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Misunderstanding of the binomial distribution, market inefficiency, and learning behavior: Evidence from an exotic sports betting market

Joon Ho Hwang*, Min-Su Kim

Korea University Business School, Anam-dong, Seongbuk-gu, Seoul 136-701, Republic of Korea

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ABSTRACT

This paper uses the setting of a volleyball game and an exotic sports betting on the point difference of volleyball games to test whether people correctly understand the probabilities related to outcomes of a process which follows a binomial distribution. We find that people consistently underestimate the probabilities of outcomes that correspond to extreme ends of the distribution. This is consistent with the extremeness aversion bias documented in decision making studies. Whereas previous studies on the extremeness aversion bias find the existence of the bias in a consumer choice setting, we document that this bias also exists in an investment setting. We find evidence of learning behavior over time; however, it is not sufficient to eliminate the bias.

1. Introduction

How people make decisions under uncertainty is vital in all fields of business. And when faced with uncertainty, understanding of the probability distribution that underlies the uncertain event is essential in making rational decisions. However, one of the difficulties in empirically testing different methods of decision analysis lies in that the decision problem in the real world is not structured enough. For example, the decision maker cannot provide exact estimations of the probability distribution (Weber, 1987). This paper overcomes such obstacle in examining people's decision making behavior by utilizing a unique betting of volleyball games in which the outcome follows a binomial distribution. We uncover a significant bias that participants underestimate outcomes that lie at either ends of the binomial probability distribution.

The finding of people's biased behavior in this study is consistent with the extremeness aversion effect documented in decision making studies (Chernov, 2004; Simonson & Tversky, 1992; Tversky & Simonson, 1993). According to the extremeness aversion bias, a choice which lies at the extreme end of a relevant continuum tends to be viewed as less attractive than an option with moderate values. While prior studies find the existence of the extremeness aversion bias in people's consumption behavior (for example, consumers avoid purchasing the most expensive or the least expensive product), we find that the extremeness aversion bias not only exists in a decision making setting in which real money is at stake, but the size of the bias is large enough to cause market inefficiency and generate opportunities for making large profit. Specifically, in a setting with an unconditional expected return of less than −50 percent due to low payout rate, a simple strategy of exploiting the bias would have yielded a return of more than 45 percent during the entire existence of the game.

The other focal point of this study is that we also explore how fast the market participants learn from their biased behavior which triggers market anomaly. The field of behavioral economics has discovered numerous market anomalies which stem from biases in human behavior.[1] However, once an anomaly is detected, examining how market participants react to or learn from such anomaly presents more challenge. One attempt to address the issue of how fast market participants learn from certain behavioral bias is conducted through an experimental approach in a laboratory setting (e.g., Camerer & Ho, 1999; Charness & Levin, 2005; Erev & Roth, 1998; Ho & Weigelt, 1996; Roth & Erev, 1995). The area of operational research is also applying these methods into explaining important issues such as the newsvendor behavior.[2]

* Corresponding author. Tel.: +82 232902830.
E-mail address: joonhwang@korea.ac.kr (J. H. Hwang).

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[1] Schwert (2003) provides a review of the vast literature on market anomalies. Shiller (2003) and Barberis and Thaler (2003) present a review from a behavioral perspective.

[2] For example, Schweitzer and Cachon (2000) initiated the study of behavioral issues such as mean anchoring, demand chasing, and inventory error minimization in explaining newsvendor mean ordering behavior. Bostian et al. (2008) show that demand chasing can lead to the "pull-to-center" behavior. Kremer et al. (2010) test the validity of the random error framework in explaining newsvendor mean ordering behavior. Rudi and Drake (2011) develop observation bias theory and study its impact on ordering level and adjustment behavior.

In this study, by using a novel sports betting data which includes betting behaviors of market participants, a better link between participants' aggregate learning behavior and market efficiency is constructed on a natural setting without relying on laboratory experiments. One of the most desirable features of the sports betting market, in contrast to a typical financial market, is that the scope of the pricing problem is reduced. Whereas assets traded in a typical financial market is priced based on an infinite horizon of cash flows, contracts in the sports betting market have a well-defined termination point at which each value of an asset (or a bet) becomes certain. And because contracts in the sports betting market are isolated from external influence, we can bypass many problems such as endogeneity and omitted risk factors which complicate the study of market efficiency in traditional financial markets. Therefore, by using sports betting market data, it is relatively easy to test whether prices are efficient forecasts of outcomes. For this reason, the sports betting market is often used as a platform for testing market efficiency.

We find that the inefficiency in our betting market which stems from people's biased behavior is gradually corrected. However, the speed of learning is weak and to date (after 4 years or 389 rounds of betting), the bias that leads to market inefficiency still exists. We also find that participants incorporate the information contained in the previous betting result by increasing their bets on these outcomes in the next betting sequence. This result is in line with the newsvendor orders' tendency to chase demand (adjusting order quantities towards prior demand) as found in Ben-Zion, Cohen, Peled, and Shavit (2008), Bostian, Holt, and Smith (2008), Kremer, Minner, and Van Wassenhove (2010), Rudi and Drake (2011), and Schweitzer and Cachon (2000). Since the results of the games in our sample are independent across time, our results imply that demand chasing in newsvendor can arise due to not only the predictable pattern of demand but also the intrinsic uncertainty component. We also provide other implications of people's learning behavior, such as people putting more weight on the evidence when the outcome is consistent with their prior expectation.

The paper is organized as follows. In Section 2, we provide a review of the literature on sports betting and on learning process. In Section 3, we describe the data used in the study. The detection of market inefficiency is shown in Section 4 and the learning curve is analyzed in Section 5. In Section 6, we conduct a test of the favorite-longshot bias, which is a well documented anomaly in the betting market, as an alternative hypothesis. We provide a discussion of our results in Section 7. Section 8 concludes the paper.

2. Literature review

2.1. Sports betting and the psychology of betting

Based on the simplicities of the sports betting market in that the outcome has a fixed termination point and is less influenced by external factors, sports betting market is often used as a platform to test market efficiency. Hausch, Ziemba, and Rubinstein (1981), Sauer (1998), and Vaughan Williams (1999) provide reviews of studies that use the sports betting market to test market efficiency.[3]

The natural question that arises is why people participate in betting where the expected return is negative. One explanation can be derived from the curvature of people's utility function. Friedman and Savage (1948) assume a convex segment within an otherwise concave utility function. Based on such assumption, people in certain area of the utility curve have incentive to gamble even at negative expected return, and this is consistent with the stylized fact that poor people rather than the rich are more likely to play lottery. On the other hand, Markowitz (1952) argues that if the *current* wealth level lies at a convex segment of the utility curve, then people of any wealth level can have the incentive to gamble. Quandt (1986) shows that such local risk preference model yields the necessary condition for market equilibrium in which low-probability, high-return outcomes (longshots) have inferior returns than high-probability, low-return outcomes (favorites). This phenomenon, referred to as the "favorite-longshot bias", has become the most documented market anomaly in the sports betting market. Thaler and Ziemba (1988) and Sauer (1998) review the evidence of the favorite-longshot bias. Recent studies offer various explanations for the favorite-longshot bias (Cain & Peel, 2004; Golec & Tamarkin, 1995; Julien & Salanié, 2000; Ottaviani & Sørensen, 2008; Snowberg & Wolfers, 2010). We explore the existence of favorite-longshot bias in our sample in Section 6 of our study.

An important psychological motive of bettors can be the pleasure or consumption benefit of gambling (Kallick, Suits, Dielman, & Hybels, 1979; Kusyszyn, 1984). Conlisk (1993) formally incorporates this component by adding the extra utility of gambling to the standard expected utility function of wealth. This model implies that the risk-seeking behavior of betting is possible without relying on the convexity of the utility function. There are also theories on betting which do not rely on rational investor assumption and are based solely on behavioral propositions. For example, prospect theory states that the utility function is concave over gains and convex over losses, and that people tend to overweight the tails of the probability distribution, thus having preference for assets with skewed payoff (Barberis, 2012; Kahneman & Tversky, 1979; Thaler & Ziemba, 1988). Other theories which motivate gambling behavior from behavioral perspective include people exhibiting incorrect evaluation of uncertain outcomes (Gilovich, 1983) and people having erroneous beliefs about their skills (Griffiths, 1990).

2.2. Learning process

Many studies in Decision Science and in Economics find that people's behavioral or cognitive biases lead to suboptimal decision making. Attempts to address the learning activity from behavioral bias can be conducted through an experimental approach in a laboratory setting (e.g., Camerer & Ho, 1999; Charness & Levin, 2005; Erev & Roth, 1998; Ho & Weigelt, 1996; Roth & Erev, 1995) or in a non-laboratory setting by analyzing empirical data. The former method has the inherent limitation of being confined in a laboratory which shields participants from external factors that may affect their decision making in the real world. As for the latter approach of using real world empirical data, studies typically focus on investors' specific investment activity or on security analysts' behavior. For example, Kaustia and Knüpfer (2008) and Chiang, Hirshleifer, Qian, and Sherman (2011) examine investors' learning with respect to IPO subscription activity, Strahilevitz, Odean, and Barber (2011) studies learning with regard to stock repurchase activity, and Choi, Laibson, Madrian, and Metrick (2009) examine the case of 401(k) saving. As for studies on analysts' behavior, Mikhail, Walther, and Willis (2003) find that the degree of analysts' underreaction to prior earnings information decreases as their experience increases. Markov and Tamayo (2006) use aggregate consensus data and explain the predictability in financial analysts' forecast errors based on the analysts' rational learning behavior.

While the aforementioned studies examine learning behavior of different subjects, these studies still have a limitation in the sense that the results do not provide direct implications on market efficiency. The reason is because, first of all, the samples used in these studies represent only a small subset of the respective market. Second, activities examined in the above studies do not provide investment

[3] As another application of sports, studies in operational research utilize the easiness of information interpretation and of measuring performance in sports, and study the cause and effect of coaching changes (Bachan, Reilly, and Witt, 2008; Bruinshoofd & ter Weel, 2003; Flores, Forrest, and Tena, 2012; Frick, Barros, and Prinz, 2010; Hope, 2003; Kahn, 1993; Tena & Forrest, 2007). Results of these studies shed light on the association between managerial changes and the organization's performance, which can be more difficult to empirically test in other settings.