Distribution-Dependent Utility of Gaming

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Abstract

There is existing evidence that decision making over risk is impacted by factors like whether or not the decision maker can self-select numbers, a type of gaming utility, a feature common in lottery games. Such preferences would violate the fundamental properties of reflexivity and FOSD, but is nevertheless within the bounds of what the current literature accounts for. This paper provides experimental evidence that the estimated financial value of such factors is non-negligible, as subjects on average are willing to forego 10% to 30% of potential winnings. A novel result is the significant variation in self-selection preferences by payoff distribution. Sales data from lottery games played in Texas are adduced to further confirm the experimental findings. In order to ascertain the dependency of the gaming utility on the payoff distribution, an additional experiment is run to control for differences in non-distributional gaming factors between the Texas lottery games. The variation persists, leading to the conclusion that a preference for self-selection of numbers is distribution-dependent for many individuals. Reasons for these apparent inconsistencies with the existing literature and decision theoretic model predictions are discussed, and a possible regret-salience motive is proposed.

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1 Introduction

Researchers have spent the past few decades modifying and refining both the underlying psychological motivations and representative theoretic modeling of decision behavior over risk. Many models maintain that if the payoff distributions of two lotteries are equivalent, a decision maker must display indifference. Other models in which lotteries are evaluated only in comparison to one another, like Regret Theory, may have the additional requirement of state space equivalence to necessitate indifference, a violation of the so-called equivalence axiom (Table 6 in Loomes and Sugden 1982). However, when comparing two lotteries with equivalent payoff distributions and only two distinct payoffs, distributional equivalence is sufficient to ensure indifference (see the appendix for a proof under Regret Theory). A question then abounds of whether these model predictions reflect real world choice behavior or even choice behavior in an experimental setting.

A scenario satisfying the distributional equivalence and two outcome sufficiency condition is as follows: Lottery A pays the subject \$10 if a computer randomly selects the same integer from 0-9 twice, each integer having an equal probability of being selected, \$0 otherwise. Lottery B requires the subject to choose an integer from 0-9, and if that matches the integer from 0-9 that a computer randomly selects, the subject receives \$10, \$0 otherwise. Both lotteries give \$10 with a 10% probability and \$0 with a 90% probability. These two lotteries differ only in a procedural sense: the "how" of the lottery resolution differs. Any decision maker that strictly prefers A or B would be violating reflexivity under the standard models. The procedure for risk resolution under Lottery A is one that does not involve the decision maker in any way once the decision to play Lottery A is made. Lottery B on the other hand requires further input from the decision maker even after the decision to play Lottery B is made, although this input is inconsequential probabilistically. This difference in participation of the decision maker in the resolution of the lotteries could drive a strict preference for either lottery if there is a process preference.

While standard decision theoretic models have little to say about the processes of risk resolution, there are numerous studies that look into preferences over such processes. Of particular relevance to this paper are those studies that assess the rationale behind the selection of numbers in lottery games (see Simon 1998 for a comprehensive discussion of number selection in lotteries). Some lottery players select lucky or personally significant numbers, or numbers that have contemporary or cultural significance, and often play such numbers repeatedly over periods of time (Clotfelter and Cook 1989; Clotfelter and Cook 1991). Some are superstitious, consulting dream books, lottery "experts" and astrologers to aid in number selection (Clotfelter and Cook 1991).

This motive is an example of the well-documented illusion of control phenomenon, an experimental example of which is subjects who had a choice of a specific lottery ticket reporting significantly higher willingness to sell amounts than subjects who were assigned a lottery ticket (Langer 1975). Superstition not only impacts which numbers are chosen, but where lottery tickets are purchased, with increased sales at lottery retail locations which recently sold a winning ticket (Guryan and Kearney 2008). Representative biases (Kahneman and Tversky 1972) also impact number selection. Both the gambler's fallacy (negative autocorrelation) and hot hand (positive autocorrelation) have been observed in lottery games (Riedwyl 1990; Clotfelter and Cook 1993; Henze 1997) and roulette play (Croson and Sundali 2005). Another selection mechanism relates not so much to the numbers themselves as much as how the numbers are set on the lottery ticket grid. Many players select numbers to make certain patterns on the grids, such as: horizontal, vertical or diagonal lines; symmetric images across some reflection line; evenly or very nearly evenly-spaced number selections that result in seemingly patterned grids (Riedwyl 1990; Henze 1997). These evidences suggest that lottery players that harbor any of these considerations would likely not indicate indifference between lotteries A and B described above.

Preferences over risk resolution processes like self-selection of winning numbers in games of chance is part of the literature on process or procedural utility. Amartya Sen (1995) calls for economics to take more seriously procedural concerns, as consequence-only approaches would imply implausible conclusions like "whether a particular utility redistribution is caused by charity, or taxation, or torture" to be immaterial. However, procedural utility is often not readily quantifiable, which contributes to its typical lack of inclusion in modeling. Accounting for procedural utility can also lead to violating certain foundational desiderata of choice theory. For example, assume someone prefers mangoes to apples. When at a gathering, this individual will take a mango from a basket of mangoes and apples as long that mango is not the last mango in the basket, as that behavior may be considered rude. So, c(mango, mango, apple, apple) = mango and c(mango, apple, apple) = apple (Sen 1997). Such choice behavior is a violation of Sen's α and consequentially WARP. It is also conceivable that if the individual had been offered the last mango, instead of having to choose it, the exhibited behavior would have been consistent with theory. Such a complication highlights the difficulty of incorporating procedural utility into modeling. Sen (1997) gives an example of procedural preference over risky choices, via the story of a doctor with a single antidote for a deadly disease that has infected two children. The doctor knows that one of the children has a slightly higher probability of survival if given the antidote than the other. However, the doctor prefers a randomization device to determine which of the two children gets the antidote over administering the antidote to the child with a slightly higher chance of survival.

This behavior is a violation of the independence axiom and therefore inconsistent with Expected Utility theory.

In this paper, simple choice experiments like the one described above between lotteries A and B are proposed to subjects. The results confirm that most subjects are not indifferent between two outcome distributionally-equivalent lotteries, and furthermore that subjects are willing to sacrifice 10% to 30% of their potential winnings to enact their preferred process. A truly novel result of the experiment is that the proportion of subjects with certain process preferences changes as the payoff distribution of the equivalent lotteries changes. Sales data from Texas lottery games are adduced to validate the experimental finding of a correlation between payoff distributions and a preference over risk resolution processes, which in this case is whether or not to self-select winning numbers. However, the sales data does not allow for a determination of whether the correlation is due to game characteristics that vary between lottery games, or if the payoff distributions of the games themselves are impacting the process preferences. An additional experiment is conducted which seeks to control for the game characteristics in the lottery data, only allowing payoff distributions to differ while more closely resembling real world lottery distributions than the first experiment. The experimental results suggest that while such controls may mitigate the relationship in the lottery data, a large and significant effect persists, implying that for many individuals the payoff distributions themselves impact the preference for self-selection. The author is not aware of any previous study with a similar finding of distribution-dependent process preferences.

The paper proceeds as follows: Section 2 recounts the relevant literature to the issues of decision making over risk and process utility. Section 3 describes the experimental approach and procedures. Section 4 looks at the experimental and empirical results. Section 5 includes a discussion of the potential driving factors behind the experimental and empirical results. Section 6 concludes.

2 Literature Review

There is a thorough literature documenting the purported non-pecuniary benefits of games of chance, like lotteries and gambling. Hirshleifer (1966) proposes a classification of such activities to account for the common simultaneous lottery and insurance participation that Expected Utility cannot readily account for. Rather than change the utility of wealth function, he takes the lottery and gambling behavior in question out of the utility of wealth consideration by classifying such activities as *pleasure-oriented* gambling, which would make such activities consumption goods and therefore not subject to evaluation by a utility of wealth function. *Wealth-oriented* gambling, which he defines as the "deliberate attempt to change wealth status", would be subject to evaluation by a utility of wealth function. *Wealth-oriented* gambling would be the kind of risky wealth growth options available in financial markets, *pleasure-oriented* gambling including those activities that some view with moral disapprobation. He suggests that a distinction between the two types of gambling can be easily observed in that *pleasure-oriented* gambling is repetitive small stakes gambling, whereas *wealth-oriented* gambling would be of the large stakes kind. His hypothesis is that at all wealth levels, *wealth-oriented* gambling will be predominantly risk aversive and *pleasure-oriented* gambling will be present, allowing for the simultaneous preference for unfair insurance and lotteries. This conclusion rests on the exclusion of *pleasure-oriented* gambling from evaluation by the utility of wealth function, which would suggest that such activities provide mostly consumption utility and negligible wealth utility, or that the potential wealth upside is insignificant in the decision to purchase such lotteries.

While such a distinction saves Expected Utility from a harrowing critique, the assumption that the distinction rests on is questionable. Assigning *pleasure-oriented* gambling value as a consumption good instead of a monetary good is appealing, but is it reasonable to do so? Rationales that are consistent with such an assignment include the (short-lived) right to dream or fantasize about potential winnings (Clotfelter and Cook 1990); contributing to socially-desirable causes that are funded by proceeds from such activities (Clotfelter and Cook 1990); an escape from the routine, mundane and predictable nature of modern industrial life (Bloch 1951); a mechanism for releasing tensions and registering non-disruptive protests against an inequitable capitalistic system (Devereux 1949; Frey 1984); and a way to establish social cohesion and maintain friendships (Guillén, Garvía and Santana 2012). While any or all of these reasons may play a role in the decision to purchase lottery or gambling products for certain individuals, classifying such products as consumption goods negates the possibility that any of these reasons may vary in intensity based upon the payoff distribution (Forrest, Simmons and Chesters 2002). Furthermore, the classification of such products as consumption goods is itself suspect; for one, it is quite hard to digest the argument that individuals purchase such products only for the non-pecuniary benefits they provide. Self-reported consumer evidence also validates this: about half of California lottery players polled stated that they played the lottery for the money more so than the fun, the share of which moved inversely to income (Los Angeles Times 1986). More recent evidence further validates this, as a poll of over 1,000 US adults estimated that '21% of Americans, and 38% of those with incomes below $25,000, think that winning the lottery represents the most practical way for them to accumulate several hundred thousand dollars' (Consumer Federation of America 2006). So, in spite of the non-pecuniary benefits of lottery play, designating it solely as a consumption good does not seem to be appropriate.

In their seminal work laying the axiomatic foundations of EU, Von Neumann and Morgenstern assert that "concepts like a 'specific utility of gambling' cannot be formulated free of contradiction...anybody who has seriously tried to axiomatize that elusive concept, will probably concur in it" (Von Neumann and Morgenstern 1944). Therefore, attempts to account for the utility of gambling would have to depart from EU. A number of models have been proposed that attempt to capture both the monetary and non-monetary motivations of gambling-type activities (Royden, Suppes and Walsh 1959; Tversky 1967; Fishburn 1980; Dyer and Sarin 1982; Conlisk 1993; Schmidt 1998; Diecidue, Schmidt and Wakker 2001; Bleichrodt and Schmidt 2002; Luce, Ng, Marley and Aczél 2008; for a comparison of some of these models see Bleichrodt and Schmidt 2002). The primary features underlying these models are the assumption of a standard decision making model, such as EU, and the addition of a term that captures the (dis)utility of gambling, which is of consequence only when comparing risky options/gambles to riskless amounts/certainties. This latter term can be constructed in a number of ways: as a constant, if the utility is thought of as being a fixed amount independent of the distribution of the gamble (Fishburn 1980); as a function of the risky option; as a function of the riskless option (for a comparison of the construction of gambling utility using the risky or riskless option see Diecidue, Schmidt and Wakker 2001). In fact, some of these gambling utility models are a special case of the Expected Cardinality-Specific Utility proposed by Neilson (1992), in which a different utility function is allowed for lotteries depending on the number of outcomes n the lottery has. In the case of gambling utility, degenerate lotteries ($n = 1$) are evaluated with a utility function, and non-degenerate lotteries ($n > 1$) are evaluated with another utility function (Bleichrodt and Schmidt 2002). Gambling utility models with a base of EU can account for additional behaviors that EU cannot, including the lottery-insurance paradox and the Allais paradox. In that sense it succeeds in much the same way that models that incorporate probability weighting do. The basic probability weighting models allow for first order stochastic dominance violations, but using weights derived from the cumulative probability distribution ensures dominance compliance (Quiggin 1982; Tversky and Kahneman 1992). However, no such "fix" exists in the case of utility of gambling models, insofar as dominance compliance is a desirable consequence of a model. Diecidue, Schmidt and Wakker (2001) show that utility of gambling models necessarily violate either dominance or transitivity, two characteristics that many in the field view as indispensable to sound models of decision making under risk. Therefore, utility of gambling models have not received anywhere near the attention that other non-EU models have that can explain EU-inconsistent behavior while maintaining normatively desirable characteristics.

All the models discussed so far, and the majority of models of decision making under risk, can be classified as outcome-oriented. In relation to games of chance, a number of proposed non-pecuniary benefits have been listed above, but these stem from the mere presence of products with certain payoff distributions. In addition to payoff distributions and non-pecuniary benefits, a third possible source of utility from games of chance is the method by which risk is resolved. "Procedural utility means that there is something beyond instrumental outputs as they are captured in a traditional economic utility function. People may have preferences about how instrumental outcomes are generated. These preferences about processes generate procedural utility" (Frey, Benz and Stutzer 2004). Procedural or process utility has seen limited attention in economic theory, but there are a number of experimental and observational studies that conclude that individuals have procedural preferences in certain cases. One good example that clarifies the concept of procedural utility is legal arbitration: litigants who found the arbitration process to be fair were more likely to accept the court-mandated award, irrespective of the outcomes, although the outcomes themselves played a somewhat smaller role (Lind, Kulik, Ambrose and Park 1993). Many studies of organizational structure and protocols, as well as legal systems, provide evidence of procedural utility (see Frey, Benz and Stutzer 2004 for a review of studies that are suggestive of procedural utility). In this paper, the procedural preferences and utility will be restricted to self-selection or random generation of winning numbers in lotteries. Also, it is important to highlight that the process utility for games of chance is what this paper refers to as the utility of *gaming,* in contrast to the utility of *gambling* models in the literature.

Le Menestrel (2001) takes a procedural approach to the utility of gambling by defining an observable behavior as composed of both a consequence and a process. In the case of a gamble or lottery, which once again is defined as a lottery that has positive probability on more than one outcome, a process (dis)utility can be considered independent of the (dis)utility of consequences. Behavioral preferences are composed of consequence preferences and process preferences, where consequence preferences can abide by EU. The author axiomatizes the three preference types and provides conditions under which observed behavior can lead to a revelation of the underlying process and consequence preferences. The author notes a situation in which a mountain climber prefers a route with a 95% chance of survival over one with 100% chance of survival over one with 80% chance of survival. The monotonicity violation is unable to be explained by consequence-only approaches like EU. However, allowing the consequential monotonic rankings of 100% $\succ^c$ 95% $\succ^c$ 80% and a process in which risk adds to the excitement, so that Risk (survival below 100%) $\succ^p$ No Risk (100% survival) could lead to the observed behavior of 95% $\succ^b$ 100% $\succ^b$ 80% ($\succ^c$ is the preference relation over consequences, $\succ^p$ is the preference relation over processes, and $\succ^b$ is the preference relation over observed behavior). However, in the same vein as the utility of gambling models mentioned above, the process Le Menestrel (2001) identifies is whether or not the lottery is degenerate, and would predict indifference between non-degenerate lotteries that only differ in how risk is resolved.

3 Experimental Procedure

I implement a simple experimental design in order to determine if number selection matters to individuals in the resolution of risk within a controlled experimental setting. The experiment was conducted during the winter of 2019 on Amazon Mechanical Turk (MTurk), an online workplace that has seen increased usage by experimentalists in recent years. A number of classical laboratory experimental economic results have been replicated on MTurk (Horton, Rand and Zeckhauser 2011). Additional benefits of MTurk include the relative cheapness of subjects, along with access to much larger samples than are available in most traditional laboratory settings, and ease of implementation of static, non-interactive designs. The experimental design attempts to determine if there is some experimental evidence of a process utility of gaming, separate from the utility of gambling mentioned in the literature. The experimental designs are simple, static and non-interactive, only requiring a few minutes of a subject's time. The approach is within-subject, since even if an effect was found with a between-subject approach, definitively attributing the effect to a process utility would be difficult, as the argument that a certain factor was not controlled for could always be levied. The subject pool was restricted to those located in the United States.

The experiment consists of two questions, each offering subjects a choice between two lotteries. The first lottery option in question one is "Picking any number you want from 0-9 and then letting a computer randomly pick a number from 0-9. If the numbers match, you receive a \$10 prize amount; otherwise you receive \$0." The second lottery option in question one is "Letting a computer randomly pick a number between 0-9 two separate times. If the numbers match, you receive a \$10 prize amount; otherwise, you receive \$0." Both of these lotteries offer \$10 with a 10% chance and \$0 with a 90% chance. As stated in the introduction, consequential models predict indifference between these two lotteries. The first option will be called the "Self" option, the second option the "Computer" option. Subjects are asked to indicate which lottery they prefer, and are also given the option to indicate indifference. If a subject indicates strict preference, the subject is then asked to provide the minimum prize amount so that the subject still prefers the option initially selected, but with the new prize amount for that option only. The subject then plays out the preferred option with the new minimum prize amount. If the subject indicates indifference, the subject gets randomly assigned one of the two options to play out at the initial \$10 prize amount. The Appendix demonstrates how this first question was presented to subjects with the appropriate instructions.

The second question offers two more options, but with a starkly different distribution than the first question. The first lottery option is "Picking any number you want from 0-9 and then letting a computer randomly pick a number from 0-9. If the numbers do not match, you receive a \$10 prize amount; otherwise you receive \$0." The second lottery option is "Letting a computer randomly pick a number between 0-9 two separate times. If the numbers do not match, you receive a \$10 prize amount; otherwise, you receive \$0." Both of these lotteries offer \$10 with a 90% chance and \$0 with a 10% chance. The second question proceeds in the same manner as the first question once a player indicates preference. Subjects received a fixed payment of 10 cents for participating, and after a second randomization done outside of the experiment, subjects were eligible for up to an additional \$10 based on their responses and luck. The average time to complete the experiment was about five minutes, the median time was closer to three minutes. 400 subjects participated in the experiment; however, only 298 of the responses were fully consistent with rational behavior and the experiment instructions. For example, if a subject selected a preference for Self but resolved the risk according to the instructions for a Computer preference, such a response was dropped. Results do not change substantially for the complete, unfiltered data.

The decision theoretic model predictions and the evidence for number self-selection in lotteries allow for the formation of two hypotheses: the former implies indifference in both questions, whereas the latter implies a strict preference for Self in both questions. Results consistent with either of these hypotheses would be viewed as in line with the existing literature. Given that the time difference in resolution for the Self and Computer options in the experiment is negligible, a third possible hypothesis of a preference for Computer in both questions is ruled out. Such a hypothesis would be appropriate if the Computer option took less time to play out and subjects were consequentially indifferent but preferred to finish the experiment quickly and perhaps move on to other paid tasks on MTurk. Therefore, the two hypotheses are:

1. **The Decision Theory (DT) Hypothesis:** Subjects will be indifferent between the Self and Computer options in both questions.

2. **The Utility of Gaming (UG) Hypothesis:** Subjects will display a strict preference for the Self option in both questions.

4 Results

4.1 Experiment I

Table 1 shows the distribution of preferences across the two questions. What is immediately apparent is that the results are not consistent with the DT hypothesis: fewer than one-quarter of subjects indicate indifference in both questions, while nearly two-thirds never indicate indifference. Over two-thirds of subjects are consistent in their preferences across questions, but about one-third of subjects demonstrate that the distribution is somehow impacting preferences over processes. 71 subjects are consistent with the DT Hypothesis, and 86 are consistent with the UG Hypothesis. Subjects consistent with either of the hypotheses correspond to the two largest response groups, amounting to about half of the total responses. However, 46 subjects prefer Computer for both questions, and 39 prefer Self when the win probability is 10% but switch to Computer when the win probability is 90%. There seems to be some evidence for relinquishing of “control” at the 90% win probability relative to the 10% win probability. Using a Wilcoxon matched-pairs signed rank test, the probability of equivalence of response between questions is p = .001. While this is quite a strong significance level by typical standards, it is worthy to note that 203 of the 298 subjects indicated process consistency across questions, while 63 indicated a relinquishing of control at the higher win probability relative to 32 in the opposite direction. The difference here is what is driving the significance, but it is important to note the difference corresponds to only about 10% of subjects. The stronger conclusion is that since nearly half of subjects do not behave in accordance with either hypothesis, there may be other factors at play in the decision calculus for many subjects, including payoff distribution considerations.

Table 1: Preference Reports of Experiment I

		10% win			
		Self	Indifferent	Computer	Total
90% win	Self	86	15	15	**116**
	Indifferent	11	71	2	**84**
	Computer	39	13	46	**98**
	Total	**136**	**99**	**63**	**298**

While the preference responses from the experiment run strongly against the DT Hypothesis, it is important to determine the economic significance of gaming utility, if any. Charness and Gneezy (2010) run an experiment in which subjects are endowed with \$10 and are asked to make investment decisions. One of the treatments they employ is an illusion of control (Langer 1975), in which subjects could roll a dice to determine the outcome of an investment. 25 of the 37 subjects elected to roll the dice themselves; however, when subjects were required to give up 5% of their endowment to roll the dice themselves, only 2 of 22 subjects pay the price. They conclude that while there is evidence of an illusion of control, it is not economically meaningful. So, requiring subjects with a strict preference to state their minimum prize amount to maintain their strict preference in my experiment aims to see if a similar inconsequential illusion of control effect is present here.

The minimum prize amounts reported in both questions are spread out, with a couple of values receiving large responses. In the question offering a 10% win probability, of those demonstrating a strict preference one way or the other, 59 subjects stated a minimum prize amount of \$5 to maintain their reported preference. These subjects were willing to give up half of their potential winnings, or half of the expected value (50 cents) to implement their preferred process. 30 subjects stated a \$9.99 minimum, a response which is in line with the findings of Charness and Gneezy (2010). In the 90% win probability question, 56 subjects state \$5 (a \$4.50 reduction in expected value) and 36 subjects state \$9.99. These are the two most frequent responses in each question. There are no significant differences in mean or median reported minimum prize amounts between the Self and Computer strict preference groups for each question. In fact, the means are within a few cents of each other for each question.

What is perhaps suspect is that for each question, 43 of the respondents who indicated a strict preference reported a minimum prize amount less than \$5, with 15 subjects reporting a minimum prize amount of \$1 in each question. While there is nothing inherently wrong with such responses, it could be argued that some of these subjects may have misunderstood the task, or instead reported how much money they would be willing to have removed from the \$10 prize amount (so an input of \$1 would correspond to a minimum of \$9). Table 2 reports a few median and mean minimum prize amounts: unfiltered, only those reporting \$5 or above, and amounts below \$5 transformed to \$10 minus that amount. For those who indicated indifference, a minimum of \$10 is imputed for mean and median calculations.

One method to ascertain the significance of the reported minimums is to determine how the data compares to the consequential prediction of a \$10 minimum. This can be done via a Mann-Whitney U Test, pitting the subject data against a constant of \$10 for the same number of observations. For both win probability questions and all of the three minimum aggregation methods, the test strongly rejects the hypothesis that the data is generated from the same distribution as the \$10 prediction, $p<.00001$. In order to determine an estimate of how significant the difference is for each question and aggregation type, the constant amount of $10 can be incrementally reduced and tested against the data, up to the point where the test loses significance, say at the 5% level. These amounts are reported in Table 2. The unfiltered and transformed data yield minimums between $9 and $10, while the truncated data yields $9.99. The truncated data test results are more in line with those of Charness and Gneezy (2010), while the other two methods reveal economically significant reductions in prize minimums. So there is some evidence of economically significant valuations of the process utility in this case. It is also worthy noting that the Charness and Gneezy (2010) experiment required subjects to give up 5% of their endowment, while this experiment is asking for a reduction in potential winnings. The reduction of an endowment would be subject to loss aversion, whereas a reduction in potential winnings would not, if lotteries are all evaluated independently. Five percent of the Charness and Gneezy (2010) endowment amounts to 50 cents. In the 90% win question, more than half the subjects report a willingness to lose more than 50 cents in expected value to pursue their preferred process. Loss aversion could perhaps be causing the difference of conclusions between the two experiments.

Table 2: Minimum Prize Amounts of Experiment I

		Unfiltered	$5 or Above	Transformed
10% win	Mean	$7.37	$8.33	$8.33
	Median	$9	$9.99	$9
	n	296	253	296
	Minimum	$9	$9.99	$9.90
90% win	Mean	$7.39	$8.33	$8.30
	Median	$9	$9.50	$9
	n	298	255	298
	Minimum	$9.50	$9.99	$9.50

4.2 Lottery Data

The experimental results suggest significant heterogeneity in number selection preferences, even between different payoff distributions. While these results are not fully in line with the predictions based on the literature, an additional source with similar patterns would make a more compelling case. Many lottery games in the United States are draw games, requiring players to select a few numbers from a set of numbers, awarding prizes to players who get full or partial matches. A feature of these games is the option for players to be given a random set of numbers, an option appropriately called Quick Pick (QP), as it only requires making a single selection on the lottery ticket. Players can also choose their own numbers, or Self Pick (SP), which will require filling out the appropriate number of selections on the lottery ticket, usually between three and six number selections per entry.

One prediction of consequential models would be an indifference between QP and SP. The expectation could then be that the percentage of QP would be around 50% across all draw games. Alternatively, as QP takes less time to complete, there could be an expectation of around 100% across all draw games, if players prefer to spend less time filling out entries. Incorporating the evidence that many players prefer to self-select numbers implies that QP would be 0% across games, if all players are assumed to have such preferences. Convex combinations of these homogeneous extremes would effectively cover any observed QP percentage, provided that percentage was relatively constant between games. Notice how the processes available essentially mimic the processes in the experiment: one process allocates the risk resolution totally to a computer, and another allows the player to pick numbers that are to be matched to numbers randomly selected via computer or lottery drum.

Table 3 presents the aggregates sales and QP percentages for the draw games offered in Texas from August 2011 through July 2019. The games are listed in descending odds for the top prize in each game. The odds for the top prize for Pick 3 is 1:1,000, whereas the odds for the Mega Millions jackpot are 1:302,575,350. All the games except Powerball and Mega Millions are games only available for purchase in Texas. First, the QP percentages are starkly different across games, inconsistent with the range of hypotheses permitted by the literature. Second, there seems to be an inverse relationship between the QP percentage and the overall odds. Games with better odds have lower prize amounts, as lottery tickets are similarly priced across games. Third, QP percentages are correlated with the parimutuel nature of the top prize: higher QP percentages occur within parimutuel games. There are a few competing explanations for the wide range of QP percentages across games.

The first explanation revolves around different utilities of gaming for the various lottery games. The two games with low QP percentages are the Pick 3 and Daily 4. Both of these games require selecting (either three or four) numbers from 0-9. All of the other games require selecting numbers from a larger number pool, such as 35 or 69. It is certainly easier to construct personally important numbers, like area codes or birthdays, using a few digits from 0-9 than from a pool of larger, two digit numbers. Another differentiating factor between Pick 3 and Daily 4 and the rest of the draw games is that they are the only two games that allow selecting with replacement. This would allow selecting a number like 777 in Pick 3 or repeating numbers, which other draw games would not allow. The single digit selection design and drawing with replacement make Pick 3 and Daily 4 ripe for playing lucky or important numbers. Selecting numbers to form patterns or designs on the playing board is also a motive, but this motive is arguably stronger in games with larger playing boards that require more number selections, which are the games with worse odds. Another related explanation is that the games with worse odds of desirable prizes require more numbers to select and a larger pool to choose from. Many players apparently find choosing six numbers for a worse odds game a daunting task (Clotfelter and Cook 1989). This could cause added mental stress in self-selecting for those games, reducing the impact of the utility of gaming from self-selecting. The two games with QP percentages near 50% are Cash 5 and All or Nothing. These games have poorer odds than Pick 3 and Daily 4, but are also not parimutuel. They also have a different number selection mechanism of selection without replacement of single and double digit integers, relative to the single digit integer selection with replacement of Pick 3 and Daily 4. The mental stress motive would be stronger for these games as well. These factors all hinder the appeal of self-selection and would therefore provide a lower utility of gaming for these games. The four parimutuel games have even larger pools of numbers to choose from without replacement. The added mental stress would further depress the gaming utility and result in the observed lower QP percentages.

Table 3: Texas Lottery Data

	Sales	QP Percentage	Parimutuel Top Prize
Pick 3	$2,083,839,142	12.41%	No
Daily 4	$753,942,261	13.01%	No
Cash 5	$404,839,457	55.84%	No
All or Nothing	$270,035,914	55.88%	No
Texas Two Step	$457,981,345	76.40%	Yes
Lotto Texas	$1,158,055,791	69.61%	Yes
Powerball	$2,438,867,623	80.54%	Yes
Mega Millions	$1,808,619,562	79.39%	Yes

Pick 3 requires selecting three numbers from 0-9; Daily 4 requires selecting four numbers from 0-9; All or Nothing requires selecting twelve numbers from 1-24; Cash 5 requires selecting five numbers from 1-35; Texas Two Step requires selecting five numbers from 1-35; Lotto Texas requires selecting six numbers from 1-54; Mega Millions requires selecting five numbers from 1-70 and one number from 1-25; Powerball requires selecting five numbers from 1-69 and one number from 1-26.

The second explanation for the varying QP percentages between games is the maximization of the expected return to playing. For fixed odds games, each entry yields exactly the same expected return, as there is no sharing of prizes in the case of multiple winning entries for any prize level. Games with a parimutuel top prize would only share this equality of expectation if all entries were determined in an effectively random manner. Bosch (1994) lists 2,588 popular number combinations of a German lottery, each being selected at least 50 times more often than by random expectation. These correspond to 0.038% of tickets sold, whereas the expected percentage by random assignment is 0.00018%. Under such circumstances, a player aware of which combinations are popular would increase the expected return by avoiding such combinations for this parimutuel game. Since a player cannot be reasonably aware of a comprehensive set of combinations that are popular for a given game, a player could opt to QP to increase the likelihood of drawing an unpopular combination. A study of the UK National Lottery estimates that 18% of the combinations are popular, in that about half of the players who self-select numbers choose from those 18% (Simon 1998). So, opting to QP would amount to an 82% chance of drawing an unpopular combination, substantially increasing the expected return of self-selecting, assuming self-selection would more likely yield a popular combination. This could explain the large gap in QP percentages between parimutuel and fixed odds games, and adding the utility of gaming explanation would account for the differences within each game type.

The first two explanations are wholly contained within the explanatory power of the existing literature. A third explanation is that the differences in QP percentages between games is somehow due to the payoff distributions themselves. Games with better odds and lower prizes, like Pick 3 and Daily 4, have low QP percentages, whereas games with poorer odds and higher prizes, like Powerball and Mega Millions, have high QP percentages. It is worthwhile to determine if payoff distributions impact preferences over self-selection of winning numbers. Unfortunately, in addition to highly variant payoff distributions, the lottery games differ in number selection mechanisms, potential mental stress of number selection, and parimutuel nature of the top prize. Returning to the experimental setting and controlling for the rationales consistent with the literature should yield some insight regarding the driver of the observed choice behavior in the lottery data.

4.3 Experiment II

The second experiment is essentially a modification of the first, with the intent being to determine the true culprit behind the QP percentage distribution across Texas lottery games. The first experiment provided some evidence that the choice behavior of many individuals cannot be accounted for with the decision theory and number selection literatures. However, the probability levels of 90% and 10% of winning are not representative of typical lottery odds. To better recreate the real-life setting, the odds of winning in the second experiment are reduced significantly. Once again, subjects are asked two questions about lottery preference and are told to choose their preferred option in each or report indifference. The first lottery option in question one is "Picking any number you want from 0-999 and then letting a computer randomly pick a number from 0-999. If the numbers match, you receive a $10 prize amount; otherwise you receive $0." The second lottery option in question one is "Letting a computer randomly pick a number between 0-999 two separate times. If the numbers match, you receive a $10 prize amount; otherwise, you receive $0." The second question reduces the odds of winning by a factor of 1,000. The first lottery option in question two is "Picking any number you want from 0-999,999 and then letting a computer randomly pick a number from 0-999,999. If the numbers match, you receive a $10 prize amount; otherwise you receive $0." The second lottery option in question one is "Letting a computer randomly pick a number between 0-999,999 two separate times. If the numbers match, you receive a $10 prize amount; otherwise, you receive $0." This experiment does not require disclosure of minimum prize amounts and therefore took less time and had no possible subject inconsistency issues, all 400 responses are included, although this was run as a separate session from the first experiment and these are not the same 400 respondents. Otherwise, it was similarly incentivized and ran in the same fashion as the first experiment.

The results of the second experiment are presented in Table 4. The 1:1,000 odds bears some similarity to Pick 3, as those are the exact odds for the top prize of $500. The 1:1,000,000 odds is typical of the odds size for some of the larger prizes in games like Lotto Texas, Powerball and Mega Millions. Unlike these games though, the number selection in the experiment more closely resembles Pick 3, which requires players to choose three digits from 0-9 with replacement. The 0.1% win question essentially requires the same, as picking three single digits from 0-9 with replacement and order sensitivity is equivalent to choosing a three digit number from 0-999. The 0.0001% win question extends the selection from three to six digits, 0-999,999. This design attempts to remove the number selection differences noted above between games like Pick 3 and Mega Millions. In addition to controlling for the number selection mechanism, if there are multiple winners in the experiment, each gets the promised prize of $10, so the parimutuel feature is controlled for. The possible mental stress of picking a three digit vs a six digit number is assumed to be equivalent or negligible. The time difference for completion of the experiment between Self and Computer is negligible, assuming players self-selecting are not mulling over which number to choose. Implementing these controls leaves the payoff distributions themselves as the variable of interest. If a variation in preferences is found between the two questions, the conclusion would be that the distributions themselves affect the preference for self-selection.

This indeed is what the experimental results suggest. In the 0.1% win question, Self is the most preferred option (165 subjects), whereas in the 0.0001% win question, allowing the computer to select is most preferred (184 subjects). A Wilcoxon matched-pairs signed rank test testing changes in response between questions is highly significant ($p<.00001$). 106 subjects opt for less "control" as the win probability drops, with only 37 subjects moving in the opposite direction. Less than 40% of subjects behave according to either hypothesis supported by the literature, namely selecting Self or Indifferent for both questions. In fact, the largest preference group is Computer for both questions. When moving from the experimental to the empirical setting, Self closely corresponds to SP and Computer to QP. However, there is no Indifferent option in the empirical setting, so individuals who are indifferent ultimately choose either to SP or QP. To make the experimental data more comparable to the empirical, the Indifferent option needs to be dealt with. One way is to drop the results reporting indifference. If so, 147 subjects prefer Self in the 0.1% win question and 113 prefer Computer, meaning 43% QP. In the 0.0001% question, 102 prefer Self and 158 prefer Computer, meaning 60% QP. One extreme case is to assign the indifference to Self. Doing so yields 31% QP in the 0.1% win question and 46% QP in the 0.0001% question. The other extreme is to assign indifference to Computer, which perhaps is more justifiable. QP is indeed quicker than SP in real life, while Self and Computer do not have much of a time difference in the experiment. Doing so yields 58% QP in the 0.1% win question and 71% QP in the 0.0001% question. Using the Texas lottery data, games more similar to the 0.1% win question have 10%-15% QP, while the other games more similar to the 0.0001% question have 70%-80% QP. While assigning Indifference to Computer gets the 0.0001% win QP percentage into the appropriate empirical range, even assigning Indifference to Self doesn't lower the 0.1% win QP percentage into the appropriate empirical range. The takeaway is that the controlled experiment is generating a significant gap in purported QP percentages in the same direction as the lottery data, but a smaller magnitude.

Table 4: Preference Reports of Experiment II

		0.0001% win			
		Self	Indifferent	Computer	**Total**
0.1% win	Self	85	18	62	**165**
	Indifferent	11	72	26	**109**
	Computer	17	9	96	**122**
	Total	**113**	**99**	**184**	**396**

5 Discussion

The experiment confirms an interaction between the payoff distribution and preferences over risk resolution for a significant percentage of subjects. A couple of psychological studies provide the only evidence the author is aware of in which a preference for the process of risk resolution varies by payoff distribution. Experimenters assessed subjects with a Desirability of Control scale (Burger and Cooper 1979) and find that high desire for control subjects bet more money when allowed to throw the dice themselves in a dice game (Burger and Cooper 1979), and this effect on dice games is more prominent when the odds of winning are relatively better (Wolfgang, Zenker and Viscusi 1984). These studies were between-subject studies with fewer than 100 subjects, and critically did not control for risk preferences in any way, so the results could also be attributable to more risk tolerance by subjects randomly assigned into treatments instead of an illusion of control. The experimental design in this paper is within-subject and can face no such criticism. Summarizing the results from the first two experiments, about 40% to 50% of subjects act in accord with the decision theory or utility of gaming literatures. There is a stronger preference for Computer in the second experiment in which win probabilities are extremely low. The preference for Computer regardless of payoff distribution could perhaps be rationalized as slightly less time consuming or mentally taxing than Self. Another 30% to 40% of subjects change their preferences for risk resolution between questions. The implication is that there is significant heterogeneity in preferences for self-selection of numbers, and for many agents this preference is dependent on the payoff distribution itself. The key contribution of this paper is evidence of the latter. The question remains as to what is driving such a dependency.

The experiments keep the prize winnings fixed at $10 and vary the win probabilities and therefore the expected values of the lotteries. In the 90% and 10% win probability experiment, 63 subjects indicated a relinquishing of "control" when moving from the low win probability to the high, relative to 32 in the opposite direction. In the 0.1% and 0.0001% win probability experiment, 37 subjects indicated a relinquishing of "control" when moving from the lower win probability to the high, relative to 106 in the opposite direction. Combining these findings indicates a U-shaped behavior by the average agent displaying distribution-dependent risk resolution preferences: at very low and high probabilities of winning Computer is preferred, while at moderately low probabilities of winning Self is preferred. This non-monotonic behavior requires some creativity to rationalize. One attempt is to frame the discussion in terms of regret.

Consider defining two types of regret, one resulting from a poor outcome from Self, the other from a poor outcome from Computer. Once a player is made aware of the winning numbers post risk resolution, a player selecting Self could retroactively choose those numbers and win, while a player choosing Computer would be no better off with that information retroactively, since numbers are assigned randomly. Therefore, playing Self elicits a tangible regret when a poor outcome obtains, whereas playing Computer elicits a weaker abstract regret in the event of a poor outcome. If minimizing the pain of regret was the only concern outside of an evaluation of the payoff distribution, opting for Computer would be optimal for all distributions. Define a poor outcome as one that is less than the expected value of the lottery, and the magnitude of regret as the difference between the expected value and the poor outcome. Regret therefore has both probability and magnitude aspects. For a fixed magnitude of regret, the pain of regret would be higher if that regret was tangible instead of abstract. Referring back to the experiments, the lowest win probability of 0.0001% gives the highest chance of a poor outcome but simultaneously the smallest magnitude of regret, \$10 * 0.000001 - 0 = \$0.00001 cents. The highest win probability of 90% gives the lowest chance of a poor outcome but simultaneously the largest magnitude of regret, \$10 * 0.9 - 0 = \$9. A low probability of winning like 10% gives a magnitude of regret of \$10 * 0.1 - 0 = \$1.

One way to explain the U-shape is by the relative salience of either the probability or magnitude of regret. At the win probability of 0.0001%, the probability of a regretful outcome is close to one and is a more salient feature of the lottery than the minuscule magnitude of regret of \$0.00001 cents. On the other hand, at the win probability of 90%, the probability of a regretful outcome is close to zero but the magnitude of regret of \$9 is the more salient feature of the lottery. At the 10% win probability, the probability and magnitude features are not nearly as different in salience compared to the other two distributions. Therefore, when either of the regret aspects is highly salient, the regret motive becomes more powerful. When the regret motive is strong, namely when either of the regret features is highly salient, self-selecting and incurring tangible regret may overpower the benefit of self-selecting to the point that the net harm is more than the pain of abstract regret by assigning risk resolution to a computer. A weaker regret motive would not hinder the benefit of self-selection enough to dissuade from self-selection. This underlying mechanism is able to account for the observed U-shaped behavior by subjects that have distribution-dependent preferences over risk resolution.

It must be admitted that the regret and gaming utility story is not conclusive, but merely rationalizes the observed behavior by a large number of subjects in the experiment. There may be other explanations which account for the behavior equally well. Also, given that lottery questions were paired together in the experiment, it is not clear as to if the observed behavior is due to the absolute payoff distributions or the relative differences in paired payoff distributions. The U-shaped behavior does not seem to be symmetric: based on the four lotteries proposed in the two experiments, the distribution dependency of risk resolution preferences is stronger at extremely low win probabilities relative to high win probabilities. Future studies may be able to tease out a better understanding of this U-shaped phenomenon through risk resolution preference elicitation over more win probability values, and could even be expanded to lotteries with more than two branches if the effect is indeed found to be robust.

6 Conclusion

This paper provides novel evidence that preferences over how risk is resolved is dependent on the payoff distributions of lotteries for a large number of individuals. The risk resolution method considered is whether winning numbers are self-selected or delegated to a random number generator. While there is existing evidence that individuals may prefer to self-select even between lotteries that standard decision models would evaluate as equivalent, this paper goes further by providing evidence that the payoff distributions themselves impact the self-selection preference. A regret-salience motive is offered to explain the choice behavior of subjects displaying distribution-dependent self-selection preferences. Lottery sales data from Texas is adduced to strengthen the experimental findings. Evidence in both the controlled experimental setting and the real world lottery market point to considerations and mechanisms that the extant literature does not sufficiently address. More studies are welcomed to to better understand the scope and motivations of such behavior, and perhaps to even lay down some behavioral principles or theoretical foundations to account for distribution-dependent process preferences.

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Appendix

Proof of the Sufficiency of Distributional Equivalence for Two Outcome Lotteries under Regret Theory

The native environment for Regret Theory is the choice between two actions that result in certain events occurring in specific states resulting in appropriate outcomes: there is no single correct way to extend the decision process to three or more outcome, although a few intuitive ones have been proposed. The actions for the purposes of this paper and proof correspond to undertaking either of two lotteries, A or B, with equivalent outcome distributions: receiving (x, y) with probabilities (p, 1-p), $x \neq y \in \mathbb{R}$. Notice that there are up to four possible outcome pairs for {A, B} over all consolidated states, listed 1 to 4: {x, y}; {x, x}; {y, x}; {y, y}. The first two states correspond to the probability of getting x under A, or p. Therefore, let $p_x \leq p$, so probability of State 1 is p_x and the probability of State 2 is p - p_x. Similarly, let $p_y \leq 1 - p$, so probability of State 3 is p_y and the probability of State 4 is 1- p - p_y.Under Regret Theory, $A \succeq B \Leftrightarrow p_xQ(x - y) + (p - p_x)Q(x - x) + p_yQ(y - x) + (1 - p - p_y)Q(y - y) \geq 0 \Leftrightarrow p_xQ(x - y) + p_yQ(y - x) \geq 0 \Leftrightarrow (p_x - p_y)Q(x - y) \geq 0$, since under Regret Theory $Q(0) = 0$ and the symmetry of Q(.) means $Q(-\xi) = -Q(\xi)$. Therefore, indifference will hold iff $p_x = p_y$. Assume $p_x \neq p_y$. The distribution of A remains (x, y) with probabilities (p, 1-p). The distribution of B is (x, y) with probabilities ($p - p_x + p_y$, $p_x + 1- p - p_y$). A and B are distributionally equivalent iff $p_x = p_y$ as premised, so $p_x = p_y$ and Regret Theory predicts indifference. $\square$

Screenshots of Experiment I

Question 1
Consider the following options:

Option 1. Letting a computer randomly pick a number between 0-9 two separate times. If the numbers match, you receive a $10 prize amount; otherwise, you receive $0.
Option 2. Picking any number you want from 0-9 and then letting a computer randomly pick a number from 0-9. If the numbers match, you receive a $10 prize amount; otherwise you receive $0.

Which option would you prefer?

- Option 1
- Option 2
- I value both options equally

If you chose Option 1, please proceed to Section 1. If you chose Option 2, please proceed to Section 2. If you value both options equally, please proceed to Section 3. You will only complete one of the sections.

Section 1

Please enter the lowest prize amount you are willing to accept in Option 1, so that you still choose Option 1 over Option 2

Enter the minimum amount in the dollars and cents format "x.xx", it must be less than 10.00

Enter minimum amount

You will now play your new Option 1 with the prize amount you just entered above. Click on the two buttons below to see if the numbers drawn match

first draw
second draw

Now proceed directly to Question 2, do not complete Sections 2 or 3

Section 2

Please enter the lowest prize amount you are willing to accept in Option 2, so that you still choose Option 2 over Option 1

Enter the minimum amount in the dollars and cents format "x.xx", it must be less than 10.00

Enter minimum amount

You will now play your new Option 2 with the prize amount you just entered above. Please input your lucky number between 0 and 9

Enter your lucky number | click to lock your number and have the computer draw a number

Now proceed directly to Question 2, do not complete Section 3

Section 3

Since you value both options equally, it was randomly determined that you will play out Option __ ONLY.

If you were assigned Option 1, click on the two buttons below to see if the numbers drawn match

first draw
second draw

If you were assigned Option 2, please input your lucky number between 0 and 9

Enter your lucky number | click to lock your number and have the computer draw a number