfect competition.

To calculate the elasticity-adjusted Lerner index (the right hand side of (7)), the "new empirical industrial organization" literature relies on industry aggregate data and exogenous shocks. Instead I have a limited sample of firm-level data which allows for direct (but imprecise) estimates of the underlying structural parameters. Genesove and Mullin (1998) show these two approaches yield similar estimates of θ. The specific values are calculated as follows.

- v. I take the average vig (commission rate per dollar bet) for all wagers in the sample (bookmakers 0, 1, 3, 4). Recall from Table 10 that the balanced book commission rate varies across sport and bet type. The bet size-weighted, sample mean is $\hat{v} = 0.031$.

- MC. Using the annualized values for the five bookmakers in Table 4 and adding in the opportunity cost of capital based on the reserves in Table 9, I estimated the regression,

$$Cost_i = 241300 + 0.009 \times Bet\,Volume_i$$

  These estimates indicate $\widehat{MC} = 0.009$. Adding higher orders of Bet Volume did not improve the adjusted R^2. While this calculation omits costs related to bookmaking's illegal status (e.g. payments to organized crime or bribes to the the police), it is not clear whether this will influence $\widehat{MC}$ since these may simply be fixed costs.

- e^D. It is unclear how to estimate this from the data since there is a common commission system. I use the variation in rates across sports and bet types. A problem is that

wager variation across these categories may reflect tastes. To mitigate this possibility, I focus on bookmaker 0 bettors who wager on both football and baseball. Using daily bet totals for the 22 days with data I estimate the log-linear specification,

$$\ln(Bet\ Volume_t) = 11.197 - 0.491 \times \ln(vig_t)$$

where vig_t is the mean commission rate for bets made in day t. This suggests $\widehat{e^D} = -0.491$. Since the goal is estimating industry-wide demand, this presumes that bettors for bookmaker 0 have average price responsiveness.

Substituting these values into (7) yields $\theta = 0.35$.

C   Geography and Trust for Small Bookmakers

The smaller bookmakers have few if any outside employees, and these bookmakers have frequent personal contact and familiarity with their bettors. Part of this familiarity stems from a relatively stable client base: Table 3 shows that few bettors exit from the small operations. Another factor is close geographic proximity. Figure 5 maps the place of business for bookmaker 1 and many of his clients based on his address book listings.[59] Two-thirds of the bettors lived within two miles of the business and/or along a major thoroughfare allowing quick access. Suggestive evidence indicates the participants share a common background. While I have detailed information regarding the bookmaker, many of the bettors are listed by code names in the records. Instead I matched address book listings to their 1990 Census tracts. Four-fifths of the bettors lived in tracts whose residents resembled the bookmaker. These tract residents were primarily white Italian-Americans, and they had roots in the community. Few had advanced education degrees, and their income was near the U.S. median value.[60] In addition, there do not appear to be any women bettors.

This common background enhances trust within small bookmaking operations. Bookmakers have to trust their bettors to repay their debts and to not contact the police. It is easier to monitor and trust a small group of individuals who live nearby, have frequent personal contact, and come from a similar ethnic background. An outsider who lacks one or more of these traits and wants to become a bettor is likely to be turned away. Only those with favorable reputations can partake in gambling. According to undercover detectives with the Kings County District Attorney office, this was one of their primary difficulties when infiltrating a small bookmaking operation.

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[59]When only a phone number is listed, I use the reverse look-up service Anywho `http://www.anywho.com/telq.html` to find the associated address. Because the listing for some numbers did not perfectly match the name or code-name for the bettor, I had to classify the imputed addresses ("probable," "possible" or no match). The bookmaker's address is for the final listing given in the court documents.

[60]I used the American FactFinder `http://factfinder.census.gov/servlet/BasicFactsServlet` to find the 1990 Census tract data (STF3 sample) for each definite or probable match from note 59. Four-fifths of this sample lived in tracts whose residents were 85% or more white, 35% or more Italian-American, 70% or more had lived in same house for the last five years, and 75% or more had no more than a high school degree. All these tracts had median family incomes within five thousand dollars of the overall U.S. median.

D   Prices

D.1   Definitions

In all sporting event the bookmaker offers bettors a "price" for each side of an event which is fixed at the time of the wager.[61] The price is determined by the spread (in football, basketball and hockey) or the money line payoff (in baseball). For spread bets, prices are the negative of the spread so higher values are less favorable. To conform to this convention, I take the actual spread (not its negative) for over bets which win if the total points scored exceeds some number.

For money lines, prices should be restated in terms of the implicit odds of winning (the original money line is not cardinal: a ten point gap has a different meaning depending on the proximity to 100 or -100). The idea is that wagers placed at higher odds receive a lower payoff, so the price is higher. A team with money line l has an implicit price/odds,

$$
price = \begin{cases} -l/(100 - l) & \text{if } l < -100 \\ 100/(100 + l) & \text{if } l \geq 100 \end{cases} \tag{8}
$$

The price/odds are defined so that a bet has zero expected return. Alternatively, $(1 - price)/price$ is the net return from a winning one dollar wager. Because of the bookmaker's commission, the sum of the odds for the two teams will slightly exceed one. It is sometimes convenient to look at price differences. Under a money line (presuming both Las Vegas and the bookmaker agree on which team is the favorite),

$$
\Delta price = \frac{100(l_{bookmaker} - l_{vegas})}{(100 + |l_{bookmaker}|)(100 + |l_{vegas}|)} \tag{9}
$$

At bookmaker 0's sample mean $l_{bookmaker} \approx -110$, when $l_{vegas} = -115$ then $\Delta price \approx 0.011$.

It is important to note that both the illegal and legal bookmakers have the same commission structure during the observation period. Hence, prices can be defined using the same formulae for both sectors.

D.2   Price-Setting Framework

This section presents a simplified conceptualization for how the bookmaker might set prices. Initially the following are maintained assumptions: the bookmaker is a risk-neutral profit maximizer; there are no commissions or variable costs; there is a single game; there are no dynamics; each bettor bets a fixed amount and no more than once; the bookmaker has limited information about each bettor's preferences. Some of these will be weakened later in the section.

Suppose the bookmaker sets a price $p \in [0, 1]$ to wager on team A. A winning bet on A pays $(1 - p)/p \in [0, \infty)$ per unit where the payoff is decreasing in p. All this holds identically for the opposing team B substituting $1 - p$ for p. The bookmaker believes q is the probability team A will actually win. Each bettor will wager one unit on exactly one side of the game.

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[61]This is distinct from a parimutuel system in which the price is not fixed until wagering has finished. All wagers on a given side have the same price under a parimutuel while under sports betting wagers on the same side can have different prices.

The bookmaker believes betting preferences are summarized by the distribution function $F(p)$: if he sets a price x for team A, he will receive $1 - F(x)$ bets on team A and $F(x)$ on the opponent. The bookmaker's expected profits are,

$$E\pi(p) = q\left(-\frac{1-p}{p}(1 - F(p)) + F(p)\right) + (1-q)\left((1 - F(p)) - \frac{p}{1-p}F(p)\right) \qquad (10)$$

The necessary profit maximizing condition is,

$$q\left(\frac{1 - F(p)}{p^2} + \frac{F'(p)}{p}\right) + (1-q)\left(-\frac{F(p)}{(1-p)^2} - \frac{F'(p)}{1-p}\right) = 0 \qquad (11)$$

where $F'(p)$ is the density of bettor preferences. One obvious implication of this condition is that the optimal price will depend on some combination of the bookmaker's preferences, q, and the bettors' preferences, $F(p)$. It is difficult to make many other statements without additional assumptions about bettor preferences. For example if $F(p)$ is uniform ($F(p) = p$, $F'(p) = 1$) then the solution is,

$$p^* = \frac{q^{0.5}}{(1-q)^{0.5} + q^{0.5}} \qquad (12)$$

which is a compromise between the bookmaker and bettor beliefs. More generally it is not optimal to "balance the books" or select price so $F(p) = 0.5$. Typically this requires knife-edge assumptions about preferences (e.g., in (12) $p^* = 0.5 \leftrightarrow q = 0.5$).[62]

Shin (1991) provides microfoundations for the above approach. In Shin's model, there are a continuum of bettors with uniformly distributed beliefs and a single insider bettor who knows the winning side. A profit maximizing, monopolist bookmaker sets prices on both sides of the gamble. When there are no commissions (the prices sum to one), my (12) holds. Shin also points out prices satisfy the square root rule $p_1^*/\sqrt{q_1} = p_{\sim1}^*/\sqrt{q_{\sim1}}$ which implies the *favorite-longshot bias*: the ratio of market to objective odds, p^*/q, is decreasing in q. This relationship holds under alternative bookmaker objective functions such as book balancing (results omitted).

One important implication of the profit maximizing hypothesis is that the objective function (10) is separable across bettors. So if price discrimination is possible, each bettor's price can be treated in isolation. Suppose then the bookmaker can identify a bettor as belonging to one of three types of bettors. The first type are are those for whom he does not have any specific information about their individual preferences. They are offered a price matching (11), e.g. he presumes their preferences are a draw from $F(p)$. The second type are arbitrageurs who have access to Las Vegas markets and wager only to profit from price differences. An arbitrageur's demand function is,

$$d^A_{arbitrageur}(p) = \begin{cases} 1 & \text{if } p_{vegas} - p > C \\ 0 & \text{otherwise} \end{cases} \quad , \quad d^B_{arbitrageur}(p) = \begin{cases} 1 & \text{if } p - p_{vegas} > C \\ 0 & \text{otherwise} \end{cases} \qquad (13)$$

---

[62]More generally, the following conditions are the weakest I could find which ensures a balanced book is optimal: **(A1)** $q = 0.5$, **(A2)** $F(p)$ is single peaked at $p = 0.5$: $F'(p) \gtreqless 0 \leftrightarrow p \lesseqgtr 0.5$, **(A3)** $F(0.5) = 0.5$.

where p_{vegas} is the prevailing Las Vegas price for team A and $C > 0$ is a transaction cost. The optimal price must come from a triple, $p^*_{arbitrageur} \in \{p_{vegas} - C, (p_{vegas} - C, p_{vegas} + C), p_{vegas} + C\} \rightarrow \{d^A = 1, d = 0, d^B = 1\}$. In the most likely scenario where p_{vegas} and q are close then the middle price is used and the arbitrageur does not wager. The third group are sentimentalists who have strong team loyalties (say to team A) and whose demand functions are,

$$d^A_{sentimentalist}(p) = \begin{cases} 1 & \text{if } p < \overline{p} \\ 0 & \text{otherwise} \end{cases} , \quad d^B_{sentimentalist}(p) = 0 \tag{14}$$

The sentimentalists will only wager for their preferred team and will do so so long as the price is less than their reservation value $\overline{p}$. The optimal price must come from a pair, $p^*_{sentamentalist} \in \{\overline{p}, (\overline{p}, 1]\} \rightarrow \{d^A = 1, d = 0\}$. In the typical case p_{vegas} and q are close, and the bookmaker will offer $\overline{p}$ and wagering occurs. It is almost surely the case that this price exceeds the one in Las Vegas, $\overline{p} > p_{vegas}$.

The framework can be extended to consider two other issues. First, suppose the bookmaker is risk-averse. In general as the bookmaker's risk-aversion increases he will select a price that gets him closer to a balanced book. In the limit when he is infinitely risk-averse he will ignore any profitable opportunities presented by the bettor preference distribution and perfectly balance his book. Second, dynamics can be added. Suppose there are two periods and bettors can wager once in each period. Also suppose some information arrives between the periods which shifts q and $F(p)$. While the bookmaker would like to shift the price in the second period to fully reflect the new parameters, he has to be concerned about middling: bettors lock in a profit by offsetting their first period wager with a bet on the other team. Middling is not necessarily a bad thing for the bookmaker since he might believe the first period wager is more likely to win, but it complicates his price setting. In some preliminary work, I have found that the bookmaker is constrained to offer a second period price which does not substantially differ from the first period price even when there are large parameter changes.

E Revenue and Profit Distributions

E.1 Revenue Distribution and Minimum Capital

This section presents the algorithm for calculating the distribution of returns and the related minimum capital requirement which ensures solvency. Let Θ be the set of possible event outcomes and $\mathcal{B}$ the set of possible bet types (straights and exotics). Then the bookmaker's (gross) profits for some outcome vector $\theta \in \Theta$ is,

$$\pi_\theta \equiv \sum_{B \in \mathcal{B}} \pi^B_\theta \tag{15}$$

where the payoff from each bet type π^B_θ can be calculated from the individual wagers and the structure in Table 10. As an example, for straight bets the payoff is a simple sum, $\pi^S_\theta = \sum_i \pi^S_{\theta_i} \equiv \sum_i \sum_b -\mathcal{S}_b(\theta_i)$, where $\mathcal{S}_b(\theta_i)$ is the bookie's pay-out on bet b if the outcome of the ith event is θ_i. The minimum capital requirement is,

$$K^* \equiv \max(-\min_\theta \ \pi_\theta, 0) \qquad (16)$$

The calculations are computationally burdensome for two reasons. First, having exotic bets means that each event cannot be treated in isolation but rather all joint outcomes must be considered.[63] Fortunately, linkages between different days can typically be ignored since almost all exotic bets involve events on the same day. Second, there are a large number of outcomes. Under the spread system used in football, basketball and hockey, several possible outcomes for *each* event must be considered since several different lines are wagered. That is, the outcome of each event is not simply discrete. Even for baseball, where bets hinge only on the discrete event outcomes (win, lose), there are 2^N outcomes where N is the number of events; on a typical day involving 14 games, payoffs for $16,384$ outcomes must calculated.

The minimum capital under various tolerances, $T \in [0,1]$, for bankruptcy will also be calculated. If the outcomes are ordered so $\pi_{\theta^1} \leq \pi_{\theta^2} \leq \ldots$ and p_{θ^i} is the probability of outcome θ^i, then

$$K_T^* \equiv \max(-\min_{\theta^j} \ \pi_{\theta^j} : \sum_{i \leq j} p_{\theta^i} \geq T, 0) \qquad (17)$$

The formal procedure I use is:

- *calculate daily return distribution.*

  1. *Baseball (bets are on discrete outcomes).* I first convert the money line for each wager into odds using (8). The probability of some event i (game outcome) p_{θ_i} is the average of these odds. The results are largely unaffected if instead the final Las Vegas odds are used. Finally, presuming each game outcome is independent the probability of some daily outcome (vector of game outcomes) θ_D is $p_{\theta_D} = \prod_{i \in D} p_{\theta_i}$.

  2. *Other sports (bets are based on outcomes against the spread).* Analytic probabilities for spread events require distributional assumptions. Following the extensive statistics literature (see Glickman and Stern, 1998 and Stern, 1991), I presume each game's point differential and total is independently normally distributed with mean at the final Las Vegas spread and standard deviation calculated from each sport's actual outcomes for that season.[64] The daily distribution can then be simulated: I take 25,000 independent draws from the vector of normal distributions with each draw representing an outcome for all of the events being wagered upon. Each draw is used to calculate the payoff from all wagers (e.g. whether the outcome point differential or total exceeds the spread fixed by the bet) and a daily payoff. The simulated daily distribution gives equal probability to the daily

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[63]Consider an example with two events A, B and a single reverse bet $\mathcal{R}(A,B)$ which depends only on wins (W) and losses (L). Using Table 10, it should be clear that the bookmaker's profit will be different for each of the four outcomes (W,W), (W,L), (L,W), (L,L).

[64]The data to calculate standard deviations come from `http://www.goldsheet.com` and `http://www.covers.com`, and I base the score differentials on the home team. Using these data I also calculated the Shapiro-Wilk normality test and was typically unable to reject the null of a normal distribution. In the few cases where normality is rejected (basketball and score totals), the violation is due mainly to asymmetric tails. The tails are not central to the calculations which are largely based on shape around the mode.

payoff from each draw, $p_{\theta_D} = p$.[65]

aside on using market prices for odds. This presumes the prices provide objective odds whereas the theory in Appendix D.2 suggests the underdog (favorite) odds are systematically overstated (understated). My bookmakers accepts greater bet volume on favorites, so this means the net revenue simulations have a positive bias. To ensure robustness I consider two transformations of the odds for bookmaker 0's money line: (i) a 25% reduction in the favorite-underdog odds differential; (ii) the square root transformation from (12). The simulations did not substantially change. This is because only a quarter of the market odds are outside the range 0.4 to 0.6, and the transformations only have large effects far from 0.5.

- *approximate weekly distribution and K_T^*.* The bookmaker typically settles up with bettors at the end of the week. Unfortunately, it is infeasible to explicitly calculate the weekly distribution, e.g. a typical week with 14 baseball games per day involves $(2^{14})^7 \approx 10^{29}$ possible permutations. I calculate three approximations, which are listed in order of increasing appeal.

  1. *average the daily returns.* The weekly distribution is presumed to be seven times the average daily return. This overstates the likelihood of extreme outcomes and thus K_T^*.

  2. *approximate the daily return with a normal distribution.* If each day's return is independent, then the weekly return is $\mathcal{N}(\sum_t \mu_t, \sum_t \sigma_t^2)$ where μ_t, σ_t^2 are the daily means and variances. The weekly minimum capital requirement can be explicitly calculated, $K_T^* = -(\sum_t \sigma_t^2)^{0.5}\Phi^{-1}(T) - \sum_t \mu_t$ where $\Phi(\cdot)$ is the standard normal distribution. The main weakness with this approach is that the normality assumption often fails (the daily returns fail the skew-kurtosis test). Visual inspection suggests that the data histogram have thin tails suggesting the normal approximation overstates the K_T^* for small T.

  3. *Monte Carlo simulation.* The weekly distribution can be generated by a large number of simultaneous draws from the underlying daily return distributions p_{θ_D} (assuming independence across days). I use 25,000 draws per week.

calculate K_T^* using (17). A K_T^* value for each week of the data (if more than one is available) is calculated for methods 1-3 above. The average of these weekly values are reported in the text.

E.2 Modified Annual Distribution (Bookmaker 0)

An earlier version of the paper discussed how to approximate annual revenue and profit distributions using Monte Carlo simulations and the limitations of this approach. Instead, I incorporate certain refinements into the calculations using the following simplified framework:

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[65]Two simplifying assumptions should be noted: (i) the dependence between totals and scores for a give game is ignored; (ii) the empirical clumping of key numbers in football score differentials (e.g. 3, 7, and 10) is smoothed over in the presumed normal distribution. It is not clear how to deal with (i) in general. As a robustness check for (ii), I employed the discrete distribution approach in Rosner (1976) on a subset of games and found qualitatively similar simulations.

- All wagers are straight bets of amount $\$M$. The bookmaker pays $\$M$ for winning bets and collects $\$(1 + vig)M$ from losing bets.

- For each event there are N wagers of which s are offsetting bets (one on each side of the event) and $N - 2s$ are unmatched bets. The bookmaker collects money from the unmatched bets with probability 0.5.

- There are G events which have independent outcomes but are otherwise identical as described above.

This abstracts from the complications of dependent events (straight and totals bets on the same game), exotic and unequal sized wagers, money line wagers (differential win probabilities and payoffs), and line moves (non-binary event outcomes). It also presumes there are no skilled handicappers which is consistent with note 11.

Net revenues are the sum of the G independent bernoulli variables,

$$Net\ Revenues = M \sum_{g=1}^{G} \left(s \times vig + (N - 2s)((0.5, -1) \oplus (0.5, 1 + vig)) \right) \quad (18)$$

where the first term is the sure return from the offsetting bets and the second term is the probabilistic return from the unmatched bets. Presuming G is large, the central limit theorem implies,

$$Net\ Revenues \sim \frac{M}{2} \mathcal{N} \left(NG\ vig, (N - 2s)^2 G(2 + vig)^2 \right) \quad (19)$$

where $\mathcal{N}(\mu, \sigma^2)$ is the normal distribution with mean μ and variance σ^2.

Profits are net revenues minus costs. Variable costs are payments to sheetholders which are modeled as a reduction in the commission ($\widetilde{vig} < vig$, see note 24). There are two forms of fixed costs. Direct fixed costs (DFC) are expenses needed to keep the operation in business such as rent or utility payments. Implicit fixed costs (IFC) include the bookmaker's implicit salary, relocation costs to avoid apprehension, and the present discounted value of asset losses if the police shutdown the operation (see note 68 below). Hence,

$$Profits = Net\ Revenues(vig = \widetilde{vig}) - DFC - IFC \quad (20)$$

and using (19),

$$Profits \sim \mathcal{N} \left(NMG\ \frac{\widetilde{vig}}{2} - DFC - IFC, (N - 2s)^2 M^2 G \frac{(2 + \widetilde{vig})^2}{4} \right) \quad (21)$$

The final step is to select parameter values for bookmaker 0. For the initial primitives I use the sample means,

$$M = \$1100,\ N = 34 \quad (22)$$

For G I sum the annual number of games in 1994-1995 for professional football, baseball, basketball, and (when Las Vegas odds are listed) college football and basketball. I adjust this total to account for the proportion of days in the sample when the bookmaker did not accept wagers. The s parameter cannot be calculated directly from the data since most of the bets are differential payoff money line wagers and several are exotic wagers. Instead I base

s on the daily net revenue simulations. From (19), $s = \frac{N}{2} - \frac{\sigma}{M(2+vig)\sqrt{G}}$ where σ^2 is the net revenue variance. I use this formula to solve for daily s values (using each day's parameter values in the data and each day's σ from the revenue simulation) and then average the daily values,

$$s = 4, \ G = 4500 \tag{23}$$

For the bookmaker commission rate vig, I use the actual Nevada margin for 1995 multiplied by two since commissions are only paid on losing bets (I increase the vig by 0.3% reflecting the net benefit of price discrimination as discussed in Section 4.1).[66] For the commission exclusive of sheetholder payments $\widetilde{vig}$, I multiply vig by one minus the empirical ratio of sheetholder payments to revenues from Table 4,[67]

$$vig = 0.08, \ \widetilde{vig} = 0.025 \tag{24}$$

The final terms are the costs in the profits equation. DFC is based on annualizing the non-sheetholder costs in Table 4. IFC is the sum of the bookmaker's implicit salary, the relocation costs, and the present discounted value of asset losses from arrests.[68]

$$DFC = \$300,000, \ IFC = \$900,000 \tag{25}$$

The qualitative conclusions in the text are robust to various modifications of these somewhat ad hoc cost values. Plugging these parameter values into (19) and (21) and using the properties of normal distributions yield the values in the text (I use $G = 85$ when calculating weekly values).

E.3   Risk Preference Calculation (Bookmaker 0)

The annual distributions can be used to approximate the bookmaker's risk preference. For analytical simplicity, suppose the bookmaker has a CARA utility function,

$$u(x) = -\exp(-\gamma x) \tag{26}$$

where x is income/wealth and γ is the CARA.

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[66]Consistent with this connection to the legal market, during July 1995 bookmaker 0's hold, -1.7%, is just above that in Nevada, -2.1% (Nevada State Gaming Control Board, 31 July 1995).

[67]As a check, I calculated $\widetilde{vig}$ as one minus the mean sheetholder rate times vig. This results in a somewhat higher $\widetilde{vig}$ as would be expected from the discussion in notes 23 and 25.

[68]The implicit salary is that for a CEO of a 75 employee firm ($\$200,000$). Relocation costs are based on the affidavits of police detectives participating in undercover surveillance and phone wiretaps of this bookmaker. These records indicate that the operation moved each of its wirerooms every other month and that each move cost in excess of $\$15,000$ (giving a total cost of roughly $\$200,000$). The PDV of asset losses presumes there is a constant annual probability of arrest, p, at which time the investment capital, K^*, is lost. Hence,

$$PDV \ Loss \equiv pK^* \sum_{t=1}^{\infty} \delta^t (1-p)^t = \frac{pK^*}{1 - \delta(1-p)}$$

where δ is the discount rate. I approximate $p = 0.05$ given there are roughly 15 bookmaking arrests per year and 300 bookmakers in New York city (the latter are estimates from the Kings County Districts Attorney office); $K^* = \$1$ million (from the text); $\delta = 0.95$. Substituting into the formula gives $PDV \ Loss = \$500,000$.

One approach compares the bookmaking operation with a safe alternative. The bookmaking investment is a risky lottery which is normally distributed with a mean μ and variance σ^2 defined in the profits distribution (21). Under CARA utility, the certainty equivalent is,

$$CE = \mu - \frac{1}{2}\gamma\sigma^2 \tag{27}$$

By revealed preference, the bookmaker prefers to invest the capital reserve K_T^* in the organization rather than get a safe return, $safe$. This means $CE \geq safe$, or using (μ, σ) derived from the profits distribution (21) and the parameters in the last sub-section,[69]

$$\gamma \leq 2\sigma^{-2}(\mu - safe) = 1.1 \times 10^{-7} \approx 0 \tag{28}$$

Since the risk parameter is defined relative to the units of income/wealth (dollars), the approximation is justified by noting that the upper bound of the coefficient of relative risk aversion, CRRA, is also virtually zero ($CRRA \equiv \gamma x$ where x is income/wealth. Setting income at the mean value for profits and investment capital, $E(x) \equiv \mu + K_{0.001}^* = \$1.6 \times 10^6$, and substituting into (28) gives $CRRA \leq 0.2$).

Another approach considers the mean-risk tradeoff under financial hedging. The bookmaker can layoff some of his $N - 2s$ unmatched bets, and on each layoff bet the net revenues are zero with certainty. With b layoff bets, (18) becomes,

$$Net\ Revenues_{layoff} = M \sum_{g=1}^{G} \left(s \times vig + (N - 2s - b)((0.5, -1) \oplus (0.5, 1 + vig)) \right) \tag{29}$$

Some algebra shows profits continue to follow the normal distribution in (21) when N is replaced by $N - b$. The rate of tradeoff between the mean $\mu(b)$ and standard deviation $\sigma(b)$ from this profits distribution is,

$$\frac{\partial\mu(b)/\partial b}{\partial\sigma(b)/\partial b} = \frac{\widetilde{vig}}{2 + \widetilde{vig}}\sqrt{G} \approx 0.8 \tag{30}$$

using the parameter values from the last sub-section. The bookmaker selects b to maximize his expected utility given the profit distribution and effective budget constraint in (30). Using the CARA utility (26) and normality in (21), this is equivalent to maximizing the certainty equivalent,

$$\max_{b \in \{0, N-2s\}} CE = \mu(b) - \frac{1}{2}\gamma\sigma(b)^2 \tag{31}$$

The bookmaker optimally selects no layoffs $b = 0$, so,

$$\gamma \leq \left(\frac{\partial\mu(b)/\partial b}{\partial\sigma(b)/\partial b} \times \sigma(b)^{-1} \right)\bigg|_{b=0} = 4.0 \times 10^{-7} \approx 0 \tag{32}$$

where the equality follows from (30), the definition of $\sigma(b)$, and the parameter values in the last sub-section. The approximation is again justified because the coefficient of relative risk aversion is bounded above at roughly zero (see the discussion following (28)).

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[69]To determine $safe$, I use $K_{0.001}^*$ and a 5% rate of return. The calculation is robust to these assumptions.

Fiscal Year	Number of Locations	Bet Volume	Bettor Losses	% Hold
1969-70	12	$395,763	NA	NA
1974-75	9	$13,083,910	$960,359	7.34%
1979-80	30	$289,630,191	$12,106,542	4.18%
1984-85	61	$930,810,122	$22,897,929	2.46%
1989-90	67	$1,482,362,000	$48,325,000	3.26%
1994-95	109	$2,250,252,000	$89,335,000	3.97%
1998-99	145	$2,301,837,000	$98,979,000	4.30%
1999-2000	157	$2,560,893,000	$117,545,000	4.59%
2000-01	156	$2,106,579,000	$112,702,000	5.35%

Legal Sports Wagering in Nevada

Year	Bet Volume	Bettor Losses
1974	$2,500,000,000	$220,000,000
1982	$15,628,000,000	$1,329,300,000
1985	$20,087,000,000	$1,714,102,000
1989	$29,506,901,093	$2,517,938,875
1995	$84,000,000,000	NA
1999	$80-$380,000,000,000	NA

Illegal Sports Wagering Estimates

Year	Number On-Line Sites	Bet Volume	Bettor Losses	% Hold
1995	0	0	0	–
1996	2	$60,000,000	NA	NA
1997	NA	$600,000,000	NA	NA
1998	53	NA	$260,000,000	NA
1999	139	$14,300,000,000	$640,000,000	4.5%
2000	204	NA	$1,000,000,000	NA

Internet Sports Wagering

Table 1: Sports Wagering Trends (excludes horse racing and greyhounds)

Sources:

All dollar amounts in nominal terms. Nevada sports gambling data are from Nevada State Gaming Control Board (various years) and are based on their fiscal year ending 30 June.

The estimates of illegal sports gambling come from a variety of sources. 1974: Commission on the Review of the National Policy Toward Gambling (1976); 1982-89: "Gross Annual Wager" in *[International] Gaming & Wagering Business*, various years; 1995: "The National Bet," *US News and World Report*, April 1997; 1999: National Gambling Impact Study Commission (1999).

The internet sports gambling data also includes non-US wagers, though in 1999 80% of internet gamblers lived in the US ("Wagering on the Internet - An Executive Summary," http://www.cca-i.com). The number of sports gambling sites is the number of online bookmaker sites listed on the Rolling Good Times Online website, http://www.rgtonline.com. The bet data come from a variety of sources. 1996, 1997: *Gambling Magazine*, http://www.gamblingmagazine.com/articles/37/37-08.htm, 11 February 1999. 1998: *Gambling Magazine*, http://www.gamblingmagazine.com/articles/37/37-55.htm, 1 July 1999. 1999: the hold is from "Internet Gambling Sites May Win if NCAA Wagering ban Ok'd," http://www.rgtonline.com, 2000. the winnings are from *Gambling Magazine*, http://www.gamblingmagazine.com/articles/48/48-328.htm, 30 January 2000. 2000: Christiansen Capital Advisors, "Internet Gambling: The State of a Developing Industry," http:/www.cca-i.com, 2001.

	Location	Observation Period	Number of Bettors	Number of Bets	Bet Volume	Available Records
Bookie 0	Brooklyn, Manhattan, Queens, Staten Island, NY	7/1/95-8/4/95 (22 days with bets)	280 active	10,252	$11,459,310	• bettor records • figure sheets • PC backup • court documents
Bookie 1	Staten Island, NY	12/16/96-1/12/97 (17 days with bets)	54	1,332	$314,810	• bettor records • figure sheets • audio tapes • address book • financial records • court documents
Bookie 2	Newark, NJ	8/31/92-9/30/92 (31 days with bets)	≈ 500	8,400	$\approx \$9,700,000$	court documents
Bookie 3	Brooklyn, NY	1/17/00-1/23/00 (7 days with bets)	112	1,308	$479,433	bettor records
Bookie 4	Brooklyn, NY	1/17/00-1/23/00 (7 days with bets)	15	134	$220,880	• bettor records • desk contents • audio tapes
Bookie 5	Secaucus, NJ	12/30/96-3/14/97 (77 days with bets)	249	—	$4,732,879	• figure sheets • audio tapes • financial records
Bookie 6	Philadelphia, PA	11/1/97	—	—	—	game lines

Table 2: Data Overview

Notes:

- Number of Bets treats exotic wagers (see Table 10) as a single bet.

- Bet Volume is the sum of the absolute value of each bet outcome

- "bettor records" include a listing of every wager (amount, odds) for each bettor. For Bookie 0, the records include the exact time when each wager is placed.

- "figure sheets" include the daily net position of each bettor (the cumulative position plus daily net return plus any payments from the bookie to the bettor).

- "court documents" include wiretap proposals, depositions, trial affidavits, civil forfeiture actions, and plea bargain/settlement agreements. These typically include a verbal description of the operation (typically from an undercover officer who worked for or observed the bookmaker), a listing of seized assets, and details of the police involvement (warrants, wire taps, etc).

- "game lines" is a listing of the prices (odds) which the bookmaker is offering.

Variable	Bookmaker 0	Bookmaker 1	Bookmaker 3	Bookmaker 4	Bookmaker 5
Bet Size					
Average	$1,117.8	$236.3	$366.5	$1,648.4	—
Maximum	$23,820	$3,000	$5,000	$4,000	—
Bets per Bettor-Day					
Average	3.58	1.45	4.44	1.28	—
Maximum	43	18	36	25	—
Bettors (%)					
Bet every day	7.1%	3.7%	9.9%	0%	2.0%
Exit	23.9%	11.1%	5.4%	6.7%	39.0%
Winnings ≥ 0	49.3%	38.9%	22.5%	53.3%	48.4%
Bet Frequency					
Bets/Minute	1.23	—	—	—	—
Bet Types (%)					
Exotic Wagers	16.5%	26.3%	19.3%	0%	—
Football	2.5%	81.7%	21.5%	0%	—
Basketball	0%	16.2%	71.2%	98.5%	—
Baseball	97.5%	0%	0%	0%	—
Daily Bet Volume					
Average	$520,877.7	$18,518.2	$68,490.4	$31,554.3	$61,466.0
Daily Net Revenue					
Average	$5,892.4	$1,554.9	$9,228.4	-$1,310.0	$9,055.8
Standard Deviation	$87,418.8	$3,501.0	$13,913.5	$6,205.0	$17,916.3
Maximum	$163,232	$8,461	$37,429	$7,480	$47,960
Minimum	-$103,891	-$4,700	-$3,190	-$12,400	-$61,205
Employees (number)					
Salaried pay	4	1	2	0	6
Commission pay	75	7	10	0	13

Table 3: Descriptive Statistics

Notes:

Bet sizes are based on taking the absolute value of the actual outcome. Bet percentages across sports are calculated treating each part of an exotic wager as a separate observation (note that the omitted sports are hockey and horses). Net revenues are signed in terms of the bookmaker's position. Number of employees excludes the bookmaker himself.

Variable	Bookmaker 0	Bookmaker 1	Bookmaker 3	Bookmaker 4	Bookmaker 5
Obs. Period (days)	22	17	7	7	77
Revenues					
Bet Volume	$11,459,310	$314,810	$479,433	$220,880	$4,732,879
(Net) Revenue	$129,632	$26,434	$64,599	-$9170	$697,294
% Hold	1.31%	8.40%	13.47%	-4.15%	14.73%
Costs					
Sheetholder Commissions	$99,189	$8,610	$36,840	$0	$453,350
Delinquent Debt Payment	$11,486	$720	NA	$50	$40,462
Salaries to Writers and Collectors	$2,520	$1,350	$500	$0	$19,800
Rent	$3,100	$1,900	$600	$250	$11,000
Line Service Subscription	$200	$550	$200	$100	$1,350
Utilities (phone, electric, pagers)	$497	$611	$701	$478	$3,567
Total Costs	$116,992	$13,741	$38,841	$878	$529,529
Profit					
Profit	$12,640	$12,693	$25,758	-$9,648	$167,765
Profit$_{annualized}$	$\approx$ $210,000	$\approx$ $220,000	$\approx$ $1,300,000	$\approx$ -$400,000	$\approx$ $800,000

Table 4: Bookmaker Accounting Statement

Notes:

All values are for the period of observation listed in Table 2 except Profit$_{annualized}$ which is scaled to an annual basis using the number of days of observation listed in the first row (all bookmakers are presumed to operate 365 days per year except bookmakers 1 and 4 which are closed between the end of the NBA finals and the beginning of the NFL regular season leaving 288 days of operation).

(Net) Revenue = Bet Volume-Pay-outs to Winning Bets. **% Hold** = $100 \times$ (Net) Revenue/Bet Volume. **Profit** = **(Net) Revenue** - **Total Costs**. Costs: "Line Service Subscription" is the fee paid to gain access to real time Las Vegas odds. Cost data sources: for bookmaker 0, from court records and financial records in the PC backup; for bookmakers 1, 4 and 5, from figure sheets and financial records (bank statements, bills); for bookmaker 3, estimated from court documents.

Dependent Var.	Sheet. Rate		Pr(Employed)	Bet Volume $(\times 10^{-4})$	Num. Bettors
Covariate (lagged)	(1)	(2)	(3)	(4)	(5)
constant	0.220	0.333		0.214	6.204
	(0.014)	(0.109)		(0.021)	(0.456)
Net Revenue from Bettors $(\times 10^{-3})$	0.090	0.071	-0.030		
	(0.020)	(0.045)	(0.056)		
Bet Volume $(\times 10^{-4})$	0.012	0.009	0.911		
	(0.003)	(0.007)	(0.292)		
Number Bettors	0.003	0.004			
	(0.005)	(0.009)			
Previous Years of Service		0.031			
		(0.016)			
Previous Year's Net Rev. $(\times 10^{-4})$		0.061			
		(0.009)			
Commission Rate			0.886	0.446	1.511
			(0.422)	(0.084)	(0.599)
Red Figure $(\times 10^{-3})$			0.006	0.011	-0.137
			(0.011)	(0.078)	(0.561)
Sheetholder FE?	Yes	No	No	Yes	Yes
Time FE?	No	No	baseline hazard	Yes	Yes
Frequency	Week	Week	Week	Day	Day
R^2	0.41	0.19		0.63	0.69
$\log L$			-159.23		
N	121	121	121	825	825

Table 5: Sheetholder Incentive System Evaluation: Bookmaker 5.

Notes:

The results are based on the 13 sheetholders observed over 11 weeks (data are censored for new entrants and exiters). Values in parentheses are robust standard errors. "FE" indicates fixed effects. Time fixed effects are for the data frequency listed at the bottom of the table. When bettor fixed effect are included, the between-R^2 and non-robust standard errors are reported. In (3)-(5) commission rate is instrumented for using employment tenure, last year's net revenue, and period indicators.

Variable	Definition	Mean	St. Dev.	Min	Max
SAMPLE SIZE					
N	number of wagers	11797	–	–	–
N_i	number of bettors	263	–	–	–
WAGER-LEVEL					
$price_{bookmaker}$	bookmaker price on wager, see (8)	0.522	0.080	0.278	0.737
$price_{vegas}$	Las Vegas price at the exact minute of the bookmaker wager	0.519	0.008	0.286	0.737
Bookie Position	\$ bookmaker must pay if wagered team wins game	11734.78	13490.36	-59566	61847
Time from Game	time between bet and games (minutes)	140.90	160.35	0	1465
Bet Amount	\$ on each part of wager presuming the favorite team wins (this assumption is needed since under a money line the size of the payoff depends on which side wins)	920.73	1293.95	0	10400
BETTOR-LEVEL					
Prior Debt	\$ which bettor owes the bookmaker at the start of the betting day (it is reset each week and equals zero if the bettor has cumulative winnings)	2410.56	5488.34	0	45750
Sunday Debt	$\texttt{PriorDebt} \times \mathcal{I}_{Sunday}$	550.058	3120.01	0	39040
Number Bets	number of bets bettor places over the sample period	37.91	55.90	1	533
Herfindahl$_T$	$\dfrac{\sum_{t \in teams} Number\ Bets \times p_t^2 - 1}{Number\ Bets - 1}$ where p_t is the proportion of the bettor's wagers on team t	0.086	0.166	0	1
Herfindahl$_{FA}$	$\sum_{t \in teams} 2p_t(p_{tF}^2 + p_{tA}^2) - 1$ where p_{tF} (p_{tA}) is the proportion of wagers involving team t which are for (against) team t	0.624	0.273	0.036	1

Table 6: Definitions and Descriptive Statistics: Bookmaker 0 Prices and Betting Patterns

Notes:

All wagers are for baseball games. Each part of an exotic bet is considered a separate wager/observation. Values for Prior Debt, Number Bets and all Herfindahl's are aggregated to the bettor-level. I assume the favorite will win in calculating Bookie Position. This is necessary because of the presence of exotic bets and because the size of baseball payoffs depends on whether the favorite or underdog wins.

Dependent Var.	$price_{bookmaker,t}$				
Sample	All Games			NYY	pro-NYY
Covariate	(1)	(2)	(3)	(4)	(5)
constant	0.013	0.001	0.006	0.016	0.024
	(0.001)	(0.001)	(0.001)	(0.003)	(0.005)
$price_{vegas,t}$	0.979	0.996	0.989	0.970	0.974
	(0.002)	(0.002)	(0.001)	(0.005)	(0.009)
Bookie Position $(\times 10^{-6})$			0.167		
			(0.010)		
Time from Game $(\times 10^{-5})$			-0.194		
			(0.077)		
Bet Amount $(\times 10^{-5})$			-0.199		
			(0.010)		
Prior Debt $(\times 10^{-7})$			0.547		
			(0.272)		
Sunday Debt $(\times 10^{-6})$			0.180		
			(0.072)		
Number Bets $(\times 10^{-4})$			0.135		
			(0.018)		
Herfindahl$_T$ $(\times 10^{-2})$			0.104		
			(0.077)		
Herfindahl$_{FA}$			0.013		
			(0.003)		
Herfindahl$_{FA}\times$ Number Bets $(\times 10^{-3})$			0.230		
			(0.061)		
Day of the week indicators?	No	No	Yes	No	No
Bettor FE?	No	Yes	No	No	No
R^2	0.91	0.98	0.98	0.81	0.85
N	11797	11797	11786	1223	811

Table 7: Bookmaker 0 Prices. OLS Regression Analysis

Notes:

Values in parentheses are robust standard errors (using bettor clusters when panel data). "NYY" means only New York Yankees games are included; "pro-NYY" means only bets in favor of New York Yankees are included. "FE" indicates fixed effects. When bettor fixed effect are included, the between-R^2 and non-robust standard errors are reported. In column (3) `Prior Debt`, `Sunday Debt`, `Number Bets`, and the `Herfindahl` variables are time invariant and bettor-specific.

Dep. Var.	Bookmaker 1			Bookmaker 3		
	$price_{i,t}$	$price_{i,t}$	$price_{i,t}$	$price_{i,t}$	$price_{i,t}$	FE from (5)
Sample	full	pro-NY bets	anti-NY bets	full	full	full
Covariate	(1)	(2)	(3)	(4)	(5)	(6)
constant	0.018	1.212	-1.226	0.146	-0.025	-0.121
	(0.029)	(0.087)	(0.063)	(0.056)	(0.014)	(0.009)
$price_{vegas,t}$	1.001	1.007	1.005	0.987	0.998	
	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)	
$\texttt{Herfindahl}_T$						0.530
						(0.135)
$\texttt{Herfindahl}_{FA}$						1.172
						(0.070)
Bettor FE?	No	No	No	No	Yes	No
R^2	0.999	0.999	1.000	0.948	0.999	0.51
N	1893	58	101	1532	1532	112

Table 8: Bookmakers 1, 3 Prices. OLS Regression Analysis

Notes:

Values in parentheses are robust standard errors (using bettor clusters when panel data). "FE" indicates fixed effects. When bettor fixed effect are included, the between-R^2 and non-robust standard errors are reported.

$price_{i,t}$ and $price_{vegas,t}$ are the negative of the spread (the actual spread is used for over bets). For columns (2), (3) I define the New York teams as follows: New York Giants, New York Jets, NY Knicks, New York Rangers, New York Islanders, New Jersey Devils, and St. Johns University (the results are robust to excluding various subsets of these teams).

VARIABLE	Average Daily Return	Normal Distribution	Monte Carlo Simulation
MINIMUM CAPITAL (\$)			
K_0^*	1,219,132	1,023,564	934,262
$K_{0.001}^*$	1,095,576	669,090	766,527
$K_{0.01}^*$	889,619	539,607	630,615

Bookmaker 0

VARIABLE	Average Daily Return	Normal Distribution	Monte Carlo Simulation
MINIMUM CAPITAL (\$)			
K_0^*	47,852	47,639	27,295
$K_{0.001}^*$	33,768	17,804	17,765
$K_{0.01}^*$	27,690	10,837	11,474

Bookmaker 1

VARIABLE	Average Daily Return	Normal Distribution	Monte Carlo Simulation
MINIMUM CAPITAL (\$)			
K_0^*	143,280	154,503	85,663
$K_{0.001}^*$	103,542	77,182	73,307
$K_{0.01}^*$	76,665	59,125	51,813

Bookmaker 3

Table 9: Minimum Capital Reserves

Notes:

The algorithms for these calculations are presented in Appendix E.1. The column headers summarize the method for approximating weekly revenues. K_T^* is the minimum capital requirement when the bookmaker has tolerance $T \in [0,1]$ for bankruptcy.

Bet Type	Definition	(FB = football, BB = basketball, B = baseball, H = Hockey) Payoff	Commission Rate
Straight	Bet on A	FB, BB: $\mathcal{S}(A) \equiv (I(\text{win } A) - (1 - I(\text{win } A)(1 + vig)))\, Bet_A$ B, H: $\mathcal{S}(A) \equiv (I(\text{win } A)c_A - (1 - I(\text{win } A)))\, Bet_A$	FB, BB: 4.8% B: $\leq 2.3\%$
Exotics			
If	If A then B	$\mathcal{I}(A, B) \equiv \mathcal{S}(A) + I(\text{win } A)\mathcal{S}(B)$	FB, BB: 7.0% B: $\leq 2.3\%$
Reverse	If A then B, AND If B then A	$\mathcal{R}(A, B) \equiv \mathcal{I}(A, B) + \mathcal{I}(B, A)$	FB, BB: 7.0% B: $\leq 2.3\%$
Reverse Box	$\binom{N}{2}$ Reverses	$\sum_{i,j \in Bets} \mathcal{R}(i, j)$	FB, BB: 7.0% B: $\leq 2.3\%$
Parlay	Joint bet on multiple events	FB, BB: $\mathcal{P}(Bets) \equiv \left(\prod_{i \in Bets} I(\text{win } i) \times 2^{\#Bets} - 1 - \#Bets \times vig \right) Bet$ B, H: $\mathcal{P}(Bets) \equiv \left(\prod_{i \in Bets} I(\text{win } i) \times (1 + c_i) - 1 \right) Bet$	FB, BB: 12.5% B: $\leq 3.2\%$
N team Round Robin	$\binom{N}{2}$ two team Parlays	$\sum_{i,j \in Bets} \mathcal{P}(i, j)$	FB, BB: 12.5% B: $\leq 3.2\%$

Table 10: Types of Bets

Notes:

- A, B are outcomes of sporting event(s). There are two main types: betting on the game outcome (with a point spread in all events except baseball) or on the total number of points scored by both teams ("Over/Under").

- Definitions: $I(\text{win } A)$ is an indicator for winning event A; Bet_i is the amount bet on outcome i; vig is the vigorish (commission). For all bookies, $vig = 0.1$.

- In baseball, the constant c_A is related to the "money line" odds which are stated as $Money\ Line < -100$ for favorites and $Money\ Line > 100$ for underdogs (my bookmakers use the dime line, $Money\ Line_{underdog} = -Money\ Line_{favorite} - 10$). The relationship is $c_A = 100/|Money\ Line|$ for favorites and $c_A = Money\ Line/100$ for underdogs.

- For football and basketball parlays, Las Vegas uses a different payoff with no vigs on losses: $\mathcal{P}(Bets) \equiv \left(\prod_{i \in Bets} I(\text{win } i) \times (1 + f2^{\#Bets}) - 1 \right) Bet$ where typically $f = 0.65$ for $\#Bets = 2$, $f = 0.75$ for $\#Bets = 3$, and $f = 0.625$ for $\#Bets \geq 4$.

- The commission rate in the last column presumes the bookmaker has a balanced book. The football and basketball values presume $vig = 0.1$, and that no commissions are fronted. The baseball values presume a dime line, and the most profitable money line, 100, occurs. Parlay and round robin values presume there are two events (the rate increases with the number of events). Hockey values are omitted for brevity. Details of these calculations are available in an unpublished Appendix.
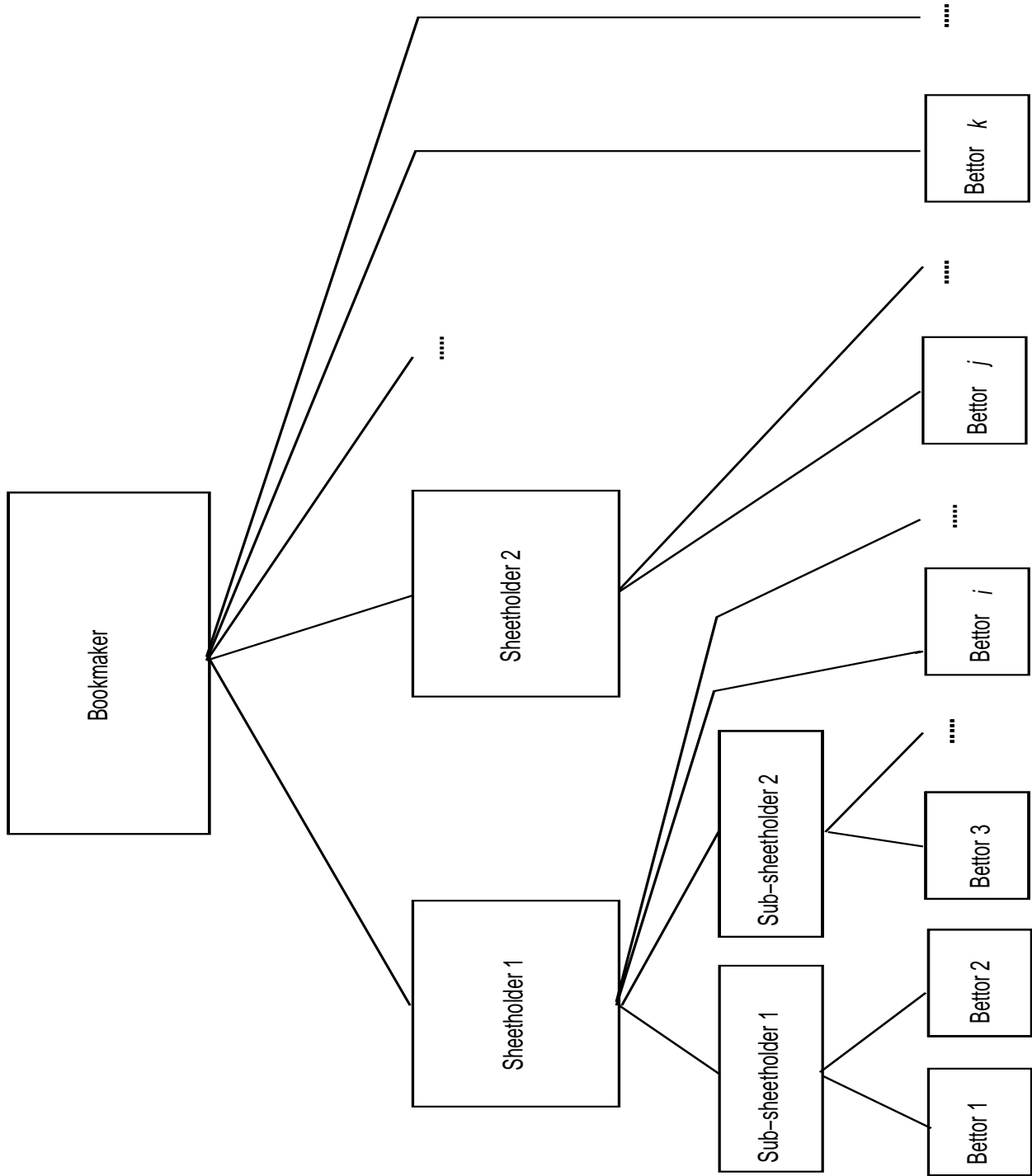
Figure 1: Sheetholding Arrangement for Large Bookmaking Operation

Notes:
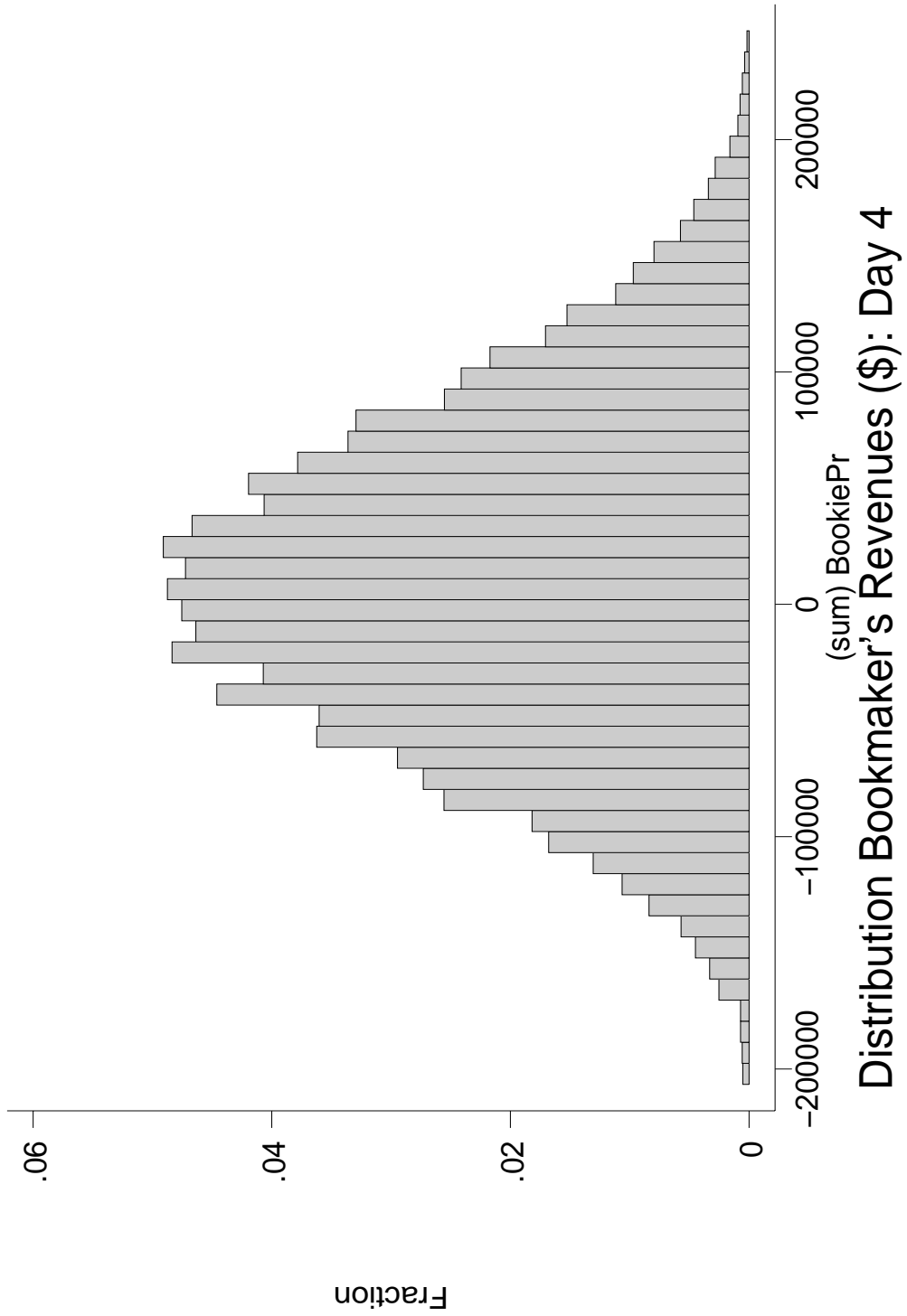Some sheetholder levels are absent in smaller operations.
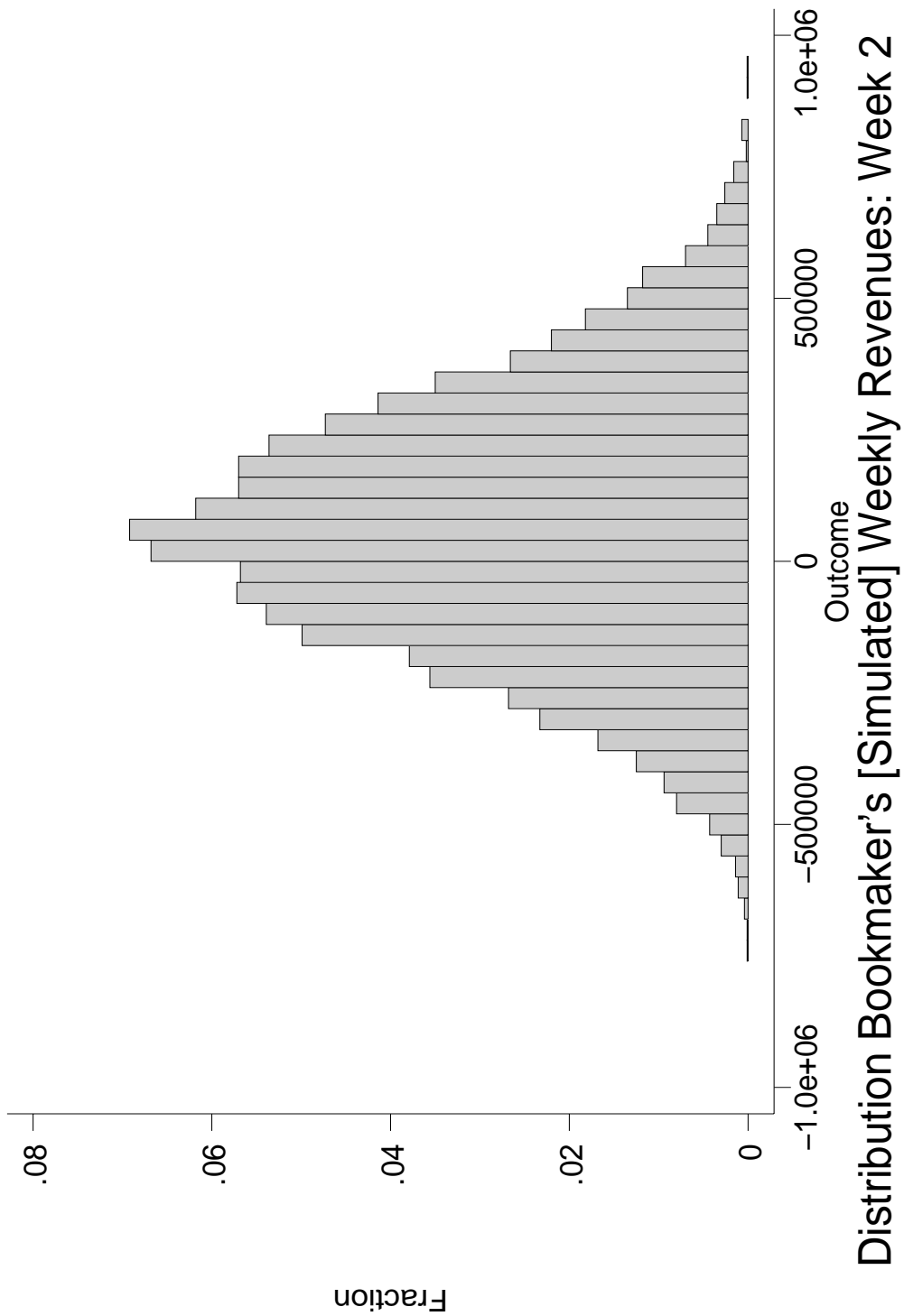
Figure 2: Daily Revenue Distribution: Bookmaker 0

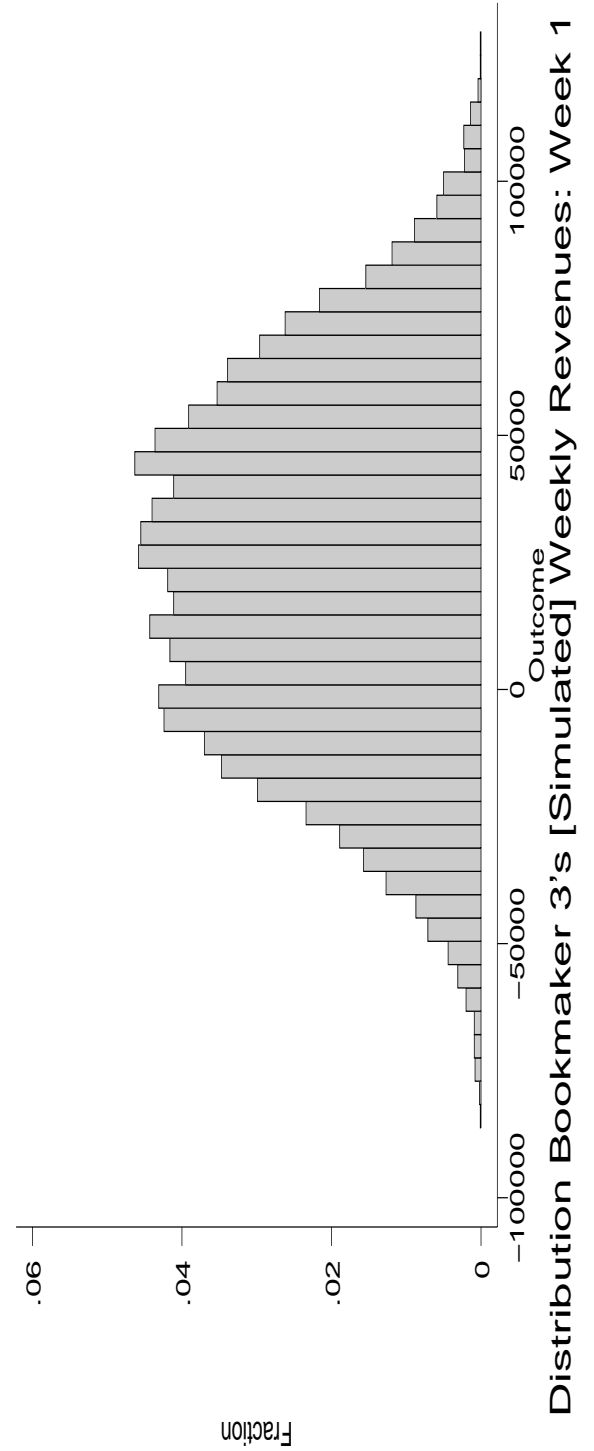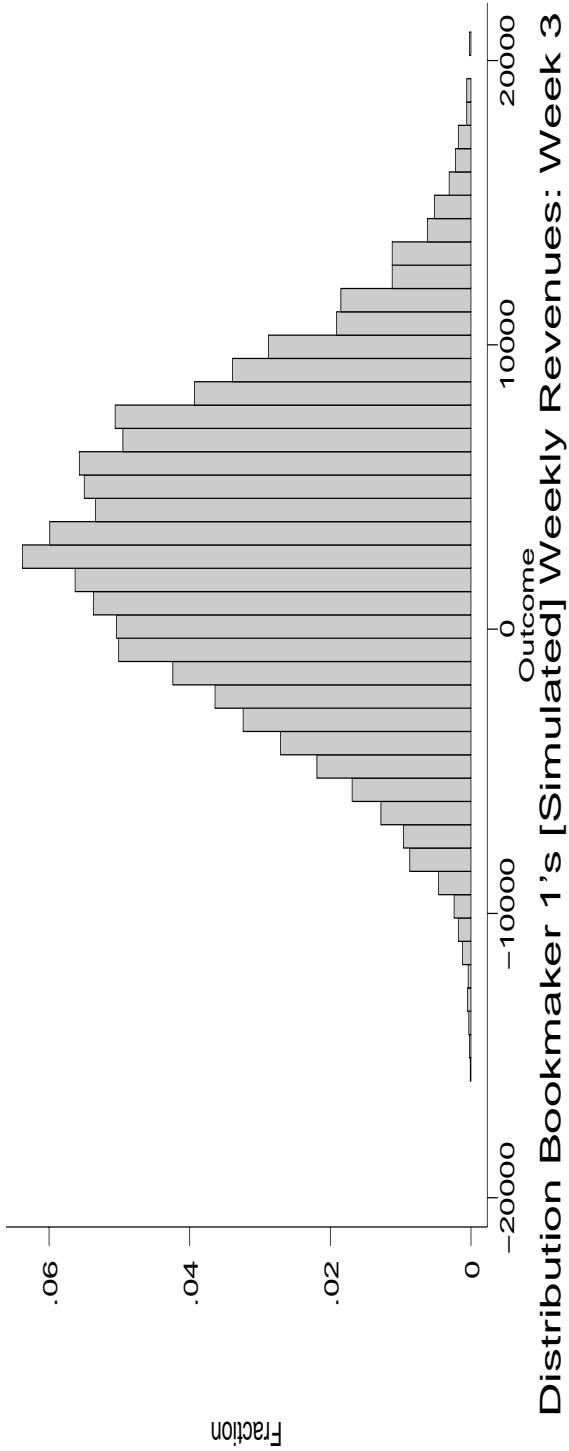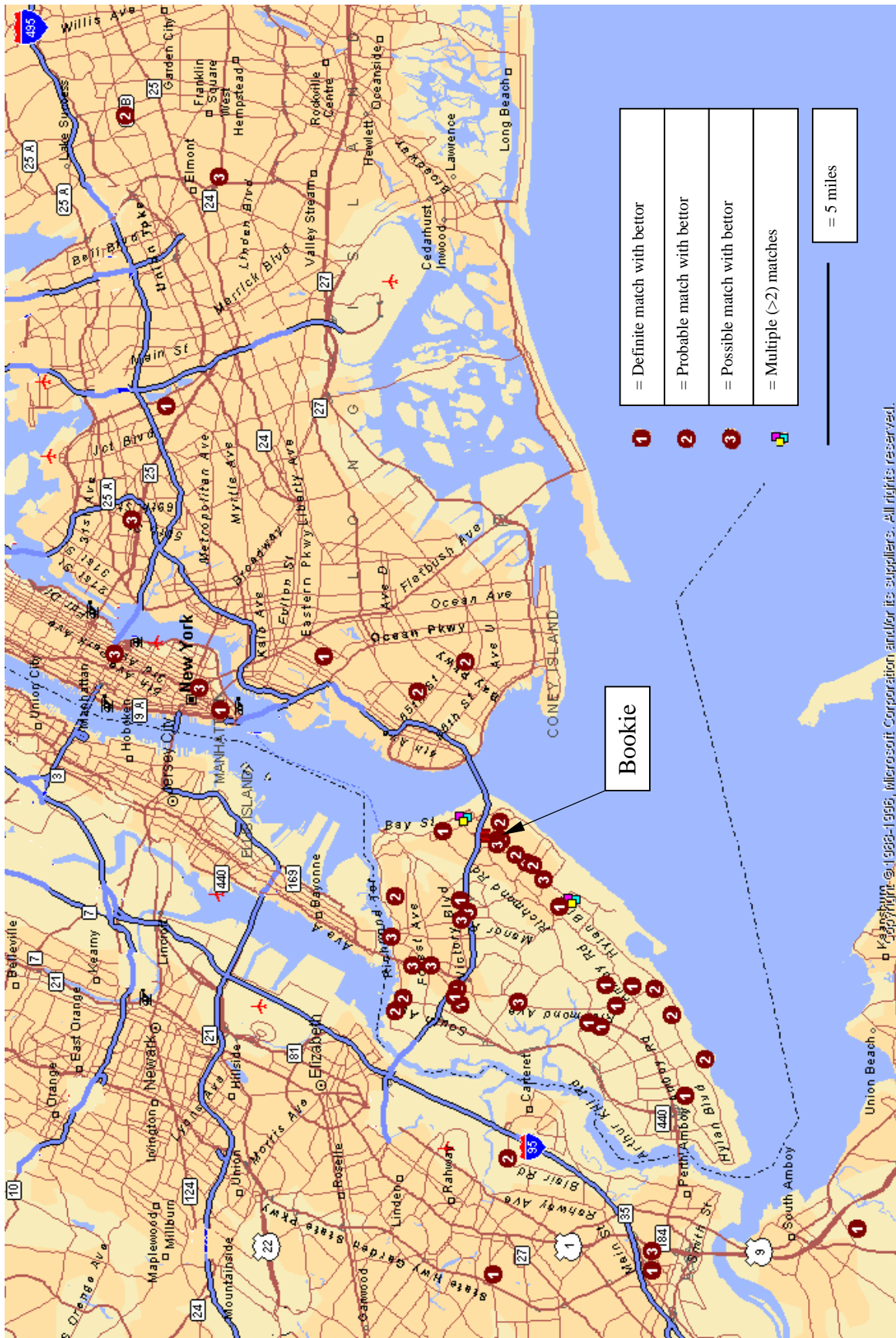Figure 3: [Simulated] Weekly Revenue Distribution: Bookmaker 0

Figure 4: [Simulated] Weekly Revenue Distribution: Bookmakers 1, 3

Figure 5: Bookmaker 1's Place of Business and His Bettors' Place of Residence