SELLING TO BIASED BELIEVERS: STRATEGIES OF ONLINE LOTTERY TICKET VENDORS

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We provide evidence that sellers respond to buyers' belief biases in a collective lottery betting market, by adopting sales strategies which cater to believers in the Hot Hand and Gambler's Fallacies. Lottery players on the buyer side tend to avoid buying tickets which are similar to the previous winning ticket, in accordance with the Gambler's Fallacy (Clotfelter and Cook 1993; Terrell 1994). At the same time, buyers tend to prefer purchasing tickets from previously winning sellers, despite the fully random nature of wins, in accordance with Hot-Hand Fallacy (Croson and Sundali 2005). These behavioral biases provide an opportunity for ticket sellers to increase their expected profits by adjusting features of the lottery portfolios they sell. We find that sellers make changes to their portfolio size, commission rate, self-purchase rate, and number choices in response to previous events, in ways that are consistent with responding to the Hot-Hand Fallacy belief, and which also lend a degree of support for responding to the Gambler's Fallacy belief. Our results show evidence of participants in a market accommodating their choices to the biased beliefs of other participants in order to gain an advantage in expected profits. (*JEL* D01, D03, D81, L86)

I. INTRODUCTION

Do sellers in the marketplace take advantage of the belief biases of their consumers? Models of markets typically assume that sellers are profit maximizing, consumers are utility maximizing, and both sides of the market have accurate, unbiased beliefs. However, an increasing collection of evidence shows that the presence of cognitive and strategic heterogeneity can account for many stylized facts in the marketplace which appear puzzling when confined to the framework of classical models.

*We thank Vincent Crawford, Brad Humphreys, Zhigang Li, Guang-zhen Sun, and Jie Zheng for helpful comments. We also thank our editor, Robert Rosenman, and three anonymous referees for comments which helped improve the paper. All errors are our own. Jaimie W. Lien acknowledges financial support from the National Science Foundation of China (#71303127 and #71203112), the Ministry of Education, China (#20130002120030), and Tsinghua University (Project #2012z02182 and #2012z02181). Jia Yuan acknowledges financial support from the University of Macau (#MYRG046-FBA12-YJ).

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We examine the behavior of sellers in a popular online market which provides an unusual opportunity to identify seller exploitation of biased beliefs held by buyers: the Chinese collective lottery betting market. In this market, shares of ticket "portfolios" for China's national lottery are sold, commissions are charged by the sellers, and the success rates of sellers are made public. As in most state-run lotteries, success is completely random, with known probabilities that are independent of previous outcomes. These objective probabilities allow us to cleanly detect deviations from rational beliefs among buyers, and assess the corresponding responses by sellers in the market, to these demand shocks of buyers. We find evidence that sellers cater to the biased beliefs of lottery ticket buyers, by tailoring certain features of their portfolio product.

Specifically, collective lottery portfolio sellers adjust their sales strategies in response to demand fluctuations that are driven by buyers' biased beliefs about the correlation of past and future lottery outcomes. Lottery ticket buyers tend to purchase tickets with numbers which have not recently won, in accordance with previous evidence of the Gambler's Fallacy in lottery sales (Clotfelter and Cook 1993; Terrell 1994). Ticket buyers also tend to purchase tickets from those

Economic Inquiry
(ISSN 0095-2583)

doi:10.1111/ecin.12198

ticket sellers who have recently experienced an exogenous increase in their win rates, in accordance with previous evidence of the Hot-Hand Fallacy (Croson and Sundali 2005; Guryan and Kearney 2008).[1]

We find combined evidence that lottery portfolio sellers take advantage of buyers' belief in the Hot-Hand Fallacy in the following ways: (1) Directly following a previous win in their portfolio, sellers *increase* their commission rate charged to the buyers, to be collected as a percentage of the lottery winnings. Sellers are thus able to collect more commission money from the buyers conditional on winning. (2) Sellers offer portfolios of *larger* value (and more ticket coverage) directly following a large win in their portfolio. Using this strategy, sellers increase their chances of holding a winning ticket in the current round, as well as being able to collect more commission money conditional on winning. (3) Sellers self-invest *less* in their own portfolios after a large win, when their popularity among buyers in the market is high. By purchasing a lower share of their portfolios on their own, sellers are able to obtain a larger expected return without investing their personal money.

We also find some evidence consistent with lottery ticket sellers adapting to buyers' belief in the Gambler's Fallacy. First, sellers generally tend to offer lottery number portfolios which are numerically *dissimilar* to recent winning tickets, thus appealing to buyers with Gambler's Fallacy beliefs. Although the more numerically dissimilar the portfolio is to the previous winning ticket, the *less* the seller himself invests in it. Sellers who have proposed very similar numbers compared to the previous winning ticket, on the other hand, self-invest more, thus entering the lottery with higher expected returns under the pari-mutuel prize structure. This self-investment pattern is not consistent with the alternative story that sellers themselves subscribe equally to the Gambler's Fallacy compared to buyers.

Our paper is unique to the existing evidence in this area in that we are the first, to our knowledge, to study sellers' responses to consumers' probabilistic belief biases, specifically the Gambler's Fallacy and Hot-Hand Fallacy. In field data, biased beliefs are typically difficult to observe and quantify. Clotfelter and Cook (1993) and Terrell (1994) find evidence for the Gambler's Fallacy in lottery customers' number choices. De Bondt and Thaler (1985) and Barber, Odean, and Zhu (2009) find that investors are more likely to purchase stocks with strong recent performances. In the horserace-betting market, Griffith (1949), Ali (1977), Asch, Malkiel, and Quandt (1982), and Hausch, Ziemba, and Rubinstein (1981) find that, on average, bettors tend to overvalue "long shots" and undervalue favorites, known as the favorite-long shot bias.

Our study has novelties over the existing evidence on belief biases in the field. First, in our setting (as in Clotfelter and Cook 1993 and Terrell 1994), the lottery game probability structure is simple and transparent. As the probabilities, as well as the information structure of the lottery game, are transparent and simple, we can be fairly confident that the demand variations in our data are due to the non-standard beliefs. Second and importantly, we focus on assessing sellers' *responses* to consumers with such beliefs, and the data allows us to observe how sellers choose to respond to a market of biased buyers. The market structure in our data has the peer-to-peer feature that anyone can become a seller, similar to the sellers on eBay, Craigslist, or other online retail communities. Thus it is very likely that sellers' observed choices reflect their individual decisions as online entrepreneurs, in contrast to cases where a firm's actions may be the result of institutional policies or group-based decision-making. We find that sellers exhibit best-response tendencies toward behaviorally biased agents, consistent with increasing their net expected gains in the lottery market structure.

We also contribute to the small but growing literature empirically documenting heterogeneity in behavioral biases among agents in markets. Brown, Camerer, and Lovallo (2012a, 2012b) propose that movie-goers are limited in their strategic thinking when they decide which movies to see. The evidence lies in the fact that movie studios consistently earn greater box-office revenues by withholding low quality movies from critics (aka a "cold opening"). In a separate paper, Brown, Camerer, and Lovallo (2012b) estimate a structural level-k model to the movie industry data to show that less sophisticated consumers can account for this pattern. For a review of recent advances in structural models of non-equilibrium strategic behavior, see Crawford, Costa-Gomes, and Iriberri (2013).

Other recent papers examine different degrees of strategic sophistication on the seller side (see

1. The biased beliefs of buyers in our specific collective lottery portfolio market are examined in detail in Lien, Yuan, and Zheng (2014), and we also provided a brief summary of their results in the current paper as a background for understanding sellers' responses.

Goldfarb et al. 2011 for a survey). In particular, Goldfarb and Xiao (2011) examine the entry behavior and personal characteristics of telecommunications managers after market liberalization in the United States in 1996. They find that CEOs with high quality economics or business training entered markets with lower competition, and argue that this is evidence that some managers are better in strategic situations than others. Malmendier and Shanthikumar (2014) distinguish between strategic and belief-based motives for inflated security recommendations by examining the within-analyst empirical relationship between forecasts and recommendations. They find that analysts affiliated with a firm's underwriter tend to produce lower forecasts for the firm, which are easier to outperform, and they subsequently recommend the firm more strongly to investors.

In a paper quite related to ours, Levitt (2004) finds that bookmakers in sports betting markets systematically exploit bettors' biases and achieve higher profits by doing so. A distinction is that the "home bias" studied in Levitt (2004) can be fully accounted for using a rational model with correct belief specifications, while we focus on the lottery structure's ability to reveal inaccurate beliefs. An additional difference is that while bookmakers can be fairly considered professionals, our sellers are non-professional at the task of selling lottery portfolios. Thus, it is perhaps surprising that our sellers have the ability to generate similar behavior as professional bookmakers.

We employ a reduced-form approach in estimating the sellers' responses to buyers' biased beliefs, focusing primarily on the direction of sellers' responses rather than the magnitude. The advantage of this approach is that it allows us to straightforwardly test whether sellers on average significantly respond to the biased beliefs of buyers. The disadvantage is that we cannot very precisely estimate sellers' magnitude of response, as we do not attempt to specify or estimate sellers' objective function. Indeed, we find the reduced-form approach most appropriate for our setting, given that the online marketplace and the motivations of participants in it, may be quite complex to model. While a structural approach also has merits, it may be substantially more difficult, while possibly not yielding substantially different insights compared to a simple reduced-form analysis.

The remainder of the paper proceeds as follows: Section II describes the background of the lottery game and the peer-to-peer market, including the data; Section III briefly describes facts about lottery buyers' purchase behavior; Section IV describes our hypotheses for sellers' responses to buyers with belief biases; Section IV presents the empirical results; Section VI concludes and discusses directions for future work.

II. FIELD SETTING

A. The SSQ Lottery Game

SSQ lottery is one of the biggest Chinese national lottery games in China. The gaming rules of the SSQ are similar to those of other popular lotteries, such as Powerball in the United States and LottoMax in Canada. SSQ stands for 双色球 (Shuang Se Qiu), which means dual-colored balls in Chinese. An individual ticket is sold for 2 Yuan (about $0.32 USD). It requires players to pick numbers from two groups of numbers. In the first group, players need to pick six numbers from the range 1 to 33, which are called the red numbers. In the second group, players need to pick one number from the range 1 to 16, which is called the blue number. To win first prize, the player needs to match all seven numbers randomly drawn as the winning number combination.

The SSQ has six levels of prizes, which are shown in Table 1. The first prize is shown in the first row, and requires matching all the drawn numbers, red and blue. The second prize requires the matching of all six red numbers except for the blue one. The first and second prizes are pari-mutuel as the final reward depends on the number of winners and the prize pool for each payout, whereas the third to sixth prizes are non-pari-mutuel fixed prizes.

B. The Online Lottery Betting Game

Taobao (sometimes referred to as "China's Amazon") is the largest online shopping service provider in China. In 2010, Taobao had over 370 million registered customers and generated over 400 billion Yuan in sales (over 60 billion U.S. dollars) with an annual growth rate of over 100%. Besides general e-business, Taobao also provides a platform called the "Taobao Lottery" for online lottery gambling in China, and one of its main services is to sell the SSQ tickets online such that potential lottery buyers can purchase SSQ tickets together

Any registered Taobao user can independently purchase a lottery ticket from the Taobao Lottery store online. However, the site is more than just an

TABLE 1
SSQ Prize Policies

	Winning Conditions		
Award Level	**Number of Red Balls Matched (out of 6)**	**Blue Ball Matched?**	**Prize Distribution**
First prize	6	Yes	If the rollover money from the last jackpot is less than 100 million RMB, then the grand prize jackpot winners will split the rollover from the previous draw and the 70% from the "high prize pool." If the prize is more than 5 million RMB, each winning ticket will only be worth 5 million RMB. If the rollover money from the last jackpot is at least 100 million RMB or more, there is a two-part prize package. The winners split the rollover money from the previous draw and 50% from the "high prize pool," as well as 20% from the "high prize pool." With each prize, a maximum of 5 million RMB is paid (total of 10 million RMB).
Second prize	6	No	To split the 30% of "high prize pool"
Third prize	5	Yes	Fixed amount of 3,000 Yuan per winning lottery ticket
Fourth prize	5	No	Fixed amount of 200 Yuan per winning lottery ticket
	4	Yes	
Fifth prize	4	No	Fixed amount of 10 Yuan per winning lottery ticket
	3	Yes	
Sixth prize	2	Yes	Fixed amount of 5 Yuan per winning lottery ticket
	1	Yes	
	0	Yes	

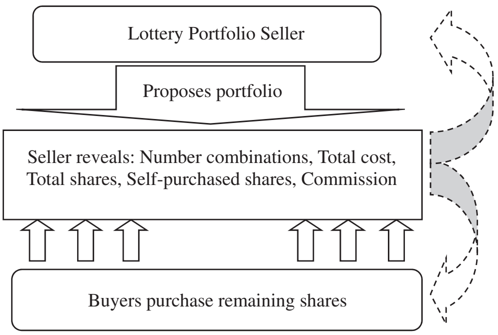
online lottery store, also providing a platform for group or "collective lottery purchases" in a peer-to-peer market. As the leading online retailer for consumer goods in China, the traffic and transactions volume on the Taobao website is likely to be among the world's largest.

In many lottery games, it is common for family, friends, or co-workers to pool their money together to buy a certain number of lottery tickets. In the event of a win, those who have contributed money to the pool receive a share of the winnings. Recent studies show that collective lottery purchases are common in many countries. Guillen, Garvia, and Santana (2012) found that 12% of U.S. players, 22% of players in the United Kingdom, and 33% of players in Spain collectively purchase lottery tickets on a regular basis. Humphreys and Perez (2013) found that in Spain sociological factors such as employment and gender significantly predict participation in collective lottery purchase.

The market in Taobao Lottery is a formalized version of the usual collective betting arrangement, with institutional rules set and enforced by the website. Collective bettors do not need to know one another, and they do not need to know the seller. Similar to other online peer-to-peer retail websites such as eBay or Craigslist, users' real identities are kept confidential. The online lottery marketplace automates the necessary transactions so that trust between participants is not a requirement for the transaction. There are a few possible reasons why an individual would purchase lottery tickets from the online market. Perhaps the most obvious reason is risk-sharing, as in the traditional collective betting arrangement. Consumers wish to "invest" in a larger set of number combinations, without having to fully use their own money to do so. The online marketplace provides a formal platform for them to do so, and a key motivation is that they do not need to find interested betting partners and coordinate with those bettors on their own. The anonymity and automated structure of the marketplace provides an additional attractive draw for consumers. If a win does occur, consumers in the online marketplace do not need to arrange the sharing of winnings with their betting partners on their own—the exchange is reduced to a transaction, without any personal complications in the arrangement. The motivation for seller participation is similar, but with the additional draw that they can earn commissions from buyers when a win occurs.

We now describe the market structure and transaction procedure. In the marketplace, there are low barriers to entry to becoming a seller. The only prerequisite is having a Taobao account. A lottery portfolio is a collection of lottery numbers chosen by a Taobao user (the "seller"). The seller announces the number of shares in a package and the corresponding price per share (Total Cost/Total Shares). For example, the seller can propose a package which consists of two lottery tickets, such that the total cost is 2 Yuan; 1 Yuan for each ticket. Meanwhile, this same user can

FIGURE 1
Structure of Taobao Online Lottery Market



Note: In event of lottery win, returns made to buyers proportionally according to purchased shares.

divide this package into 100 shares, so that more people can participate in the package. Therefore, there will be 100 shares for this lottery package and each share will be worth 0.02 Yuan. In this example, at most 100 lottery gamblers can take part by purchasing shares in this portfolio.

Besides the lottery number selection, total portfolio size, total shares, and price per share, the seller also has to reveal the number of shares self-purchased (i.e., the seller's own investment in this lottery portfolio). The seller also states a commission fee: the percentage of the total winning prize that the seller collects before the prize is divided among the investors according to their shares in this package. For example, suppose that a lottery package wins a total payout of 100 Yuan and the commission fee of the seller is 3%. Before the others share the prize, the proposer will first receive 3 Yuan of the winnings, leaving 97 Yuan to be shared among the rest of the shareholders. Figure 1 illustrates how the Taobao collective lottery purchase system works.

Taobao Lottery also requires that sellers self-invest either at least 1% of the shares in their own proposed portfolio, or the same percentage as the commission rate they charge buyers, whichever is larger. This ensures that sellers have some of their own money at stake in the portfolios that they are offering on the market. Sellers can self-invest on up to 100% of the portfolio, where investing 100% is equivalent to a solo purchase. Sellers are also allowed to propose more than one portfolio in each round. In practice there are about 10,000 sellers participating in each lottery round, with the large majority of them posting a single portfolio.

Portfolios can be open for sale directly after the previous round of the SSQ lottery is over. Once a portfolio is posted online, the seller cannot change it. Similarly once buyers purchase shares, they cannot request a refund. Selling of shares closes 3 hours before the actual SSQ lottery drawing. If by that time, a seller's portfolio is not 100% sold out, the portfolio is canceled and all investors have their money automatically refunded to their account.

Once a portfolio is sold out, Taobao receives the money invested in it. Taobao then purchases the tickets on behalf of the seller, and is responsible for distributing the winnings among investors in the event of a win.[2] Taobao thus eliminates any concerns from buyers about the trustworthiness or reliability of the seller.

III. BELIEF BIASES OF BUYERS

We focus on two main belief biases of buyers in the lottery market: the Gambler's Fallacy and the Hot-Hand Fallacy. Both fallacies have been previously documented independently in the field among lottery players. Clotfelter and Cook (1993) and Terrell (1994) documented the Gambler's Fallacy in number picks for fixed prize lotteries and pari-mutuel lotteries, respectively. Specifically, they found that players were unlikely to choose a particular number in their ticket if that number had recently been drawn on a winning ticket. Guryan and Kearney (2008) found that lottery retailers that had recently sold a jackpot winning ticket experienced a growth in lottery sales immediately afterwards, consistent with the predictions of a Hot-Hand Fallacy, or what they describe as a "Lucky Store Effect."

These biases of lottery players have been previously documented in the literature and can be taken as given in our analysis of seller behavior. To confirm the validity of the belief biases, we also find strong empirical support for the Gambler's and Hot-Hand Fallacies by buyers in our data. The detailed results for the Taobao Lottery market are reported in Lien, Yuan, and Zheng (2014), which focuses on buyers' beliefs, including the theoretical relationship between the Hot-Hand Fallacy and the Lucky Store Effect. While the patterns that we document here classify technically as a Lucky Store Effect (a seller is more

2. For providing this service Taobao receives a commission from the official lottery authority, and they have the additional benefit of advance cash flow when the lottery investment is made.

attractive to buyers after just one "win"), for simplicity, we refer to it throughout this paper as the Hot-Hand Fallacy.[3] We have discussed only the behavior of buyers briefly, as our primary objective in the current paper is to study sellers' responses to the buyers. To introduce these buyer biases, we first explain our main measures of the Gambler's Fallacy and Hot-Hand Fallacy.

A. Buyers' Susceptibility to the Gambler's Fallacy

As documented by the previous literature, lottery players tend to avoid picking numbers which have won in the preceding round. The Gambler's Fallacy says that they do this because they believe those numbers are unlikely to be drawn again soon, contrary to the independent nature of the draws in each round. To measure the similarity of a lottery portfolio to the winning lottery ticket, we create a Similarity Index which summarizes how similar or different a chosen ticket is to the most recent previously winning ticket. Our approach differs slightly from Clotfelter and Cook (1993) and Terrell (1994) because we need to consider entire tickets or portfolios of tickets offered by the seller as the objects of comparison, rather than individual numbers on a ticket. To accommodate this difference, we use an indexing approach.

Each lottery ticket in SSQ consists of seven numbers with six red balls drawn without replacement from the integers in the range [1,33], plus one blue ball drawn from the range of integers [1,16]. We use the following notation to denote a lottery number combination for a single ticket i, where r denotes red numbers and b denotes the blue number:

$$\text{Ticket}_i = \left\{ r_1,\ r_2,\ r_3, r_4,\ r_5,\ r_6 |\ b_1 \right\}.$$

Let the winning numbers in lottery round t be denoted by the vector w:

$$\left\{ w_1^t,\ w_2^t,\ w_3^t, w_4^t,\ w_5^t,\ w_6^t |\ w_7^t \right\}.$$

Let $I(\cdot)$ be an indicator function. If the event in parentheses is true, the value is one; and the value is zero otherwise.

Then, we define $\text{S\_Index}_{i,t}$ as follows:

$$\text{S\_Index}_{i,t} = \frac{1}{2}\left\{ \left[\sum_{n=1}^{6}\sum_{m=1}^{6} I\left(r_n = w_m^t\right) \right] /6 \right\} + (1/2)\ I\left(b_7 = w_7^t\right)$$

The Similarity Index consists of two components. One component is the similarity measure on the red numbers chosen, in which we count the number of matched number picks between the previous winning ticket and a seller's ticket, where the ordering of numbers does not matter. The second component is the similarity on the blue number, which is merely an indicator for whether the blue number on the seller's ticket matches the previous winning blue number. We use equal weighting on these two components.[4]

As an example, if the chosen blue number b_7 is the same as the winning blue number w_7^t in round t, by the definition above, this similarity contributes to one half of the total index. Second, on the red ball division, according to the above definition, if any of $\left\{ w_1^t,\ w_2^t,\ w_3^t, w_4^t,\ w_5^t,\ w_6^t \right\}$ shows up in the ticket $\{ r_1, r_2, r_3, r_4, r_5, r_6 \}$, that number contributes 1/12 [= (1/2) × (1/6)]) to the total index. It is clear that $\text{S\_Index}_{i,t}$ for the hypothetical purchased lottery ticket $Ticket_i = \left\{ w_1^t,\ w_2^t,\ w_3^t, w_4^t,\ w_5^t,\ w_6^t |\ w_7^t \right\}$ is equal to 1.

When a lottery portfolio consists of several different lottery tickets, we take the average of the Similarity Index across tickets in the portfolio as the portfolio's Similarity Index.[5]

Buyer's Gambler's Fallacy: Buyers in the online lottery market are less likely to purchase lottery portfolios when the portfolio numbers are more similar to the winning ticket in the previous round.

B. Buyers' Susceptibility to the Hot-Hand Fallacy

To detect the Hot-Hand Fallacy, we require a measure of lottery sellers' success rates. According to the literature, players will gravitate toward

3. Specifically, Lien, Yuan, and Zheng (2014) show that a cross-sectional extension of the representativeness bias framework presented in Rabin (2002) and Rabin and Vayanos (2010), can generate the Lucky Store Effect after just a single lottery win by a seller, rather than over streaks of wins as assumed by the Hot-Hand Fallacy. They suggest that when considering a class of belief fallacies in which decision-makers believe that "winners in the past will win again," the Lucky Store Effect can be considered a special case of a generalized Hot-Hand Fallacy.

4. We believe this is a reasonable model of players' impression of the relative importance of red and blue numbers due to the format of the SSQ game which highlights this point. Our results are robust to different weightings of the red and blue ball components.

5. The Similarity Index may not be the perfect indicator in the sense that if difference among lottery packages is too tiny, some people may not be sensitive to small differences in the index. However, it is able to capture the difference if several winning numbers are involved.

TABLE 2
Variable Definitions

Similarity index	Similarity Index of a lottery portfolio, as defined in Section III.A
WinRate	Winning rate of the seller, as defined in Section III.B
Commission	Commission rate charged by seller, as a percentage of the total winnings of the portfolio
Size	Total amount of money in the lottery portfolio
Shares	Total number of shares in the portfolio
Price	The price of a single share
Self-investment	The percentage of shares purchased by the seller
Time expose	The time prior to lottery draw when portfolio is available for purchase

sellers who have previously won, because they believe that those sellers are particularly lucky (i.e., somehow having a higher theoretical return rate than other sellers).

In Taobao Lottery, buyers can observe each seller's information such as the total wager and past performance, as well as package-specific information, such as total shares, share price, commission rate, and so forth. However, note that the return rate of the seller in any period is a transient shock, which cannot predict any future performance of the seller. Therefore, if lottery players' beliefs are rational, their purchase behavior should not be affected by sellers' past wins or current return rate. The return rate of a seller *j* in the previous round is defined as follows:

$$\text{WinRate}_j = \left(\text{TotalWin}_j / \text{TotalWager}_j\right)$$

where TotalWin_j the total amount of money won by seller *j* in the previous round and TotalWager_j is the total lottery investment by seller *j* in the previous round.

Buyer's Hot-Hand Fallacy: Buyers in the online lottery market are more likely to purchase lottery shares from sellers who have won in the previous round.

C. Data

Our data is based on 4,529,730 observations over 25 rounds of SSQ lottery games. We observe each seller's portfolio on the market, including the exact numbers chosen for each of these rounds. We also observe several other variables important for our analysis, displayed in Table 2.

The sample summary statistics for these and other variables are shown in Table 3. In each round over 2 million lottery portfolios are put on the market by over 41,000 sellers. The mean value for win rate of sellers is 58% for the whole sample and around 23% excluding the single jackpot win in our data, which is consistent with the theoretical expected rate of the lottery game. For details on the calculation of the prize odds and structure in the SSQ lottery, we refer the reader to Yuan and Gao (2014). The summary statistics show that portfolio size and number of tickets included per portfolio vary widely. There is also substantial variation in self-investment behavior and commissions charged. Approximately 77% of lottery portfolios in our data successfully sell out.

Before our regression analysis, we want to first examine the prediction power of the past WinRate on the future WinRate. Theoretically, as WinRate is a random shock, there should be no serial correlation present. However, to test the validity of this claim, we check whether past lottery performance has any statistically significant or economically significant impact on future performance. Therefore, we regress the current WinRate on the past four rounds of WinRate and the regression results are shown in Table 4. We can see that the R^2 is zero and the coefficients are all insignificant and extremely small, which confirms the independent nature of lottery draws and further provides the foundation for the following empirical analysis.

D. Empirical Evidence for the Hot-Hand Fallacy and Gambler's Fallacy of Buyers

The results in this section providing empirical evidence for buyers' belief fallacies are borrowed from Lien, Yuan, and Zheng (2014), which discusses buyers' beliefs in greater detail. We use a standard Tobit model with a cutoff value of 100% to analyze how lottery players choose lottery portfolios given the return rate (WinRate) of the sellers and the Similarity Index. We focus on the fraction of the lottery portfolio which has been purchased at the time the market closes. This serves as a proxy for buyers' preferences over the lottery portfolios in the market among buyers.

The regression model for buyers' behavior is as follows:

$$\begin{aligned}\text{PROGRESS}^* = {} & \beta_0 + \beta_1 \text{WinRate} \\ & + \beta_2 \text{ Similarity Index} + \beta_3 \text{ COMMISSION} \\ & + \beta_4 \text{ SIZE} + \beta_5 \text{ SHARES} + \beta_6 \text{ PRICE} \\ & + \beta_7 \text{ SELFBUY} + \beta_8 \text{ TIMEEXPOSE} + \epsilon\end{aligned}$$

TABLE 3
Summary Statistics

Variable	Minimum	Mean	Median	Standard Deviation	Maximum	Observations
Similarity index	0	.098	0.083	0.082	1	283,083
WinRate (all)	0	.58	0	35.41	14,930.84	248,523
Excluding jackpot	0	.229	0	1.87	376.25	248,460
Commission	0	.0575	0.08	0.0437	0.10	301,982
Size (all)	8	774.32	18	8035.93	937,770	301,982
Successful only	8	53.46	14	400.31	58,848	233,481
Shares	1	911.67	50	13859.6	2,491,060	301,982
Price	0.2	3.91	0.5	87.55	12,400	301,982
Self-investment	0.01	.55	0.6	0.27	1	301,982
Number of tickets in each package	4	387.16	9	4017.96	468,885	301,982
Number of buyers for each package	1	9.76	5	46.39	6,118	301,982
Portfolios in each round	18899	20132	20260	1015	22,242	301,982
Time expose (hours)	0.01	25.67	24.02	19.532	70.49	301,982
Sold-out portfolios			77%			301,982
Total number of sellers						41,418

TABLE 4
Correlation of Previous Return Rates on Future Performance

	WinRate
WinRate (Lag 1)	−0.00012 (0.0022)
WinRate (Lag 2)	−0.00019 (0.0040)
WinRate (Lag 3)	−0.00004 (0.0040)
WinRate (Lag 4)	−0.00016 (0.0040)
N	84,579
Adjusted R^2	−0.000

Note: Standard errors in parentheses.

$$\text{PROGRESS} = \begin{cases} \text{PROGRESS}^* & \text{IF} \quad \text{PROGRESS}^* < 100 \\ 100 & \text{IF} \quad \text{PROGRESS}^* \geq 100 \end{cases}$$

where PROGRESS represents the sales progress of a portfolio, in other words the proportion of shares in this portfolio that are sold at the time the market closes. PROGRESS* is the latent variable which we cannot observe, due to the fact that once a portfolio is completely sold out, no further shares can be sold. WinRate and S_Index are the variables defined above. COMMISSION is the seller's chosen commission fee, SIZE is the total amount of money to be collected if the lottery portfolio is completely sold out, SHARES represents the total number of shares in the portfolio, PRICE is the value for each single share, SELFBUY measures the percentage of the shares purchased by the seller himself and TIMEEXPOSE measures how early the portfolio is put up online for sale. These variables are controlled for in the regression since buyers' decisions may also depend on these features.[6] In the empirical analysis, including all the subsequent regressions on the sellers' behavior, we also include round dummy variables to control for round-specific factors.

In the Taobao online lottery data, buyers are significantly more attracted to ticket sellers who have experienced an increase in their WinRate in the previous round, all else equal, in accordance with the Hot-Hand Fallacy. Buyers are significantly more attracted to lottery portfolios which have a low Similarity Index, and avoid lottery portfolios which have high similarity to the previous winning ticket; in accordance with the Gambler's Fallacy.

As the focus of the current paper is on seller behavior, the basic empirical results of this regression are relegated to Tables S1 and S2, Supporting Information, which show the results of the Tobit specification discussed in Section III.C, taken from Lien, Yuan, and Zheng (2014). The objective is to test whether the coefficient on WinRate is significantly positive, consistent with the Hot-Hand Fallacy; and whether the coefficient on Similarity Index is significantly negative, consistent with the Gambler's Fallacy. We see that across specifications including several control variables, the Hot Hand and Gambler's Fallacies remain robust. Table S2 checks the robustness of

6. In the robustness check, we further add the jackpot size and the number of winning tickets in the previous round in the regressions, and the results remain robust.

these results under a Probit specification.[7] As the regression results in the Tables S1 and S2 show, a high WinRate is significantly positively associated with higher sales progress of a portfolio, and a high Similarity Index is significantly negatively associated with sales progress. As both WinRate and Similarity Index are independent of the current lottery round's performance, the differences in sales success of these portfolios can be attributed to buyer's biased beliefs. We note that the coefficients on portfolio features in the buyer regression are in the directions as expected. The identification of the belief fallacies from the buyers' side provides the foundation for us to further study the sellers' behavior.

IV. SELLERS' RESPONSES

Sellers in the market must make several choices in putting their portfolios online for sale. In each round, the winning lottery numbers and the winning return rates of the sellers in the previous round will shift their decisions. They must decide on their *commissions* to be earned in the event of a win, the portfolio *size* and number of shares (thus jointly determining the share *price*), how much to *self-invest* in their own portfolio, and the actual *numbers* in their lottery portfolio.

In a competitive market such as this one, with no barriers to entry, if all participants in the market had unbiased beliefs about probabilities, none of these choices should make any difference in the sales success of sellers. We hypothesize in accordance with a rational model of seller behavior, that sellers will respond to the aforementioned buyer beliefs in their decisions about portfolio feature, in specific ways in order to increase their expected profits.

Each of the seller's choices can alter expected profits in the following ways, holding all other factors and choices constant.

1. ***Commissions*** are, by definition, the proportion of the buyers' share of the winnings that are paid to the seller.

Holding all else constant, *increasing the commission rate* increases the seller's revenue and profits.

2. The *portfolio size* is simply how much money has been invested in the lottery in the seller's portfolio.

Holding all else constant, *increasing the portfolio size* increases the expected profits of a seller through the expected commission money on his customers' shares, and through the increased probability of holding a winning ticket (assuming that increasing portfolio size also results in greater purchase of unique tickets).

3. *Self-investment* is the proportion of a seller's own lottery portfolio that he himself purchases.[8]

Holding all else constant, a seller can increase his expected profits by *reducing his self-investment*. This is because the expected commissions earned from his customers' purchased lottery shares are a marginal cost-free method of increasing expected revenues—sellers can earn an extra expected profit without putting any additional of their own money into the portfolio.

With these three ways of increasing expected profits in mind, Subsections IV.A and IV.B specify precisely how we expect sellers to take advantage of the Hot-Hand and Gambler's Fallacies of buyers to increase their expected profits. The key is that sellers choose portfolio features to take advantage of their level of popularity on the demand side, in a manner consistent with responding to the belief fallacies held by buyers.

A. Response to the Hot-Hand Fallacy

Recall that a lottery ticket buyer who subscribes to the Hot-Hand Fallacy will tend to buy from a seller who has won a large prize in the previous round in the lottery game, as he or she believes that such a seller stands a higher chance of winning this round than other sellers who have not won.

This change in the buyers' demand over ticket sellers' services is induced by the randomness of the previous lottery round's outcome. Faced with an increase in willing customers, we expect the sellers to adopt the following strategies, directly after experiencing a large lottery win in the previous round, in order to take advantage of this

7. To check the robustness of the regression results, we also implement a Probit model. These results can be found in Table 2 in Tables S1 and S2. The regression coefficients are of the same sign direction as the Tobit model, which suggests that the regression results are robust.

8. Recall that by the lottery market regulations, the seller must self-invest in no less than 1% of his own portfolio, and at least as high a percentage as the commission rate he charges.

anticipated increase in popularity of their own ticket portfolio.

Hot-Hand Response Hypothesis: Sellers charge higher *commission* rates, offer larger *portfolio size*, and *self-invest* less directly following a large win.

B. Response to the Gambler's Fallacy

Recall that a lottery ticket buyer who subscribes to the Gambler's Fallacy tends to buy from sellers whose portfolios offer numerically dissimilar lottery tickets compared to the previous winning ticket, as he or she believes that the numbers on the previous winning ticket are less likely to appear again in this time's winning ticket.

We wish to point out a key difference between exploitation of the Hot-Hand Fallacy, and exploitation of the Gambler's Fallacy in this lottery market setting. In the case of the Hot-Hand Fallacy, sellers' ability to take advantage of it depends on sellers' attractiveness to the lottery buyers, which by the SSQ lottery procedure, is beyond sellers' control. In the case of the Gambler's Fallacy, however, sellers can *choose* which lottery tickets to include in their portfolio.

Thus, in addition to the three variables sellers can determine in the case of reacting to the Hot-Hand Fallacy (commission, portfolio size, self-investment), sellers can additionally decide what kind of numbers to include in their portfolio, conditional on the previous winning ticket numbers. We hypothesize that sellers will tend to offer lottery portfolios which are dissimilar to the recent winning tickets. The other three portfolio features chosen by the seller are hypothesized to follow the same direction as the predicted reaction to the Hot-Hand Fallacy, the effects increasing in the degree to which a portfolio caters to Gambler's Fallacy beliefs, by avoiding recent winning numbers.

Gambler's Fallacy Response Hypothesis: Sellers tend to offer lottery portfolios which are *numerically dissimilar* to the winning tickets in the previous round. They tend to charge a higher *commission,* offer larger *portfolio sizes,* and *self-invest* less on these Gambler's Fallacy targeted portfolios

We now take these hypotheses to the data, to test whether holding all else equal, sellers adopt these specific strategies after the results generated by previous lottery outcomes, when faced with a population of buyers holding biased beliefs.

V. RESULTS

We use an ordinary least squares (OLS) regression to test the Hot-Hand and Gambler's Fallacy Response Hypotheses, with the exception of the hypothesis about sellers' lottery number choices, which we test by tabulating the popularity of previously winning lottery numbers in the market.

In each of the OLS regressions, we assume that sellers have rational expectations that buyers' belief fallacies are *strongest* with respect to the most recent lottery that has occurred. There may be time dynamics in terms of biased beliefs with respect to lottery outcomes in a more distant past, but our analysis treats these as noise.

A key feature in the regressions is that in the lottery market, wins are randomly assigned because the lottery is a game of pure chance. This random assignment of wins is implemented across the sample of sellers in our data, and the portfolio characteristics they selected. Thus, the coefficient on the winning indicator variable can be reasonably interpreted as a "causal" effect on the portfolio characteristics, although the mechanism for the causality is not evident from the OLS regression results alone. This requires the additional evidence on buyer's responses to lottery outcomes in the marketplace, which can be found in Tables S1 and S2 (and is consistent with previous literature on lottery player biases in the non-portfolio setting).

Our primary objective in the regressions is to check whether lottery market events which would induce biased beliefs by buyers, are systematically associated with adjustments made by sellers to their portfolios. We do not attempt to account for the bulk of variation in sellers' decisions on these portfolio variable choices here. However, since we observe several features of the sellers' portfolio, we do include these features as control variables wherever possible, to ensure our results are robust to variation in these other variables.

A. Hot-Hand Response Results

Hot Hand Response Hypothesis: Sellers charge higher *commission* rates, offer larger *portfolio size*, and *self-invest* less directly following a large win.

We begin with the part of the hypothesis on sellers' commission rates. We regress sellers' current commission rates on an indicator variable for whether his or her previous lottery round's rate of return exceeded 200%. Portfolio-specific traits such as portfolio size, self-investment ratio

TABLE 5
Dependent Variable: Commission[a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Big Win indicator	0.567*** (0.071)	0.548*** (0.071)	0.643*** (0.069)	0.626*** (0.069)	0.657*** (0.069)	0.663*** (0.069)	0.658*** (0.069)
Size (in 10^{-4})		3.87*** (.236)	5.43*** (.230)	2.66*** (.335)	3.52*** (.336)	3.51*** (.336)	3.48*** (.336)
Self-investment			4.797*** (0.0431)	4.800*** (0.0431)	4.864*** (0.0431)	4.864*** (0.0431)	4.938*** (0.0441)
Shares (in 10^{-4})				2.99*** (.263)	2.47*** (.263)	2.47*** (.263)	2.46*** (.263)
Price					−0.00980*** (0.000393)	−0.00980*** (0.000393)	−0.00974*** (0.000393)
Similarity index						−0.157 (0.113)	−0.165 (0.113)
Time expose							0.00388*** (0.000496)
N	218,709	218,709	218,709	218,709	218,709	218,709	218,709
Adjusted R^2	.000	.002	.055	.056	.058	.058	.059

Notes: Standard errors in parentheses; $^{**}p < .05$, $^{***}p < .01$.
[a]Ordinary Least Squares, Big Win Indicator = 1 if WinRate > 200%.

of the seller, shares offered, price, and similarity index are included as control variables to ensure that the relationship between commission and large wins is robust to these other potentially influencing portfolio features.

As the results in Table 5 show, a "big win" in the previous period is associated with a significantly higher commission rate set the current period, of magnitude between 0.56 and 0.66 percent. Accounting for heterogeneity in the portfolio control variables increases the size of the effect. Another way to interpret it is that if a seller's winning rate increases from 0 to 200%, which is highly possible given the huge standard deviation of the winning rate shown in the Table 3, he will increase his commission by around 0.5% (in absolute value) thanks to the biased belief of the buyers, even though his winning rate is pure luck. We also consider a threshold win rate value of 100% (such that a buyer would earn back his investment if such a win rate were to be realized again), and a specification containing the continuous variable *WinRate* instead of a threshold variable. The results are robust to these alternative specifications, and the robustness check results are provided in Tables S3 and S4.

We now turn to the part of the hypothesis on sellers' portfolio size, or the total monetary value of the portfolio offered, in response to the Hot-Hand Fallacy. To test this hypothesis, we regress the monetary value of the portfolio offered on the indicator variable for whether the previous round's rate of return exceeded 200%. We include commission rates, self-investment ratio of the seller, price, and similarity index as control variables, as before. As Table 6 shows, large wins in the immediately previous round are associated with significantly larger monetary portfolios in the next round.

As in the regressions in Table 5, the assignment of large wins is randomly assigned. The relationship between large wins and seller response can be interpreted as: large wins induce sellers to increase their volume of tickets sold in the next round. To be precise, if the winning rate increases by 200%, the seller will increase the size of the lottery package by around 50 RMB. As all portfolios must sell out in order to be implemented, sellers must believe that more customers will be willing to purchase their shares this period, after they have won previously. Thus sellers' attempt to sell higher volumes of tickets is a response to customers' revealed incorrect belief that those sellers who won last time are more likely to win again this time.

Finally, we turn to the part of the hypothesis proposing that sellers will self-invest less in their own portfolio after experiencing a win in the previous round. Table 6 shows the results of regressing the self-investment ratio on the indicator for a previous large win, and the control characteristics of portfolio size, shares, price and Similarity Index. All else equal, sellers also invest less in their own portfolio after experiencing a large win, as seen from the coefficient estimates for BigWin

TABLE 6
Dependent Variable: Portfolio Size[a]

	(1)	(2)	(3)	(4)	(5)	(6)
Big Win indicator	50.28***	48.48***	44.70***	41.03***	41.89***	41.33***
	(6.494)	(6.491)	(6.476)	(6.462)	(6.478)	(6.477)
Commission		3.164***	4.669***	4.996***	4.995***	4.960***
		(0.193)	(0.198)	(0.198)	(0.198)	(0.198)
Self-investment			−135.9***	−144.6***	−144.6***	−135.8***
			(4.096)	(4.095)	(4.095)	(4.192)
Price				1.162***	1.162***	1.168***
				(0.0363)	(0.0363)	(0.0363)
Similarity index					−19.94	−20.81*
					(10.49)	(10.49)
Time expose						0.448***
						(0.0460)
N	218,709	218,709	218,709	218,709	218,709	218,709
Adjusted R^2	.000	.001	.006	.011	.011	.012

Notes: Standard errors in parentheses; $p < .05$, $^{***}p < .01$.
[a]Ordinary Least Squares, Big Win Indicator = 1 if WinRate >200%.

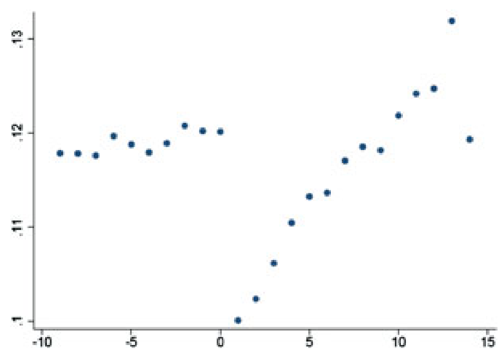
Indicator. To be precise, if the winning rate increases by 200%, the seller will decrease his self-investment ratio by around 2%. These results are quite significant and robust to the inclusion of other control variables in the regression.

B. *Gambler's Fallacy Response Results*

To test sellers' responses to the Gambler's Fallacy, we first address the issue of portfolio selection. Recall that sellers choose their own numbers for each ticket in the portfolio, after the previous round of winning numbers has been realized. The Similarity Index, our measure of (un)attractiveness of a portfolio, is thus a choice made by sellers, not an exogenous outcome as in the case of WinRate under the Hot-Hand Fallacy. To test the Gambler's Fallacy Response Hypothesis, we first examine trends in number selection choices, then regress the sellers' other choice variables on the Similarity Index of the portfolio, along with other portfolio control variables.

We conduct a simple aggregate analysis to determine how sellers, on average, react to previous winning numbers in their choice of numbers. Suppose in round 0, there is a winning lottery ticket. Figure 2 plots the trend of Similarity Index$_{i,0}$, or how similar the lottery ticket i in round t is to the winning number combination in round 0. The horizontal axis plots rounds from 10 rounds prior to the winning ticket to 15 rounds after the winning ticket. The vertical axis represents the average Similarity Index in the SSQ lottery market at each time period.

FIGURE 2
Similarity Index of Portfolios as a Function of Time since the Winning Ticket



Note: Horizontal axis: time since revelation of winning ticket; Vertical axis; average Similarity Index.

Figure 2 shows clearly that prior to the revelation of the winning numbers at time 0, the Similarity Index is quite stable around the 0.12, which is equivalent to the average Similarity Index when numbers are completely randomly drawn. When the winning numbers are revealed to the public at time 0, we observe a sharp drop in the Similarity Index of lottery portfolios in the market, meaning that sellers, on average, began offering portfolios which were less similar to the winning ticket from time 0 onward. Eventually as time goes on, the Similarity Index value returns to the original average level. This closely mirrors the findings of Clotfelter and Cook (1993) in their analysis

TABLE 7
Dependent Variable: Commission[a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Similarity index	−0.100	−0.0933	−0.0511	−0.0621	−0.0822	−0.157	−0.165
	(0.116)	(0.116)	(0.113)	(0.113)	(0.113)	(0.113)	(0.113)
Size (10^{-4})		3.90***	5.46***	2.64***	3.49***	3.51***	3.484***
		(.236)	(.230)	(.335)	(.337)	(.336)	(.336)
Self-investment			4.792***	4.795***	4.858***	4.864***	4.938***
			(0.0431)	(0.0431)	(0.0431)	(0.0431)	(0.0441)
Shares (10^{-4})				3.04***	2.53***	2.47***	2.46***
				(.263)	(.263)	(.263)	(.263)
Price					−0.00974***	−0.00980***	−0.00974***
					(3.93×10^{-4})	(3.93×10^{-4})	(3.93×10^{-4})
Big Win indicator						0.663***	0.658***
						(0.0699)	(0.0699)
Time expose							0.00388***
							(0.000496)
N	218,709	218,709	218,709	218,709	218,709	218,709	218,709
Adjusted R^2	.000	.001	.055	.055	.058	.058	.059

Notes: Standard errors in parentheses; ** $p< .05$, *** $p < .01$.
[a]Ordinary Least Squares, Big Win Indicator = 1 if WinRate >200%.

of time trends in number picks for the Maryland Pick-3 game.

We now examine the relationship between commission rates and portfolio Similarity Index in Table 7. This part of the Gambler's Fallacy Response Hypothesis is not strongly confirmed in the data, as seen by the coefficients and standard errors in the top row (*Similarity Index*). In the first row of Table 7, we can see that the coefficients are in the predicted direction (low similarity, higher commissions), but are not statistically significant in any of the specifications. In other words, sellers do not seem to strongly manipulate their commissions based on how similar the portfolios are to the previous winning ticket. This result is in contrast to the Hot-Hand Response result, where sellers do increase the commission when they have just won in the previous round.

One interpretation is that although buyers do not like similar lottery numbers, their willingness to pay for dissimilar numbers is much smaller than their willingness to pay for a store with a higher previous winning rate. In other words, buyers may not be willing to pay a higher price (i.e., the commission) for this easily manufactured portfolio feature, and so the commission response from the seller side is weaker here.

We now turn to the relationship between portfolio size and Similarity Index. As Table 8 shows, we find some tentative evidence that sellers attempt to sell more tickets for portfolios catering to the Gambler's Fallacy belief, but not as precisely as in the Hot-Hand response result. The Gambler's Fallacy Response Hypothesis suggests that the coefficient on Similarity Index should be significantly negative, as sellers offering very dissimilar portfolios may try to exploit their popularity by offering larger portfolios in the market. The coefficients are in the predicted directions, but are at the margin of 10% significance. We take this as evidence that sellers generally do exhibit this tendency, but not as sharply as the tendency to take advantage of the Hot-Hand Fallacy using the portfolio size variable.

Finally, we turn to the last part of the Gambler's Fallacy Response Hypothesis—that sellers will self-invest less on portfolios catering to the Gambler's Fallacy. We in fact see this hypothesis strongly confirmed in the data. The regression is identical to that used to test the self-investment portion of the Hot-Hand Response Hypothesis in Table 9. However, this time we focus attention on the coefficients for Similarity Index. The regression shows that more similar portfolios do have significantly higher rates of seller self-investment.

One way to understand this result is through the cost-free increase in expected profits, which sellers can obtain by leaving a greater fraction of their portfolios (portfolio size held fixed) for buyers to purchase. By self investing less in the popular (i.e., less similar) portfolios, sellers can achieve this objective. At the same time, self-investing more in the less popular (i.e., more similar) portfolios gives sellers a chance to exploit

TABLE 8
Dependent Variable: Portfolio Size[a]

	(1)	(2)	(3)	(4)	(5)	(6)
Similarity index	−17.27	−16.95	−17.93	−15.20	−19.94	−20.81*
	(10.52)	(10.52)	(10.49)	(10.46)	(10.49)	(10.49)
Commission		3.188***	4.697***	5.022***	4.995***	4.960***
		(0.193)	(0.198)	(0.198)	(0.198)	(0.198)
Self-investment			−136.5***	−145.1***	−144.6***	−135.8***
			(4.096)	(4.095)	(4.095)	(4.192)
Price				1.166***	1.162***	1.168***
				(0.0363)	(0.0363)	(0.0363)
Big Win indicator					41.89***	41.33***
					(6.478)	(6.477)
Time expose						0.448***
						(0.0460)
N	218,709	218,709	218,709	218,709	218,709	218,709
Adjusted R^2	−.000	.001	.006	.011	.011	.012

Notes: Standard errors in parentheses; $^{**}p < .05$, $^{***}p < .01$.
[a]Ordinary Least Squares, Big Win Indicator = 1 if WinRate >200%.

TABLE 9
Dependent Variable: Self-Investment[a]

	(1)	(2)	(3)	(4)	(5)	(6)
Similarity index	0.0284***	0.0319***	0.0303***	0.0304***	0.0306***	0.0322***
	(0.00614)	(0.00617)	(0.00615)	(0.00615)	(0.00614)	(0.00599)
Big Win indicator		−0.0234***	−0.0215***	−0.0213***	−0.0222***	−0.0185***
		(0.00375)	(0.00374)	(0.00374)	(0.00373)	(0.00364)
Size (10^{-5})			−3.28***	−2.93***	−3.31***	−2.96***
			(.115)	(.168)	(.168)	(.164)
Shares (10^{-6})				−3.76**	−1.40	−.891**
				(1.31)	(1.31)	(1.28)
Price (10^{-4})					6.61***	5.85***
					(.249)	(.243)
Time expose						−0.00245***
						(0.0000246)
N	196,888	196,888	196,888	196,888	196,888	196,888
Adjusted R^2	.001	.001	.005	.005	.009	.056

Notes: Standard errors in parentheses; $^{**}p < .05$, $^{***}p < .01$.
[a]Ordinary Least Squares, Big Win Indicator = 1 if WinRate >200%.

the pari-mutuel prize structure of the lottery, as less popular number combinations will yield a higher prize conditional on winning. These two forces likely reinforce one another to explain the positive relationship between portfolio Similarity Index and seller self-investment.

VI. CONCLUSION

In this paper, we examined seller behavior in the Chinese national lottery market, a marketplace where buyers have predictably biased beliefs. Specifically, lottery ticket buyers subscribe to the Hot-Hand Fallacy, tending to buy tickets from sellers who have sold winning tickets in the previous round; buyers also subscribe to the Gambler's Fallacy, tending to buy ticket portfolios which are numerically dissimilar to winning numbers in the previous round. These two belief fallacies on the part of buyers, make their behavior predictable to lottery portfolio sellers, and we show that sellers respond to this behavior by tailoring the features of their lottery ticket portfolios in order to increase their expected profits. We provide the first evidence, to our knowledge, of sellers' responses to these belief biases by consumers.

We find evidence which is consistent with the following claim: Sellers respond to their increase in popularity resulting from buyers' belief fallacies in three main ways which increase their expected profits, holding market conditions and sellers' other choices constant: (1) By setting commissions high following a winning lottery outcome, to take advantage of buyers' Hot-Hand Fallacy; (2) by selling a higher volume of tickets as evidenced by their opening of a larger portfolio size, following a winning lottery outcomes, to take advantage of buyers' Hot-Hand Fallacy; (3) by self-investing less, in order to gain an increase in expected revenue at zero cost (all else constant). We find that sellers implement this self-investment strategy both in the case of an exogenous previous win, and in the case of choosing to open a dissimilar (i.e., more popular) portfolio. This provides solid evidence that sellers tend to adjust their self-investment in response to both the Hot-Hand and the Gambler's Fallacies.

We find weaker evidence in our data, that sellers adjust their portfolio size and commissions in response to the market popularity generated by opening dissimilar ticket portfolios. One interpretation of these weaker results is that although buyers do not like similar lottery numbers, their willingness to pay for dissimilar numbers is much weaker than their willingness to pay for placing their money with a previously "lucky" seller. This may be related to the fact that choosing a dissimilar portfolio is a relatively easy task, while obtaining a previous win in the lottery game is difficult. Sellers may anticipate that buyers will not be as drawn to a numerically attractive portfolio as they are to a previously winning seller, and thus adjust their portfolios less, accordingly.

A key advantage of the SSQ lottery market we examine in studying these behaviors, is that there is no informational or skill advantage, as each lottery round is independent of all previous outcomes. Thus the Hot-Hand and Gambler's Fallacies of buyers can be well-identified as inaccurate beliefs. Without these biased beliefs of buyers, sellers would have little incentive to choose any of their choice variables (i.e., lottery number picks, commission rate, portfolio size, self-investment) systematically in response to previous outcomes. Yet, we find that sellers set these variables systematically, in ways consistent with increasing their returns subject to the buyers' beliefs, implying some degree of awareness of these biased beliefs in the marketplace.

We anticipate several directions for future research. First, in this paper we have presented reduced-form evidence for our main hypotheses about seller reactions to biased believers. Another approach may be a structural one which attempts to specify the sellers' (and buyers') objective functions and estimates the relevant parameters. We have also limited our analysis to seller behavior in the aggregate. As aggregate level analyses have limitations in studying individual behavioral patterns, future work may examine sellers' behavior at the individual level. While our paper focuses on behavior in the lottery market setting, it would be useful to explore using other sources of field data, the degree to which the patterns of seller behavior detected carry over to other settings. Finally, it would be meaningful to explore whether sellers exploit buyers' other types of biased beliefs such as (for example) a belief in lucky numbers, in similar ways.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

TABLE S1. Dependent Variable: Sales Progress
TABLE S2. Dependent Variable: Sold Out Indicator
TABLE S3. Dependent Variable: Commission
TABLE S4. Dependent Variable: Commission