Dynamic Inconsistency in Risk Preferences

Jindi Huang*

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Abstract

I conducted an experiment to show that risk preferences are dynamically inconsistent. Preference reversals may happen when individuals make decisions on the same risk choice with different uncertainty resolution time, especially when the choice involves payment in the loss domain. The observed inconsistency cannot be explained by the background risk, asymmetric discounting of gain and loss, and most belief-based utility models, but seem consistent with the attention-based anticipatory utility model. The results suggest strongly that the resolution time of uncertainty matters when considering risk preferences.

Keywords: risk preferences, belief-based utility, dynamic inconsistency

JEL: D81, D84, D91

*huangjindi@pku.edu.cn, Class of 2017, National School of Development(NSD), Peking University. The author is grateful to the insightful comments and generous help from Lixing Li, Juanjuan Meng, Benjamin Enke, Thomas Graeber, Nanyu Jiang and Xiang Yu.

1 Introduction

While textbook discussions of utility theory usually abstracting away the timing of uncertainty resolution, delayed resolution is in the norm for many important decisions. For example, in futures markets, participants buy and sell commodity and futures contracts for delivery on a specified future date. When making decisions in this market, participants need to plan far into the future and consider risks not immediately resolved. For another example, consider a graduate student gets two offers in his job market, one is an assistant professor position at a prestigious research university and the other is the tenured position at a less well-known college. The uncertainty of whether he will get a tenure may resolve 7 years later but he needs to make risk decisions far before that.

Within the framework of prospect theory and temporal discounting models, risk preferences are generally considered constant and independent of the uncertainty resolution time. If the individual prefers lottery A to lottery B in one time, he should hold the same preference in all times given other conditions unchanged. However, as studied in the dynamic choice theory(Kreps and Porteus, 1978), uncertainty is "dated" by the time of its resolution and individuals may regard uncertainties resolving at different times as being different. In this case, the same lottery played out at different times are perceived nonidentical and individuals may make different decisions on whether to participate in that lottery depending on when it is played out.

A salient feature of the dynamically inconsistent preferences is that individuals do not act as planned. Instead, they make different decisions when confronted with the same choice at different times and feel regret with their previous decisions. Dynamic inconsistency in time preferences has been extensively documented and analyzed(Thaler, 1981; Strotz, 1955; O'Donoghue and Rabin, 1999). Similarly, individuals sometimes regret their risk decisions as they regret their temporal decisions. When the time of uncertainty's resolution approaches, individuals may systematically change their risk choices.

One motivating example would be about a boy in love. Imagine a boy who has decided to confess to his beloved girl on the next day. However, when tomorrow comes, the boy gives up because he is not willing to take the risk of the confession, and decides to postpone it for a few days. For another example, today someone may desire to change a hairstyle tomorrow, even though he completely understands the potential risks of the new hairstyle. However, when the next day actually rolls around, he may worry more about the risks and his taste at that time may be to keep the original hairstyle.

In both examples, individuals are given the same risk choices at different time points without receiving any additional information. However, they tend to make different decisions depending on whether they decide for today or decide for future. Formally, the situation could be considered in a two-period model. In $t = 1$, the individual makes decision on whether to take some risks and in $t = 1$ or $t = 2$, if the individual chooses to take the risks, the uncertainty resolves. I propose that the timing of the uncertainty resolution (in $t = 1$ or $t = 2$) affect the individual's risk decisions in $t = 1$. Specifically, if the individual decides for today(the uncertainty resolves today), he or she would be more risk-averse.

To date, a notably large body of research focuses on discussing context-dependent risk preferences. Deck et al. (2008) suggests that the instability of risk preferences across experimental tasks could be related to the fact that risk attitudes may vary depending on the context. Empirical observations(MacCrimmon and Wehrung, 1990) and experimental results in psychology(Weber et al., 2002) also show that risk-taking is in fact highly domain specific. However, what I would like to stress here is that the inconsistency of risk preferences discussed in this paper is not domain-dependent, but instead resolution-time-dependent even in the same domain. In the experimental design, I carefully control the environment to rule out the confounding of context.

I analyze the risk decision problem under the framework of three types of anticipatory utility models, which are developed to model preference for the uncertainty resolution time and are most closely related to the current topic. The three types of models, including the attention model, the curvature model and the optimal expectation model, differ in how anticipatory utility enters the utility function and whether beliefs are allowed to be irrational. For each model, I derive testable hypotheses regarding the change of risk attitudes with uncertainty resolution time in the gain and loss domains.

To provide evidence of the dynamically inconsistent risk preferences and test the predictions of the theories, I conducted an experiment with 150 subjects on Prolific. In the experiment, subjects were divided into two treatment groups and were asked to make the same risk decisions with different uncertainty resolution time (today or tomorrow). Three sets of risk choices are designed involving both the gain and the loss domains, which serves to separately elicit basic utility curvature and loss aversion parameters and test the hypotheses.

The experimental results show that subjects are significantly more risk-averse when they make decisions for today than for tomorrow. This result is mostly driven by the change of risk attitudes in the loss domain, which is in accordance with the prediction of the attention-based anticipatory utility model. Although other explanations, including background risks(Halevy, 2008) and asymmetric discounting of gain and loss(Thaler, 1981), seem plausible regarding some of the observations, I show that they are incompatible with other parts of the findings.

This paper contributes to the field of literature in three main aspects. First, it documents the dynamically inconsistent risk preferences which is a natural implication of the dynamic choice theory and a phenomenon often observed in reality but not systematically documented before. Second, it provides theoretical analysis of possible explanations to the observed inconsistency and use experimental evidence to support the analysis. Third, results in this paper have substantial implications for inter-temporal risk decision theory suggesting that risk and time could not be considered separately, especially in cases involving risk over time.

The remainder of the paper is organized as follows. Section 2 discusses the conceptual background and the corresponding hypotheses. In Section 3, we describe experimental design to test these hypotheses. Section 4 presents experimental results. Section 5 is a discussion and section 6 is a conclusion.

2 Conceptual Background

Both prospect theory and quasi-hyperbolic discounting model predict constant risk preferences over time. The key point here is that prospect theory only considers risk preferences at one single time point while the hyperbolic discounting model discounts utility at a future time point as a whole. I will analyze in this section the risk decision problem under the framework of three types of anticipatory utility models, which are developed to model preference for the uncertainty resolution time and are most closely related to the current topic. To motivate the experimental design, I derive testable hypotheses for each model regarding the change of risk attitudes with uncertainty resolution time.

Kreps and Porteus (1978) provides a mathematical framework in which there is a preference for the uncertainty resolution time. A lottery is specified by its time of resolution along with its possible outcomes and probabilities, so that a lottery that pays off tomorrow based on a coin flip today is different from an identical lottery based on a coin flip tomorrow. Consider the choice between getting a sure amount of money and participating in the lottery. Within this framework, the lottery played out today differs from the same lottery played out tomorrow in the uncertainty resolution time. Assuming later resolution of uncertainty is preferred, the individual would be more likely to prefer the lottery to the sure amount of money if the lottery is played out later. However, when the later date actually rolls around, the individual may change his mind to prefer the sure amount of money.

The preference for the uncertainty resolution time is mostly modeled using anticipatory utility, in which beliefs about the future affect current utility. I mainly discuss here three groups of models assuming anticipatory utility: the optimal expectations model (Brunnermeier and Parker, 2005; Oster et al., 2013), the attention model (Tasoff and Madarasz, 2009; Karlsson et al., 2009; Ganguly and Tasoff, 2017; Golman and Loewenstein, 2018), and the curvature model (Kőszegi, 2003; Eliaz and Spiegler, 2006). Those models all predict that individuals have certain preference for the uncertainty resolution time. The models differ, however, in how anticipatory utility enters the utility function and whether beliefs are allowed to be irrational. The difference in the model setup results in different predictions on preference for resolution time in the gain and loss domains.

2.1 The Optimal Expectation Model

The optimal expectation model allows manipulation of beliefs. The idea of the model is that belief about the future(in our case, the lottery result) generates anticipatory utility. Formally, following Brunnermeier and Parker (2005)'s framework, when the individual decides for tomorrow($t = 2$), he make decisions in $t = 1$ to maximize

$$\beta \hat{E}\left[u\left(c_2\right)\right] \tag{1}$$

where β is the discount factor and $\hat{E}\left[u\left(c_2\right)\right]$ is the anticipatory utility calculated using the distorted beliefs which maximize well-being:

$$\mathcal{W} = \frac{1}{2}\beta \hat{E}\left[u\left(c_2\right)\right] + \frac{1}{2}\beta E\left[u\left(c_2\right)\right] \tag{2}$$

The second term of the well-being ($E\left[u\left(c_2\right)\right]$) is based on the rational beliefs. In our case, since the individual could only choose between participating in the lottery ($\tilde{l}$) and getting a sure amount of payment (c), they only need to compare the following two payoffs when choosing the optimal beliefs:

$$\beta u(c) \text{ OR } \beta\left(\tfrac{1}{2}u(\tilde{l}^{max}) + \tfrac{1}{2}E[u(\tilde{l})]\right)$$

where $\tilde{l}^{max}$ is the best possible payoff in the lottery $\tilde{c}$. The i If, on the other hand, the individual make decisions for today, the two payoffs he need to consider becomes:

$$u(c) \text{ OR } E[u(\tilde{l})]$$

Clearly, $E[u(\tilde{l})] < \frac{1}{2}u(\tilde{l}^{max}) + \frac{1}{2}E[u(\tilde{l})]$, which suggests that the individual would prefer lotteries more when they make decisions for tomorrow. The intuition of the model is that when individuals make decisions for tomorrow, their utilities include the anticipatory utility for tomorrow, this anticipatory utility is based on the distorted probability of lotteries which maximize their well-being for now. In this case, subjects would be more willing to participate in the lottery tomorrow since when considering tomorrow, they hold an irrational belief that the lottery would have a better payoff than they actually are. Since the model is symmetric regarding gains and losses, it yields the following prediction for risk preferences in the gain and loss domains:

Hypothesis 1 *Individuals are more risk-averse when considering future losses or future gains.*

2.2 The Curvature Model

The curvature model assumes rational beliefs and it generates preference of uncertainty resolution time because of the curvature of the anticipatory utility function. Given that expected beliefs about the lottery enter the utility function, if the anticipatory utility function is concave, the individual would prefer not resolving the uncertainties. More concretely, the unresolved lottery($\tilde{l}$) is perceived better than the same resolved lottery if the following inequality holds.

$$u(E[\tilde{l}]) - E[u(\tilde{l})] > 0 \tag{3}$$

The intuition is that a concave utility function implies diminishing marginal utility over beliefs about lotteries. The curvature model generates reverse predictions to the attention based model. If the anticipatory utility function is reference-dependent, since the utility function is always convex in the loss domain and concave in the gain domain, the individual would be more risk-averse when considering future loss while risk-loving when deciding for future gain.

Hypothesis 2 *Individuals are more risk-averse when considering future losses but more risk-loving when considering future gains.*

2.3 Attention-based Anticipatory Utility Model

Attention-based anticipatory utility model also assumes rational beliefs and the anticipatory utility is derived from paying attention to or thinking about different experiences in the future. The key assumption is that information that changes expected consumption utility about a future experience shifts attention away from present consumption to the future experience. Formally, following Ganguly and Tasoff (2017), the attention-based anticipatory utility after receiving information is given as:

$$a\left(\mu_0, \mu_1\right)\left(E_{\mu_1}\left[u(x)\right] - u_p\right) \tag{4}$$

Where u_p denotes utility of present, μ_0 denotes prior utility based on rational beliefs, μ_1 denotes posterior utility after receiving the information of the lottery result, x denotes the result of the lottery, $a\left(\mu_0, \mu_1\right) = \alpha > 0$ if the possible lottery result deviates from prior utility. If no information is received, the anticipatory utility is equal to 0. Hence, individuals receive a discontinuous shock to utility when receiving information of the uncertain resolution because they pay more attention to the future utility. The utility shock will be negative if the uncertainty is in the loss domain($E_{\mu_1}\left[u(x)\right] - u_p < 0$) and and positive if in the gain domain($E_{\mu_1}\left[u(x)\right] - u_p > 0$). Hence, compared with the same lottery played out later, if the lottery is played out immediately, players would be forced to pay attention to the lottery results and the risk attitudes may change depending on the domains of the lottery. The model then makes the following prediction:

Hypothesis 3 *Individuals are more risk-loving when considering future losses but more risk-averse when considering future gains.*

3 Experimental Design

The experimental design sets out to provide evidence of the existence of the inconsistency in risk preferences and test the hypotheses developed in the previous section. Three sets of questions are included in the experimental design. The lottery in the first set of questions involves both gains and losses. This corresponds most closely to the real-life situation where a preference reversal happens. The other two sets of lotteries separately elicit risk preferencess in the gain and the loss domains.

The experiment was an across-subjects design, subjects were divided into two treatment groups and were asked to make decisions regarding the same lotteries played out today or tomorrow. I describe below the measuring of risk preferences, lotteries used in elicitation and implementation details.

3.1 Measuring risk preferences

Instead of using price lists which is commonly used in eliciting certainty equivalents for lotteries (e.g., Tversky and Kahneman, 1992; Bruhin et al., 2010; Bernheim and Sprenger, 2019), I separately show each lottery to subjects and ask whether they would like to participate in the lottery or get a certain amount of sure payment. The advantage of the simple elicitation method is that subjects would pay more attention to the key treatment (lottery played out today or lottery played out tomorrow) since they do not need to understand complex rules of the price lists and the decision procedure is closer to the real-life decisions, which is more familiar to them.

Treatment group A made decisions on lotteries played out today and the result of the lottery would be shown immediately after they made all decisions. Treatment group B made decisions on lotteries played out tomorrow and they were informed that the result of lotteries would be released in the next day.

One of the most challenging aspects of implementing the experiment is making the resolution time of lotteries salient enough for subjects. I took several steps in an attempt to accomplish this. First, subjects were asked to finish a comprehension question about when the lottery would be played out. If they failed the comprehension check, they would not be allowed to participant in the following experiment. Second, in decision screen of each lottery ticket, I made the resolution time very salient both in the lottery ticket and instructions. See Figure 1 in Appendix for a screenshot of a decision screen. Third, showing each decision separately instead of using choice lists forces subjects to pay more attention to the lottery and feel more like making the real-life decisions.

3.2 Lotteries

Gain and Loss combined. The first five questions elicit subjects' risk attitudes when there are both gain and loss, for each lottery ticket below, subjects are asked whether they would like to participant in the lottery.

No.	Lottery
1	With 90% probability: Get \$3; With 10% probability: Loss \$2;
2	With 70% probability: Get \$3; With 30% probability: Lose \$2;
3	With 50% probability: Get \$3; With 50% probability: Lose \$2;
4	With 30% probability: Get \$3; With 70% probability: Lose \$2;
5	With 10% probability: Get \$3; With 90% probability: Lose \$2;

Table 1: Lotteries in the First Set of Questions

The Gain Domain. The next seven questions elicit subjects' risk attitudes in the gain domain. Given the following lottery ticket, subjects choose between participating in the lottery and getting a sure amount of payment (\$3, \$2.5, \$2, \$1.5, \$1, \$0.5, \$0).

Lottery: With 50% Probability: Get \$3; With 50% Probability: Get \$0.

The Loss Domain. Similar to the questions in the gain domain, there are seven questions eliciting subjects' risk attitudes in the loss domain. subjects are asked to choose between the following lottery ticket and losing a sure amount of money (\$3, \$2.5, \$2, \$1.5, \$1, \$0.5, \$0).

Lottery: With 50% Probability: Lose \$3; With 50% Probability: Lose \$0.

3.3 Implementation

Subject Pool. All experiments reported in this paper were conducted on Prolific(www.prolific.co). As discussed in Peer et al. (2017) and Palan and Schitter (2018), subjects on Prolific are more responsive and naive compared with Amazon Mechanical Turk(MTurk) since MTurk has a "superworker" problem that most studies are taken by very few subjects. I recruited N = 150 subjects for the experiment. After reading the instructions, subjects completed three comprehension questions. Subjects who answered one or more control questions incorrectly were immediately routed out of the experiment. In total, 19(12.7%) of all prospective subjects were screened out of the experiment in the comprehension checks.

Experimental Payment. All payments, both sooner and later, were paid through Prolific payment system, which allowed us to equate transaction costs across sooner and later payments and minimize payment risk. subjects received a baseline payment of \$4.00. Their final payment depends on their decisions. For each subject, one of questions of the experiment was randomly selected for payment. Hence, all the questions in the experiment are financially incentivized.

Timeline. Subjects first completed five decisions involving both gain and loss. Then, subjects completed seven decisions each in the gain and the loss domains.

4 Results

The results are presented in three subsections. First, risk choices in the gain and loss combined condition are examined. I document significant difference of risk attitudes depending on the lottery resolution time. Second, choices in the domain of loss and domain of gain are separately reported and analyzed. The results show that subjects are significantly more risk-loving in the loss domain and slightly risk-averse(though not significant) in the gain domain when deciding for tomorrow. Third, I did a back-of-the-envelope calculation of the risk preferences parameters, including the utility curvature parameters for gain and loss and loss aversion parameter. I compare the calculated parameters to that documented in the literature.

4.1 Gain and Loss Combined

If subjects are dynamically consistent in risk preferences, choices regarding 5 lotteries should not be effected by when the lottery is played out. Figure 1 shows the choices of subjects in different treatment groups. Switching lottery refers to the the number of the lottery at which subjects first switch to not participating in the lottery. Switching later means less risk averse. Subjects with multiple switching points are excluded from the analysis($N = 5$). It is very clear from the figure that subjects who make decisions for tomorrow tend to switch later. Most subjects deciding for today switch at Lottery #3 (prefer a sure amount of money to a lottery ticket), which has a risk premium of $0.5 while a considerable number of subjects decide for tomorrow switch at Lottery #4, suggesting that they are very willing to take risks in Lottery #3 to get the risk premium. To validate the observation from the graph, I estimate the following model to show the relationship of the lottery resolution time and the risk premium:

$$RiskPremium_i = \beta Decide\_for\_Tomorrow_i + \Gamma_i + \epsilon_i \tag{5}$$

Where $Decide\_for\_Tomorrow_i = 1$ if subject makes decisions for lotteries played out tomorrow. Γ_i is a set of control variables including sex, student status and age. The risk premium of the subjects is calculated using the switching points and 5 subjects with multiple switching points are excluded from the analysis. The experiment results are presented in Table 2.

The regression result suggests that, firstly, subjects are considerably risk-averse. The

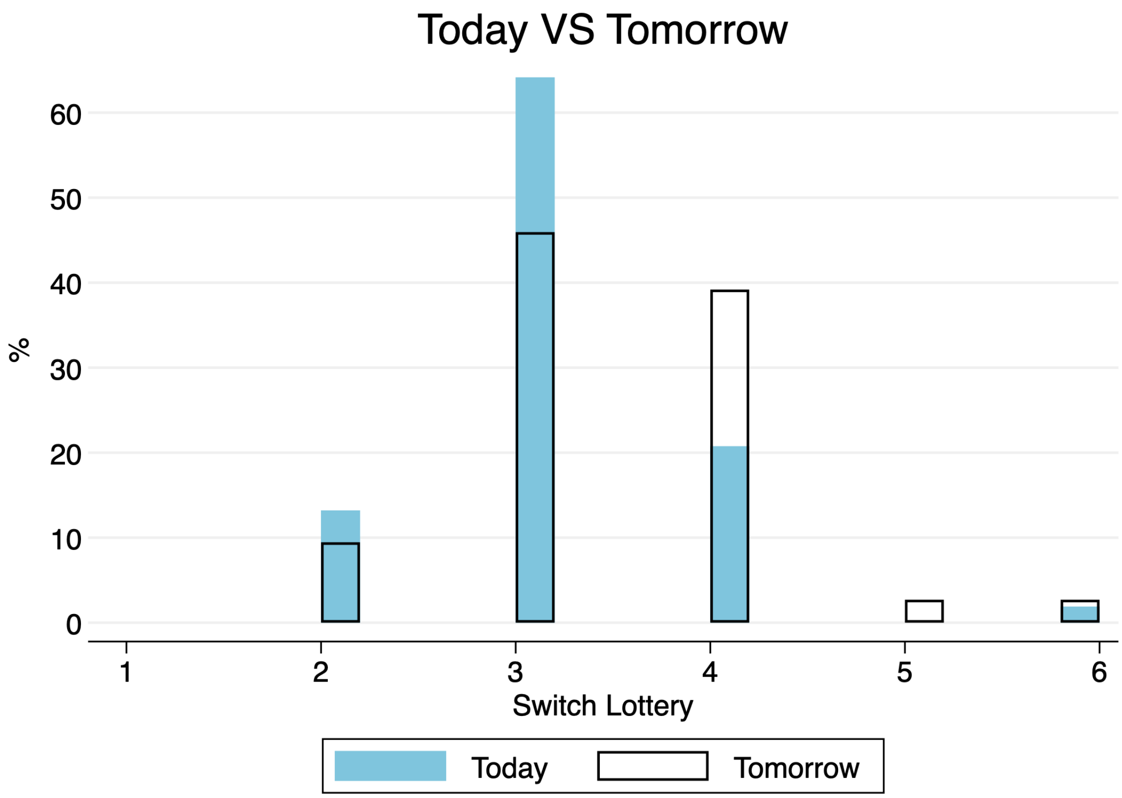

Figure 1: The distribution of Switch Lotteries

average risk premium when deciding for today is approximately \$0.87. Secondly, subjects have significantly lower risk premium(-0.298) if they make decisions for tomorrow. The result is robust after adding controls. Column(3) shows how likely subjects participate in the Lottery #3, in which there are 50% probability to get \$2 and 50% probability to lose \$3. When deciding for tomorrow, subjects are more likely to participate this lottery.

4.2 Gain/Loss Domain

In this section, I present regression results of model (1) in the gain and loss domain separately. In the loss domain, subjects deciding for today is on average risk-neutral, but subjects deciding for tomorrow is risk-loving. In the gain domain, subjects are overall risk-averse and subjects deciding for tomorrow is slightly more risk-averse, though the result is insignificant. Moreover, the average risk premium in the gain domain is approximately 0.19, which is

VARIABLES	(1) Risk Premium	(2) Risk Premium	(3) 50% +3; 50% -2
Decide for Tomorrow	-0.298**	-0.362***	0.259***
	(0.132)	(0.121)	(0.077)
Male		0.186	-0.068
		(0.134)	(0.081)
Student		0.528***	-0.265***
		(0.143)	(0.096)
Age		-0.015	0.013*
		(0.011)	(0.007)
Constant	0.873***	0.784**	0.121
	(0.095)	(0.322)	(0.225)
Observations	127	127	127
Adjusted R-squared	0.0299	0.180	0.157

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Regression Result of Gain and Loss Combined Lottery

much smaller than that risk premium(0.78) estimated in the first regression, suggesting a considerable extent of loss aversion.

4.3 Back-of-the-Envelope Calculation

From the estimated risk premiums in the previous two section, we could do a back-of-envelope calculation of the risk aversion parameters. Following Tversky and Kahneman (1992)'s decomposition of utility, I assume that the observable utility U is a composition of a loss aversion index $\lambda > 0$, reflecting the different processing of gains and losses, and the basic utility u. Formally:

$$U(x) = \begin{cases} u(x) & \text{if } x \geqslant 0 \\ \lambda u(x) & \text{if } x < 0 \end{cases} \tag{6}$$

Further assume that $u(x) = x^{\alpha}$ for gains and $u(x) = -|x|^{\beta}$ for losses. The calculated parameters are presented in Table 4.

VARIABLES	Risk Premium of Loss (1)	(2)	Risk Premium of Gain (3)	(4)
Decide for Tomorrow	-0.289***	-0.312***	0.071	0.072
	(0.097)	(0.093)	(0.101)	(0.105)
Male		0.119		-0.026
		(0.101)		(0.110)
Student		0.108		0.003
		(0.142)		(0.143)
Age		-0.011*		0.001
		(0.006)		(0.009)
Constant	-0.024	0.110	0.192***	0.181
	(0.077)	(0.277)	(0.072)	(0.325)
Observations	125	125	125	125
Adjusted R-squared	0.0626	0.110	-0.00427	-0.0285

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Regression Result of the Gain/Loss Domain

	α	β	γ
Decide for Today	0.875	0.985	3.385
Decide for Tomorrow	0.825	0.787	3.02

Table 4: Estimation of Risk Aversion Parameters

The mean exponents of the value function of two treatment groups for gains were approximately the same and very close to the estimation of 0.88 in Tversky and Kahneman (1992). In the loss domain, the mean exponents of the value function for loss is 0.985 when deciding for today and 0.787 when deciding for tomorrow. The calculated parameters in the loss domain are different from that calculated from Tversky and Kahneman (1992) probably because in the group deciding for today, subjects are forced to pay attention to the resolution time of the lottery which may change their perception of losses. Both results are in accord with diminishing sensitivity. The calculated λ is over 3 in both groups, indicating pronounced loss aversion and is larger than that in other estimations. This may due to not considering nonlinear probability weighting in the calculation. To sum up, the calculation shows that subjects in the experiment is quite representative and the estimated curvature of loss is much larger when subjects decide for today.

5 Discussions

In this section, I will first discuss the implications from the previous results and show that the attention-based anticipatory utility model could potentially explain the result. Secondly, I discuss other possible theories that seem plausible to explain the experimental results, including the background risk and the asymmetric discounting of gains and losses. It will be shown that none of them completely explains the observed pattern of the inconsistency.

5.1 Attention-based Anticipatory Utility Model

The experimental results show a significant lower risk premium in the loss domain and a slightly higher risk premium(though not significant) in the gain domain when the uncertainties are resolved later. The results are in aligned with Hypothesis 3, suggesting that the attention-based anticipatory utility best models the behavior. The possible reasons that the preferences inconsistency in the gain domain is not significant are as follows. Firstly, gains are not as salient as losses. Individuals are loss-averse and they are more responsive to the future loss compared with the future gain. Secondly, individuals may perceive future gains and losses differently. According to the "sign effect" proposed in Thaler (1981), sure loss is discounted less than sure gain. The psychological cost of a sure loss happens more when individuals know they would face a loss while the psychological joy of a sure gain happens more when individuals actually receive the payment. In this case, the discontinuous shock to utility when receiving bad news is larger than the shock when receiving good news, making the preference inconsistency in the loss domain much more salient than that in the gain domain.

5.2 Other Plausible Explanations

5.2.1 Background Risk

It is possible that the observed inconsistency in risk preferences over time be driven by the inherent risk of future considered together with the objective probability. There are some evidence showing an identity relationship between the certainty effect and present bias(Keren and Roelofsma, 1995; Weber and Chapman, 2005) which provides rationale to add background risk to the objective probability. More concretely, following Halevy (2008)'s analysis, denote by r the constant stopping probability and by k the time from "decision point" to "risk point":

$$U(X) = \sum_{i=1}^{n} \pi \left((1-r)^k p_i\right) u\left(x_i\right) \tag{7}$$

In this case, consider a risk choice between two lotteries (x_1, p_1) and (x_2, p_2). The decision maker actually faces different risk choices depending on the relative length of time from "decision point" and "risk point". The risk decisions at risk point is "(x_1, p_1) or (x_2, p_2)" while the risk decisions at decision point is "$(x_1, (1-r)^k p_1)$ or $(x_2, (1-r)^k p_2)$". It is possible that decision maker makes different decisions when confronted with those two problems due to the nonlinear probability weighting, especially certainty effect.

However, if the dynamic inconsistency of risk preferences is driven by the background risk, subjects should have the same inconsistency in the gain and loss domains. Meanwhile, background risks in the future are identical to risks of not running the lottery at the present. In the experimental design, only one of the risk decisions is selected and paid out, which is very similar to adding uncertainty in the present environment. Hence, background risk could not fully explain the observed results.

5.2.2 Asymmetric Discounting of Gain and Loss

If the time discounting of gain and loss is asymmetric, reversals may happen when loss and gain are intertwined. Formally, allowing different discount factor and present bias factor of gain and loss, the classical model is augmented into the following form:

$$U(X) = u\left(x_0\right) + \sum_{t=0}^{T} \beta_{gain}\delta_{gain}^{t} u\left(x_t^{gain}\right) + \beta_{loss}\delta_{loss}^{t} u\left(x_t^{loss}\right) \tag{8}$$

Consider the same lottery discussed in Section 2.2. If $\beta_{gain} \neq \beta_{loss}$ or $\delta_{gain} \neq \delta_{loss}$, $p_1c_1 + p_2c_2 < c_3$ does not necessarily leads to $\beta_{gain}\delta_{gain}p_1c_1 + \beta_{loss}\delta_{loss}p_2c_2 > \beta_{gain}\delta_{gain}c_3$.

However, the asymmetric discounting of gain and loss predicts that the individual holds constant risk preferences if the lottery is only in the gain or loss domain. The back-of-the-envelop calculation also suggests a similar loss aversion parameter γ for different uncertainty resolution times. Those evidences shows that asymmetric discounting of gain and loss is not the driven factor of the phenomenon.

6 Conclusion

Risk preferences are always considered independent of the uncertainty resolution time. While prospect theory discusses risk preferences at one single time point, the quasi-hyperbolic discounting model discount utility at a future time point as a whole, making it impossible to discuss different risk attitudes depending on uncertainty resolution times.

I analyze the risk decision problem under the framework of three types of anticipatory utility models, which are developed to model preference for the uncertainty resolution time. I show that one natural implication of the models is that risk preferences depend on risk resolution time. In a risk choice experiment, I manipulate uncertainty resolution time and document dynamic inconsistency in risk preferences. Subjects are more risk-loving when they make decisions regarding lotteries played out in the future compared with the same lotteries played out immediately. The inconsistency exists when the lottery payment involves the loss domain.

Possible theories are considered to explain the observed inconsistency, including varies anticipatory utility models, background risks and asymmetric discounting of gain and loss. The prediction of attention-based anticipatory utility model best corresponds to the experimental results.

The results in this paper have substantial implications for inter-temporal risk decision theory. Since risk preference reversals may happen over time just as time preference reversals, we should not consider risk and time preferences separately especially in cases involving risk over time.

There are some other related questions to be answered. Firstly, this paper uses a between-subject design in which we could compare the difference of risk attitudes in two randomly assigned groups. However, this makes the study of individual-level heterogeneity impossible. Apart from anticipatory utility theories, there are other psychological theories (Wu, 1999) predict that people are more likely to take immediately resolved risks since they dislike the anxiety associated with unresolved uncertainty. Although the prediction is not in line with the experimental result, the theory still sounds appealing. Hence, it might be important to further investigate whether there is heterogeneity across subjects regarding the change of risk preference over time. Secondly, in this paper, we only provide evidence in support of the attention-based utility model by testing certain predictions of the model. It might be more persuasive to directly test the attention-based utility model through manipulation of present utility in clean experimental design. Last but not the least,time inconsistent risk preferences may have great real-world implications. For example, in financial markets, people may be more conservative when developing trading strategy for a short window while they are more aggressive when making decisions for a long-run investment. It would be interesting to study this difference using empirical data set. We leave further exploration of these problems to future research.

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Appendix: Experimental Instructions and Control Questions

Welcome

Thank you for participating in this study! This study will take approximately 10 minutes to complete.

Your baseline earnings for completing the study will be **$10.00** and your final earnings will depend on your decisions in the study. To complete the study, you will need to read all instructions carefully and answer the corresponding comprehension questions correctly.

This study has 3 parts and there are several questions in each part. At the end of the study, **one of the questions** will be randomly selected and your decision in that question will determine your final earnings.

You will receive your final earnings **at the end of the study.**

Important information

- You should think about each question **independently** of all other questions in this study. There is no point in strategizing across questions.
- You will note that we sometimes ask you similar-sounding questions. Theses questions might have similar answers, or very different ones. Please consider each individual question **carefully**.

Next

Instructions

Please read these instructions carefully. There will be comprehension questions that verify your understandings. If you fail the comprehension checks, you will not be able to complete the study and you will only earn $0.50.

In this study, you will make decisions on whether to participate in varies lotteries for today. The lotteries will have different payment with different probability. An example lottery is as follows:

Lottery for Today

- With **35%** probability, you **get** **$3.00** today
- With **65%** probability, you **lose** **$1.00** today

If you participate in this lottery, you will **either** get $3.00 **or** lose $1.00 (with different probability) today.

The lotteries will actually be played out **immediately after you make your decisions** by the computer. The result of the lottery will determine your earnings. For example, given your baseline earnings of $10.00, if the lottery is played out and you are very lucky to get $3.00, your final earnings will be $7.00. If, on the other hand, you lose $1.00, your final earnings will be $3.00.

Throughout the experiment, there are no right or wrong answers, because how much you like a lottery depends on your personal taste. We are only interested in learning about what you prefer.

Click "Next" to proceed to comprehension questions.

Next

Comprehension Questions

The questions below test your understanding of the instructions. If you fail to answer any one of these questions correctly, you will not be able to complete the study and you will only earn $0.50.

1. Which one of the following statements is correct if this lottery is played out for you?

Lottery for Today

- With **50%** probability, you **get** **$8.00** today
- With **50%** probability, you **get** **$5.00** today

○ It is possible that I get paid both $8.00 and $5.00, i.e., I may receive a total amount of $13.00 from this lottery.

○ I receive EITHER $8.00 OR $5.00 from this lottery.

○ It is possible that I receive no money from this lottery.

2. Which one of the following statements is correct if the following lottery is played for you?

Lottery for Today

- With **50%** probability, you **lose** **$5.00** today
- With **50%** probability, you **lose** **$3.00** today

○ It is possible that I lose both $5.00 and $3.00, i.e., I may lose a total amount of $8.00 from this lottery.

○ I lose EITHER $5.00 OR $3.00 from this lottery.

○ It is possible that I lose no money from this lottery.

3. Which one of the following statements is correct regarding when the lottery will be played and when you will receive your earnings?

○ The lottery will be played immediately after I make the decision and I will receive my earnings today.

○ The lottery will be played tomorrow and I will receive my earnings tomorrow.

Next

Part 1

Congratulations! You have correctly answered all comprehension questions.

In this part, you will make decisions on whether to participate in 5 different lotteries today. The 5 lotteries have **the same payment** with **different probability for each payment**.

Lottery for Today

- With **X%** probability, you **get** **$3.00** today
- With **(100-X)%** probability, you **lose** **$2.00** today

The number X will be different in each lottery. If you choose to participate in the lottery, you will **either** get $3.00 **or** lose $2.00 today with different probability.

Click "Next" to proceed to the questions.

Next

Decision Screen

Below is a lottery ticket. If you choose to participate in the lottery, **the lottery will immediately be played out.**

Lottery 1 for Today

- With **90%** probability, you **get** **$3.00** today
- With **10%** probability, you **lose** **$2.00** today

Do you want to participate in the lottery?

○ Participate in the Lottery ○ NOT Participate in the Lottery

Next

Part 2

In this part, you will make decisions on **whether to participate in the following lottery or get a certain amount of money for sure** today.

Lottery for Today

- With **50%** probability, you **get** **$3.00** today
- With **50%** probability, you **get $0.00** today

If you participate in this lottery, you will get $3.00 with 50% probability. If you do not participate in this lottery, you will get a certain amount of money for sure.

Click "Next" to proceed to the questions.

Next

Decision Screen

Below is a lottery ticket. If you choose to participate in the lottery, **the lottery will immediately be played out.**

Lottery for Today

- With **50%** probability, you **get** **$3.00** today
- With **50%** probability, you **get $0.00** today

Do you prefer to participate in the lottery or **get** **$0.00** for sure?

○ Participate in the Lottery ○ Get $0.00 for sure

Next

Part 3

In this part, you will make decisions on **whether to participate in the following lottery or lose a certain amount of money for sure** today.

Lottery for Today

- With **50%** probability, you **lose** **$3.00** today
- With **50%** probability, you **lose** **$0.00** today

If you participate in this lottery, you will lose $3.00 with 50% probability. If you do not participate in this lottery, you will lose a certain amount of money for sure.

Click "Next" to proceed to the questions.

Next

Decision Screen

Below is a lottery ticket. If you choose to participate in the lottery, **the lottery will immediately be played out.**

Lottery for Today

- With **50%** probability, you **lose** **$3.00** today
- With **50%** probability, you **lose** **$0.00** today

Do you prefer to participate in the lottery or **lose** **$3.00** for sure?

○ Participate in the Lottery ○ Lose $3.00 for sure

Next